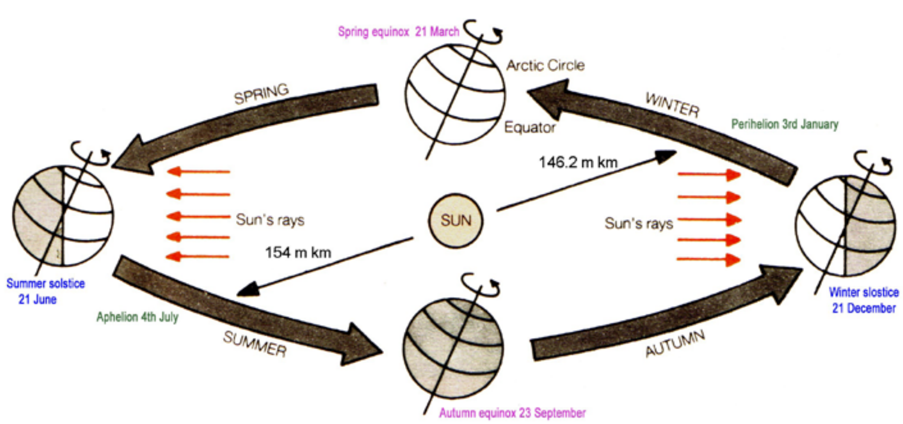
WEATHER ELEMENTS AND THEIR INFLUENCE ON DIFFERENT CROPS

The weather elements are solar radiation, temperature, soil temperature and light, radiation.

Solar radiation – Spectrum of radiation – Characteristics of different wave lengths and their effect on crop production.

Sun

- Sun is the prime source of energy
- Sun is the nearest star to the planet earth
- Diameter of the sun is 1.39 X 106 km
- It rotates on its axis about once every four weeks(27 days near equator & 30 days –polar)
- Sun is on an average 1.5 X 108 km away from the earth (149.64 M km deviation is 2.41 Mkm)
- Surface temperature of the sun is 5462° K
- Every minute, the sun radiates approximately 56 X 1026 calories of energy.
- The interior mass of the sun has a density of 80 to 100 times that of water.
- Energy is due to the fusion, Hydrogen is transformed to helium.
- 99% of the energy to biosphere is only from the sun and the rest one percent is from stars,lightning discharge, sun's radiation reflected from the moon, re-radiation from the earth etc.



Insolation

Electro magnetic energy radiated into the space by the sun

Factors affecting insolation

1. The solar constant which depends on

a. Energy output of the sun

b. Distance from earth to sun

2. Transparency of the atmosphere

3. Duration of daily sunlight period

4. Angle at which sun’s noon rays strike the earth.

Transfer of heat

All mater, 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 equalized. Eg. The energy transmission through an iron rod which is made warmer at one end.

Convection

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 involve this process. Eg. 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.

Solar radiation

The flux of radiant energy from the sun is solar radiation.

Heavenly bodies emit – short wave radiation

Near surfaces including earth emit - long wave radiation

Radiation flux

The amount of radiant energy emitted, received, transmitted across a particular area is known as radiant flux.

Radiant flux density

The radiant flux divided by the area across which the radiation is transmitted is called radiant flux density.

Emissive power

The radiant flux density emitted by a source is called its emissive power.

Energy measurement

Units Cal	**cm-2 min-1**	**J cm-2 mi-1**	**W cm-2**
Cal cm-2 min-1	1	4.1868	0.069
J cm-2 mi-1	0.238	1	0.00165
W cm-2	14.3	60.6	1

Spectrum of Radiation

Band	Spectrum	Wavelength (μ)	Importance
Ultra	Cosmic rays	< 0.005	Shorter wave lengths of spectrum & Chemically active, unless filtered there is danger of life on earth
	Gamma rays and X-rays	0.005 – 0.20	
	Ultraviolet rays	0.20 – 0.39	
Visible	Violet	0.39 – 0.42	Visible spectrum known as Light essential for all plant processes
	Blue	0.42 – 0.49	
	Green	0.49 – 0.54	
	Yellow	0.54 – 0.59	
	Orange	0.59 – 0.65	
	Red	0.65 – 0.76	
Infra red	Infrared rays	> 0.76	Essential for thermal energy of the plant (Source of heat)

Units of measurements of wavelength

Micron 1μ = 10-6 m = 10-4 cm

Milli micron 1 mμ = 10-9 m = 10-7 cm

Angstrom Å = 10-10 m = 10-8 cm

Solar radiation and crop plants

Crop production is exploitation of solar radiation

Three broad spectra

1. Shorter than visible range: 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 Xrays 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.

2. Higher than visible wavelength

- 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.

3. Visible spectrum

- 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.

Critical stages of plant growth for light

- Radiation intensity during the third month of Maize plant
- Rice – 25 days prior to flowering
- Barley – flowering period

Band	Wavelength(nm)	Specific effect on plant
1.	Radiation within 1000 and more	No specific effect on plant activity. Radiation absorbed by plants are transformed into heat. This radiation does not interfere with bio-chemical processes.
2.	1000-720	Radiation in this band helps in plant elongation, can be accepted as an adequate measure of plant elongation activity. The far red region (700-920 nm) has important role on photo-periodism, germination of seeds, flowering and colouration of fruits.
3.	720-510	In this spectral region light is strongly absorbed by chlorophylls. It generates strong photosynthetic and photo-periodic activity.
4.	610-510	This is green-yellow region. Absorption in this spectral region has low photosynthetic effectiveness and weak formative activity.
5.	510-400	It is the strongest chlorophyll and yellow pigment absorption region. In the blue-violet range, photosynthetic activity becomes very strong. This region has very strong effect on formation of tissues.
6.	400-315	Radiation in this band produces formative effects. It has dwarfing effect on plants and thickening effect on plant leaf.
7.	315-280	Radiation in this band has detrimental effect on most plants
8.	Less than 280	Lethal effect most of the plants get killed due to radiation in this band UV ranges have germicidal action.

Radiation balance – Solar constant – albedo – Sensible heat – Heat energy – Latent heat

A part of the incident radiation on the surface is absorbed, while a part is reflected and the remaining is transmitted.

Absorptivity

Absorptivity of a substance is defined as the ratio of the amount of radiant energy absorbed to the total amount incident upon that substance. The absorptivity of a blackbody is unity. Natural bodies like sun and earth are near perfect black bodies

Reflectivity

Reflectivity is defined as the ratio of the radiant energy reflected to the total incident radiation upon that surface. If it is expressed in percentage it becomes albedo.

Transmittivity

Transmittivity is defined as ratio of the transmitted radiation to the total incident radiation

upon the surface.

Emissivity

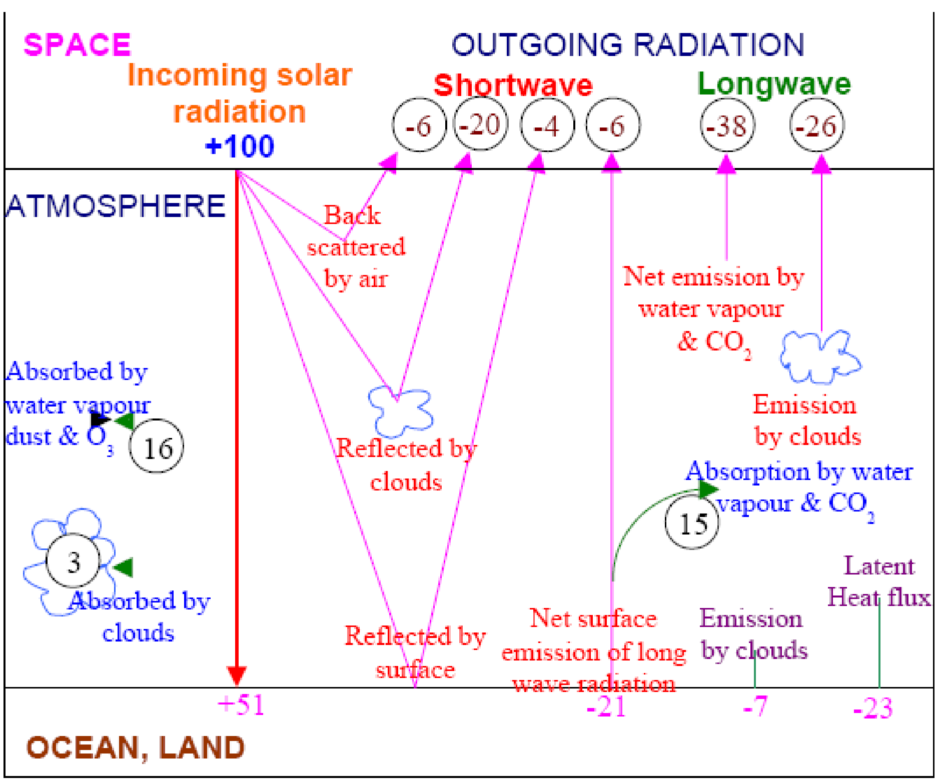
Emissivity is defined as the ratio of the radiant energy emitted by a given surface to the total heat energy emitted by a black body. The emissivity of a black body is unity.

Blackbody radiation

A Blackbody is defined as a body, which completely absorbs all the heat radiations falling on it without reflecting and transmitting any of it. It means reflectivity and transmittivity become zero. When such a black body is heated it emits radiation of all wavelengths depending upon its temp.

Radiation balance

The difference between all incoming and outgoing radiation at the earth's surface and top of the atmosphere is known as radiation balance at the earth's surface.



Solar constant

Solar constant is the energy received on a unit area at the outer most boundary of the earth (atmosphere) surface held perpendicular to the sun's direction, at the mean distance between the sun and the earth.

Solar constant is not a true constant. It fluctuates by as much as ± 3.5 % about its mean

value depending upon the distance of the earth from the sun.

Value is 2 cal / cm2 / min. (1.92 and 2.02) Recent measurements indicate value of 1.94

cal / cm2 / min (133 wm-2) [1 Langley = 1cal]

35% of the energy is contributed by U.V. and visible parts and 65% by Infra Red.

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.

Depends up on

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

Outgoing long wave radiation

After being heated by solar radiation, the earth becomes source of radiation.

Average temperature of the earth's surface 285º k (12º C)

99% of radiation is emitted in the farm of IR range (4 to 120 μ)

About 90% of the outgoing radiation is absorbed by the atmosphere.

Water vapour absorb in wavelengths of 5.3 to 7.7 μ and beyond 20μ.

Ozone 9.4 to 9.8 μ.

CO_2 – 13.1 to 16.9 μ

Clouds – in all wavelengths

Long wave radiation escapes to the space between 8.5 and 11 μ 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.

Radiation laws

The direct transfer of heat from the sun to the earth through the space and atmosphere indicates that radiation of heat from one place to other occurs in the form of electromagnetic waves in the same manner and with same speed of as light. The wavelength of electromagnetic radiation is given by the equation

$$\lambda = \frac{C}{V}$$

Where λ = Wavelength (The shortest distance between consecutive crests in the wave trance)

C = Velocity of light (3x1010 cm sec-1)

V = Frequency means number of vibrations of cycles per second

Plank's law

Plank introduced the 'particle concept'. The electromagnetic radiation consists of a stream or flow of particles or quanta, each quantum having energy content E determined by of each quantum is proportional to the frequency given by the equation.

E= h v where

h= Plank's constant (6.62x10-34 J sec-1

V= Frequency

The law states that greater the frequency (shorter wave length) greater is the energy of quantum.

Kirchoff's law

A good absorber of radiation is a good emitter, in similar circumstances. This law states that the absorptivity 'a' of an object for radiation of a specific wavelength is equal to the emissivity 'e' for the same wavelength. The equation of the law is :

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

Stefan-Boltzmann's law

The intensity of radiation emitted (E) by a radiating body is directly proportional to the fourth power of the absolute temperature of that body. (Emissivity of black body = 1)

E = σ T4

Where,

T= (273+°C) because temperature is in Kelvins

= Stefan-Boltzmann's constant which is equal to 5.673 x 10-8 W m-2 K-4

Wein's Displacement laws

The wavelength of the maximum intensity of emission (λmax) from a radiating black body is inversely proportional to its absolute temperature

$$\lambda_{max} = 2897\ T^{-1}\ \mu = 2897/T\ \mu \text{ Where T is in } ^{o}K$$

If the temperature of a body is high, radiation maximum is displaced towards shorter wavelengths. For the sun's surface temperature of 5793°K, the λ_{max} is 0.5μ (2897/5793). The most intense solar radiation occurs in the blue-green range of visible light. The wavelength of maximum intensity of radiation for the earth's actual surface temperature of 14°C or 287°K is about 10.0 (2897/287) microns, which is in the infrared band.

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 laten 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.

Temperature

It is defined as the measure of the average speed of atoms and molecules

Kinetic energy

Energy of motion.

Heat

It is the aggregate internal energy of motion and molecules of a body. It is often defined as energy in the process of being transferred from one object to another because of the temperature between them.

Sensible heat

It is the heat that can be measured by a thermometer and thus sensed by humans. Normally measured in Celsius, Fahrenheit and Kelvin.

Latent heat

It is the energy required to change a substance to a higher state of matter. This same energy is released on the reverse process. Change of state through Evaporation and condensation is known as latent heat of evaporation and latent heat of condensation. From water to water vapour takes 600 calories and water to ice takes 80 calories.

Blue colour of the sky

If the circumference of the scattering particle is less than about 1/10 of the wavelength of the incident radiation, the scattering co-efficient is inversely proportional to the fourth power of the wavelength of the incident radiation. This is known as **Rayleigh scattering**. This is the primary cause of the blue colour of the sky. For larger particles with circumference >30 times of wavelength of the incident radiation, scattering is independent of the wavelength (i.e) white light is scattered. This is known as **Mei scaring**

Red Colour of the sky at sunset & sunrise.

It is because of increased path length in the atmosphere. % of solar energy in the visible part decreases. With in the visible part, the ratio of the blue to the red part decreases with increased path length.

Disposition of Solar radiation

a. 25% of solar radiation is reflected back to the space by clouds (more by middle and high latitudes and less in the sub tropics)

b. 6% reflected back by air, dust and water vapour.

c. 30% scatted downwards (more in the form of shorter wavelengths able) them that in longer wave length (red).

d. 17% of solar radiation is absorbed by the atmosphere. (Mostly by Oxygen, O3, CO2 & H2O

vapour).

O_2 – absorb the extreme UV wavelengths (0.12 to 0.6 μ)

O_3 – UV (0.2 to 0.32 μ) and Visible part of radiation (0.44 to 0.7 μ)

H_2O vapour – Near infra red (0.93, 1.13, 1.42 μ)

CO_2 - IR band 2.7 μ.

e. About 50% of solar radiation reaches earth's surface, after reflection, scattering and absorption.

LIGHT – EFFECT OF LIGHT INTENSITY, QUALITY, DIRECTION AND DURATION ON CROP PRODUCTION – AIR TEMPERATURE – FACTORS AFFECTING TEMPERATURE.

Light

Light is the visible portion of the solar spectrum with wavelength range is from 0.39 to 0.76μ. 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 ie. 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.

Light intensity

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

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

(i) Sciophytes (shade loving plants): The plants grow better under partially shaded conditions. (eg) Betel vine, buck wheat etc.

(ii) Hetrophytes (Sun loving): Many species of plants produce maximum dry matter under high light intensities when the moisture is available at the optimum level. (eg) Maize, sorghum, rice etc.

Quality of Light

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:

Violet 400 – 435 m μ	Blue 435 – 490 m μ
Green 490 – 574 m μ	Yellow 574 – 595 m μ
Orange 595 – 626 m μ	Red 626 – 750 m μ

The principal wavelength absorbed and used in photosynthesis are in the violet – blue and the orange - red regions. Among this, short rays beyond violet such as X rays, gamma rays and larger rays beyond red such as infrared, are detrimental to plant growth. Red light is the most favourable light for growth followed by violet – blue. Ultra – violet and shorter wave lengths kill bacteria and many fungi.

c) 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 phtoperiodism. The plants are classified based on the extent of response to day length which is as follows.

(i) Long day plants

The plants which develop and produce normally when the photoperiod is greater than the critical minimum (greater than 12 hours). eg. Potato, Sugarbeet, Wheat, Barley etc.

(ii) Short day plants

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

(iii) 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 are shortened and flowering is delayed till the long days come in the season. Similarly when short day plants are subjected to long day periods, there will be abnormal vegetative growth and there may not be any floral initiation.

Direction of light

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

Photomorphogenesis

Change in the morphology of plants due to light. This is mainly due to U.V and violet ray of the sun.

AIR TEMPERATURE

Temperature is defined as, “The measure of speed per molecule of all the molecules of a body”. Where as heat is, “the energy arising from random motion of all the molecules of a body'. (Degree of molecular activity). It is the intensity aspect of heat energy.

Conduction

Heat transfer when two bodies of unequal temperatures come into contact. Heat passes from point to point by means of adjacent molecules.

Convection

Transfer through movement of particles (part of mass) in fluids and gasses. These ar able to circulate internally and distribute heated part of the mass.

Radiation

It is the process of transmission of energy by electromagnetic waves between two bodies without the necessary aid of an intervening material medium.

Factors affecting air temperature

i. Latitude

ii. Altitude

iii. Distribution of land and water

iv. Ocean currents

v. Prevailing winds

vi. Cloudiness

vii. Mountain barriers

viii. Nature of surface

ix. Relief

x. Convection and turbulence etc.

1. Latitude

The time of occurrence of maximum monthly mean temperature and minimum monthly mean temperature also depends on latitude of a place. (eg.) The coldest month is January in northern regions of India while December in the south. Similarly, the warmest month is May in the south while June in the north across the country.

2. Altitude

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

3. Distribution of land and water

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

4. Ocean currents

The energy received over the ocean surface carried away by the ocean currents from the warm areas to cool areas. This results in temperature contrast between the equator and poles. The occurrence of El-Nino is due to change in sea surface temperature between two oceanic regions over the globe.

5. Prevailing winds

Winds can moderate the surface temperature of the continents and oceans. In the absence of winds, we feel warm in hot climates. At the same time, the weather is pleasant if wind blows.

6. Cloudiness

The amount of cloudiness affects the temperature of the earth's surface and the atmosphere. A thick cloud reduces the amount of insolation received at a particular place and thus the day time temperature is low. At the same time, the lower layers in the atmosphere absorb earth’s radiation. This results in increasing atmospheric temperature during night. That is why, cloudy nights are warmer. This is common in the humid tropical climates.

7. Mountain barriers

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.

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 moon.
- 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.

Horizontal air temperature distribution

- The lines connecting points of equal temperature is called as **isotherm**
- It is largely depends latitude. A general decrease in temperature from equator towards poles is one of the most fundamental factors of climatology.
- Irregular distribution of land and water on earth's surface breaks the latitudinal variation in temperature.
- Land areas warm and cool rapidly than water bodies
- Mountain barriers influence horizontal distribution of temperature by restricting movement of air masses.
- On local scale topographic relief exerts an influence on temperature distribution.

Vertical air temperature distribution

Decrease in temperature with increase in height

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 occurs 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.

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 ºC for different crops (Most commonly used value is 6.0ºC)

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.

$$GDD = \Sigma \frac{T_{max} + T_{min}}{2} - T_b$$

Where

T_{max} – Maximum air temperature of the day

T_{min} – Minimum air temperature of the day

T_b - 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.

HEAR INJURIES

‘Thermal death point” – the temperature at which the plant cell gets killed when the temperature ranges from 50-60°C. This varies with plant species. The aquatic and shade loving plants are killed at comparatively lower temperature (40°C).

High temperature

- results in desiccation of plants
- disturbs the physiological activities like photosynthesis and respiration
- increases respiration leading to rapid depletion of reserve food.

Sun clad

Injury caused on the barks of stem by high temperature during day time and low temperature during the night time.

Stem griddle

The stem at ground level scorches around due to high soil temperature. It causes death of plant by destroying conductive tissues. Eg. This type of injury is very common in young seedlings of cotton in sandy soil when soil temperature exceeds 60°C.

COLD INJURY

(i) Chilling injury

Plants which are adapted to hot climate, if exposed to low temperature for sometime, are found to be killed or severely injured or development of chloratic condition (yellowing) (eg.) cholratic bands on the leaves of sugarcane, sorghum and maize in winter months when the night temperature is below 20°C.

(ii) Freezing injury

This type of injury is commonly observed in plants of temperate regions. When the plants are exposed to very low temperature, water freezes into ice crystals in the intercellular spaces of plants. The protoplasm of cell is dehydrated resulting in the death of cells. (eg.) Frost damage in potato, tea etc.

(iii) Suffocation

In temperature regions, usually during the winter season, the ice or snow forms a thick cover on the soil surface. As a result, the entry of oxygen is prevented and crop suffers for want of oxygen. Ice coming in contact with the root prevents the diffusion of CO2 outside the root zone. This prevents the respiratory activities of roots leading to accumulation of harmful substances.

(iv) Heaving

This is a kind of injury caused by lifting up of the plants along with soil from its normal position. This type of injury is commonly seen in temperate regions. The presence of ice crystals increases the volume of soil. This causes mechanical lifting of the soil.

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. The diffusion rates of gases and liquid changes with temperature.
5. Solubility of different substances is dependent on temperature.
6. Biochemical reactions in crops (double or more with each 10°C rise) are influenced by air temperature.
7. Equilibrium of various systems and compounds is a function of temperature.
8. Temperature affects the stability of enzymatic systems in the plants.

9. Most of the higher plants grow between 0°C – 60°C and crop plants are further restricted from 10 – 40°C, however, maximum dry matter is produced between 20 and 30°C

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

11. High night temperature increases respiration and metabolism.

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

13. 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 temperatures.

Sl No	Crop	Minimum	Optimum	Maximum
1	Wheat and Barley	0 – 5	25 – 31	31 – 37
2	Sorghum	15 – 18	31 – 36	40 – 42

Thermo periodic response

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

Soil temperature

The soil temperature is one of the most important factors that influence the crop growth. The sown seeds, plant roots and micro organisms live in the soil. The physio-chemical as well as life processes are directly affected by the temperature of the soil. Under the low soil temperature conditions signification is inhibited and the intake of water by roof is reduced. In a similar way extreme soil temperatures injures plant and its growth is effected.

Eg. On the sunny side, plants are likely to develop faster near a wall that stores and radiates heat. If shaded by the wall, however, the same variety may mature later. In such cases soil temperature is an important factor.

Importance of soil temperature on crop plants:

The soil temperature influences many process.

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.)

Factors affecting soil temperature:

Heat at ground surface is propagated downward in the form of waves. The amplitude deceases with depth. Both meteorological and soil factors contribute in bringing about changes of soil temperature.

I) Meteorological factors

1. Solar radiation

a) The amount of solar radiation available at any given location and point of time is directly proportional to soil temperature.

b) Even though a part of total net radiation available is utilised in evapotranspiration and heating the air by radiation (latent and sensible heat fluxes) a relatively substantial amount of solar radiation is utilized in heating up of soil (ground heat flux) depending up on the nature of surface.

c) Radiation from the sky contributes a large amount of heat to the soil in areas where the sun's rays have to penetrate the earth's atmosphere very obliquely.

2. Wind

Air convection or wind is necessary to heat up the soil by conduction from the atmosphere.

(eg.) The mountain and valley winds influence the soil temperature.

3. Evaporation and condensation

a) The greater the rate of evaporation the more the soil is cooled. This is the reason for coolness of moist soil in windy conditions.

b) On the other hand whenever water vapour from the atmosphere or from other soil depths condenses in the soil it heats up noticeably. Freezing of water generates heat.

4. Rainfall (Precipitation)

Depending on its temperature, precipitation can either cool or warm the soil.

II. Soil factors

1. Aspect and slope

a) In the middle and high latitudes of the northern hemisphere, the southern slopes receive more insolation per unit area than the northern exposure.

b) The south west slopes, are usually warmer than the south east slopes. The reason is that the direct beam of sunshine on the south east slope occur shortly after prolonged cooling at night, but the evaporation of dew in the morning also requires energy.

2. Soil texture

a) Because of lower heat capacity and poor thermal conductivity, sandy soils warm up more rapidly than clay soils. The energy received by it is concentrated mainly in a thin layer resulting in extraordinary rise in temperature.

b) Radiational cooling at night is greater in light soils than in heavy soils. In the top layer, sand has the greatest temperature range, followed by loam and clay.

c) The decrease of range with depth is more rapid in light soils than heavy soils when they are dry but slower when they are wet.

d) A soil with rough surface absorbs more solar radiation than one with a smooth surface.

3. Tillage and Tilth

a) By loosening the top soil and creating a mulch, tillage reduces the heat flow between the surface and the sub soil.

b) Since, the soil mulch has a greater exposure surface than the undisturbed soil and no capillary connection with moist layers below, the cultivated soil dries up quickly by evaporation, but the moisture in the sub-soil underneath the dry mulch is conserved.

c) In general soil warms up faster than air. The diurnal temperature wave of the cultivated soil has a much larger amplitude than that of the uncultivated soil.

d) The air 2-3 cm above the tilled soil is often hotter (10°C or above) than that over an untilled soil.

e) At night loosened ground is colder and more liable to frost than the uncultivated soil.

4. Organic matter:

a) The addition of organic matter to a soil reduces the heat capacity and thermal conductivity. But, the water holding capacity increases.

b) The absorbtivity of the soil increases because of the dark colour of the organic matter.

c) At night, the rapid flow of heat from sub-soil by radiation is reduced with the addition of organic matter because of its low thermal conductivity.

d) The darker the colour, the smaller the fraction of reflected radiation.

e) The dark soils and moist soils reflect less than the light coloured and dry soils.

5. Soil moisture

a) Moisture has an effect on heat capacity and heat conductivity.

b) Moisture at the soil surface cools the soil through evaporation.

c) Therefore, a moist soil will not heat up as much as a dry one.

d) Moist soil is more uniform in temperature throughout its depth as it is a better conductor of heat than the dry soil.

Variations in soil temperature:

There are two types of soil temperature variations; daily and seasonal variation of soil temperature

1. Daily variations of soil temperature:

a) These variations occur at the surface of the soil.

b) At 5 cm depth the change exceeds 10°C. At 20 cm the change is less and at 80 cm diurnal changes are practically nil.

c) On cooler days the changes are smaller due to increased heat capacity as the soils become wetter on these days.

d) On a clear sunny day a bare soil surface is hotter than the air temperature.

e) The time of the peak temperature of the soil reaches earlier than the air temperature due to the lag of the air temperature.

f) At around 20 cm in the soil the temperature in the ground reaches peak after the surface reaches its maximum due to more time the heat takes to penetrate the soil. The rate of penetration of heat wave within the soil takes around 3 hours to reach 10 cm depth.

g) The cooling period of the daily cycle of the soil surface temperature is almost double than the warming period.

h) Undesirable daily temperature variations can be minimised by scheduling irrigation.

2. Seasonal variations of soil temperature:

a) Seasonal variations occur much deeper into the soil.

b) When the plant canopy is fully developed the seasonal variations are smaller.

c) In winter, the depth to which the soil freezes depends on the duration and severeness of the winter.

d) In summer the soil temperature variations are much more than winter in tropics and sub tropics.

HUMIDITY –ABSOLUTE HUMIDITY – SPECIFIC HUMIDITY –RELATIVE HUMIDITY – MIXING RATIO, DEW POINT TEMPERATURE – VAPOUR PRESSURE DEFICIT – DIURNAL VARIATION IN RELATIVE HUMIDITY AND ITS EFFECT ON CROP PRODUCTION.

Humidity

The amount of water vapour that is present in atmosphere is known as atmospheric moisture or humidity.

Absolute humidity

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

Specific humidity

Weight of water vapour per unit weight of moist air. It is expressed as grams of water vapour per kilogram of air (g/kg).

Mixing ratio

The ratio of the mass of water vapour contained in a sample of moist air to the mass of dry air. It is expressed as gram of water vapour per kilogram dry air.

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.

Dew Point temperature

The temperature to which a given parcel of air must be cooled in order to become saturation at constant pressure and water vapour content. In this case, the invisible water vapour begins to condense into visible form like water droplets.

Vapour Pressure deficit

The difference between the saturated vapour pressure (SVP) and actual vapour pressure (AVP) at a given temperature. This is an another measure of moisture in the atmosphere which is useful in crop growth studies. When air contains all the moisture that it can hold to its maximum limit, it is called as saturated air, otherwise it is unsaturated air, at that temperature. The vapour pressure created at this temperature under saturated conditions is vapour pressure or saturated vapour pressure (SVP).

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%.

Variation in Humidity:

1. Absolute humidity is highest at the equator and minimum at the poles.

2. Absolute humidity is minimum at sunrise and maximum in afternoon from 2 to 3 p.m. The diurnal variations are small in desert regions.

3. The relative humidity is maximum at about the sunrise and minimum between 2 to 3 p.m.

4. The behaviour of relative humidity differs a lot from absolute humidity. At the equator it is at a maximum of 80 per cent and around 85 per cent at the poles. But, near horse latitudes it is around 70 per cent.