RAMA UNIVERSITY

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FACULTY OF MEDICAL SCIENCES

SOIL TEMPERATURE

Heat is a form of energy and temperature is a measur e of the heat energy. The heat energy refers to kinetic energy or random motion (vibration) of molecules of a substance. The speed of vibration is directly proportional to temperature.

Solar radiation is the source of soil heat. The flux of heat (color ies or joules) into and out of the soil determines the soil thermal regime, which is characterized in terms of soil temperature (°C).

On an average only 50% of solar radiation reaches the earth, because of clouds and dust particles intercept the sun rays. This energy is primarily utilized to evaporate water from soil or leaf surface or is radiated or reflected back to the sky. Only about 10% is absorbed by soil, which is of critical importance to soil processes and to plants growing on the soil.

The fraction of incident radiation that is reflected by the land surface is termed the "Albedo", and ranges from 0.1 to 0.2 for dark coloured, rough soil surfaces to as high as 0.5 or more for leaf surface or is radiated or reflected back to the sky. Only about 10% is absorbed by soil, which is of critical importance to soil processes and to plants growing on the soil.

smooth, light coloured surfaces.

Heat capacity or Thermal capacity

The "heat capacity" of a soil is defined as the ratio of heat supplied to a body to the corresponding rise in its temperature.

C= ?Qh / ? T

The heat capacity per unit mass of a body is called the "specific heat (e) and is defined as the quantity of heat required to raise the temperature of a unit body through 1°C.

The heat capacity is expressed as quantity of heat required to raise the temperature of unit volume of soil by 1°C and is known as "Volumetric heat capacity" or simply the "heat capacity" (gram calorie) Cv = J/m^3/°C or Cal/cm^3/°C

The specific heat is the heat capacity of a substance in relation to that of water.

Specific heat of water = 1.00 cal/g ; Soil forming minerals = 0.2

cal/g OM –0.46 cal/g ; Air – 2.4 cal/g

Dry soil – 0.233 cal/g; Soil with 50% moisture – 0.53 cal/g

Practically all substances have heat capacities lesser than that of water.

Thermal conductivity is defined as the quantity of heat passing in a unit time through a unit area of soil under a unit temperature difference between the faces and is expressed as Joules / meter / second / °C

Actual heat conductance depends on thermal conductivity and on the heat gradient. Thermal conductivity of a soil depends on its water content, texture, structure, mineralogical composition, organic matter content and compaction.

Thermal conductivity increases with increased water content, till about 50% of the soil saturation. It is observed to decrease with a reduction in particle size. Thermal conductivity of soil varies in the order : Sand > loam > clay > peat.

Thermal diffusivity ? (m^2/s) is defined as the ratio of thermal conductivity to heat capacity ? = ?

/ Cv . It is the measure of the rate at which changes in temperature occur in the body.
The reciprocal of thermal diffusivity indicates the ability of the body to retain heat .

Thermal conductivity of water $= 1.42 \times 10^{-3}$

Air $= 0.062 \times 10^{-3}$ Cal $cm^{-1} sec^{-1} °C^{-1}$

Quartz $= 20.0 \times 10^{-3}$

Quartz, water and air = 333 : 23 :1

Thermal Diffusivity = $\frac{Thermal conductivity}{Volumetric Heat Capacity} \square \frac{Thermal conductivity}{Specific Heat X Density}$

THERMAL RETENTIVITY: The ability of the body to retain heat is thermal retentivity. It is equal to the reciprocal of thermal diffusivity.

HEAT TRANSFER IN SOILS: The major physical processes responsible for the transport of heat are conduction, convection and radiation.

a) Conduction: It may be defined as " the fl ow of heat through an unequally heated body from the places of high temperature to lower temperature". It is through the momentum of molecules. The molecules of the body nearer to the source absorb heat and increase their kinetic energy and begin to vibrat e about their positions faster than before. They collide with other molecules and in this process they share their energies with the adjacent molecules so that other molecules increase their K.E and behave similarly to transfer heat energy from one end to another.

b) Convection : May be defined as the motion of the hot body itself carrying its heat with it. In this process absorption of heat causes increase in volume there by decrease in density of molecules. Such a decrease in density make the hotter molec ules to go up, giving their places to the cooler molecules which also behave like that after absorbing heat energy. This process occurs only in fluids.

c) Radiation: Radiation may be defined as the process by which heat is transmitted from one place to ot her with out aid of intervening medium. In this process heat is transferred through the space in the form of electromagnetic waves..

Management of soil temperature

The soil temperature depends upon the heat flux in to the soil and the heat transfer processes occurring in the soil and in between the soil and atmosphere, which in turn, depend upon the thermal characteristics of the soil solids, gases and water. The soil

thermal regimes greatly modify the microclimate of the area and exercise a major influ ence on growth and development of plants, particularly during germination and early seedling development stages.

Soil temperature can be modified by a) regulating energy balance on the soil surface b) changing the soil thermal properties and c) heating the soil through artificial means.

Temperature regulation by energy balance

The source of heat for soil is the solar radiation. The rate at which the radiant energy reaches the earth's atmosphere from the sun is called the solar constant, which has the val ue of about 2 cal cm^{-2} min^{-1}.

The solar radiation, which reaches the soil surface, is partly reflected, partly used for heating soil, partly used as latent heat for evaporation and partly reradiated as long wave radiation.

About 90% of long wave radiation is absorbed by the water vapours present in the earth's atmosphere, which partly reradiate to the earth's surface. It implies that the energy available for heating the soil is function of the incoming and outgoing radiation. If a greater fraction of incoming radiation is absorbed by the soil than the fraction reflected or reradiated

the soil will be heated. The energy balance on the soil surface and therefore be modified through tillage and shaping of fields, mulching and vegetation; and shading and row spacing.

Tillage and shaping of fields

Since both slope and direction affect soil temperature and heat flux, soil thermal regimes can be modified by specific tillage practices such as ridges and shaping. Comparatively high temperature is recorded on ridges as compared to furrows. Besides, the slope facing west would be comparatively warmer. Soil temperature is highest in east - west oriented ridges and decreases for other ridge directions in the order.

North – south ridges > East – west ridges > N-S conventional > Listing

Mulching and vegetation

From the energy point of view, mulching is the application or creation of a soil cover that constitutes a barrier to the transfer of heat or water vapour, where as the vegetation intercepts a considerable part of the incoming radiation. Vegetation and mulching affect the soil thermal regimes by 1) interception of the incoming radiation 2) changes in albedo conditions and 3) reduction in latent heat transfer by evaporation.

The mulches commonly used include : soil, stubble, straw, weed or trash, gravel, plastic (black, transparent, opaque etc.) paper (different textures and colors) asphalt and aluminum foils.

In general, light coloured mulches will increase albedo of the surface, thereby reduces soil temperature.

Black plastic mulch – reduces out going temperature

(heating) Paper and straw mulches – increases outing

temperature (cooling)

Aluminum foil mulch – sharply increases out going temperature (cooling)

Transparent plastic mulch – green house effect

Opaque mulches – thermal insulators (decreases maximum temperature and increases minimum temperature)

Shading and row spacing

Artificial shading is often practiced either to reduce the intensity of the direct radiation falling on the soil surface or to conserve the soil crop canopy heat.

Increased width in between rows, increases the temperature in rows and also shows lot of variation in temperature in between rows. In regard to row direction, east – west direction planted rows showed more variation in temperature between the rows.

Modification of soil thermal properties

Soil thermal characteristics can be modified by changing soil physical conditions through tillage practices, soil compaction, irrigation and drainage.

Tillage will loosen soil, increase the soil porosity and decrease the soil thermal conductivity and heat capacity.

Importance of soil temperature:

- Too low or too high temperatures affect the germination of seeds. Different crops have different optimum temperature for germination.
- Absorption of water and nutrients is impaired under low temperatures.
- Temperature influences nutrient availability by affecting the weathering of minerals and decomposition of organic matter.
- Low soil temperature results in white succulent roots with less branching.
- Low temperature enhances disease incidence by parasitic fungi
- Soil microbial activity and decomposition of organic matter is restricted below 10 ^{o} C and ceases below 5^{o}C.
- Biological nutrient transformations like nitrification, ammonification etc are affected by very high or low temperature