PRACTICAL MANUAL

ON

Introductory Agrometeorology and Climate Change

APA 207 2(1+1)

(For Undergraduate Agriculture students)

Dr. Gunjan Guleria

2020

College of Agriculture
RANI LAKSHMI BAI CENTRAL AGRICULTURAL UNIVERSITY, Jhansi-284003

Syllabus: Introductory Agro meteorology & Climate Change 2(1+1)

Visit of Agro meteorological Observatory, site selection of observatory, exposure of instruments and weather data recording. Measurement of total, shortwave and longwave radiation, and its estimation using Planck's intensity law. Measurement of albedo and sunshine duration, computation of Radiation Intensity using BSS. Measurement of maximum and minimum air temperatures, its tabulation, trend and variation analysis. Measurement of soil temperature and computation of soil heat flux. Determination of vapor pressure and relative humidity. Determination of dew point temperature. Measurement of atmospheric pressure and analysis of atmospheric conditions. Measurement of wind speed and wind direction, preparation of wind rose. Measurement, tabulation and analysis of rain. Measurement of open pan evaporation and evapotranspiration. Computation of PET and AET.

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Date: Course Teacher

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Practical No. 1

Objective: To visit agro-meteorological observatory

Exercise 1: Draw the layout plan of agrometeorological observatory you are visiting.

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Practical No. 2

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Practical No. 3

Objective: Exposure of instruments and weather data recording

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Exercise 2: How to record weather parameters with different instruments. What precautions are to be followed in handling of instruments while recording weather data?

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Practical No. 4

Objective: To measure shortwave and longwave radiation and its estimation

Exercise 1: How to measure shortwave and longwave radiations? Write about instruments used for measuring with diagram.

Practical No. 5

Objective: To measure total radiation and estimation of albedo

Exercise 1: How to measure total radiations? Write about instruments used for measuring with diagram.

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Practical No. 6

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Working: ……

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Procedure………

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Practical No. 8

Objective: To measure maximum and minimum air temperatures

Exercise 1: What are the different instruments used for measuring maximum and minimum temperature? Also draw diagrams of the instruments.

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Practical No. 9

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Exercise 2: Draw diagrams of soil thermometers.

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Exercise 3: How to compute soil heat flux?

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Practical No. 10

Objective: To determine relative humidity and vapour pressure

Exercise 1: How to measure relative humidity and vapour pressure.

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Practical No. 11

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Practical No. 12

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Exercise 2: How to measure wind speed and wind direction?

Objective: To study wind rose

Exercise 1: Prepare a wind rose with the help of wind statistics that describes the frequency, direction, force, and speed.

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Practical No. 14

Objective: To measure, tabulate and analyse rainfall.

Exercise 1: How to measure rainfall?

Instruments required: ……………………………………………………………………………………………………

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Measurement procedure:

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Care and maintenance:

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Exercise 2: How to analyse and present the rainfall data?

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Practical No. 15

Objective: To study atmospheric pressure and analysis of atmospheric conditions

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Principles: ………

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Practical No. 16

Objective: To measure evaporation.

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Practical No. 17

Objective: To measure evapotranspiration

Exercise 1: Perform and write the procedure for measuring evapotranspiration.

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Practical No. 18

Objective: To compute potential evapotranspiration and actual transpiration.

Exercise 1: How to compute potential evapotranspiration?

Exercise 2: How to compute actual evapotranspiration?

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APPENDICES

METEOROLOGICAL OBSERVATORY

Meteorological observatory is a place where all the necessary instruments are exposed for measuring weather phenomenon.

Four types of weather stations are recognized depending on the number of weather elements measured, the frequency of measurement and status of the observer. These four types of weather stations are Synoptic stations, Agricultural stations, Climatological stations and Rainfall stations. The surface observatories are divided into six classes and each class is coded with letter as follows:

Class A observatories: These are provided with eye reading instruments and self-recording instruments. the observations are recorded after every hour round the clock.

Class B observatories: Most of these are furnished with eye-reading instruments and self-recording instruments. Regular observations are made at least twice in a day.

Class C observatories: These have the same instruments or equipment that are described in Class B observatories, but observatories are recorded only once in a day.

Class D, Class E and Class F observatories: These have a smaller number of instruments or equipment or are non-instrumental.

Agro-meteorological observatory

- Agro-meteorological observatory is a place where several instruments are installed and exposed to observe meteorological as well as biological parameters of crops.
- The observations are recorded at stipulated time. Agromet observatories are classified into three categories *viz*; i) Principal, ii) Ordinary and iii) Auxiliary types, depending upon the instruments (essential and optional) available in the observatory.
- The observations from Agro-meteorological observatories are recorded at stipulated time.
- These observatories are specifically located at the centre of the agricultural research farms of agricultural colleges and universities.

Principal Agro-meteorological observatory: The Central Agromet Observatory situated at Pune is one of such observatories. Principal Agromet Observatories undertake routine works, planned programmes and international collaborative projects.

Essential instruments

1. Maximum and minimum thermometers.
2. Wet and dry bulb thermometers.
3. Soil thermometers.
4. Grass minimum thermometer.
5. Rain gauge (ordinary and self-recording).
6. Wind vane and anemometer.
7. U.S.W.B. open pan evaporimeter.
8. Sunshine recorder.
9. Assmann psychrometer.
10. Dew gauge.
11. Thermo hygrograph.
12. Soil moisture equipment.
13. Solar radiation instruments.

Optional instruments

1. Lysimeter
2. Thermopile sensing elements for short and long wave net radiation.
3. Potentiometer.
4. Microvoltmeter.

Ordinary agrometeorological observatory: These stations record meteorological as well as biological observations on routine basis.

Essential instruments

1. Maximum and minimum thermometers.
2. Wet and dry bulb thermometers.
3. Soil thermometers.
4. Grass minimum thermometer.
5. Rain gauge (ordinary).
6. USWB open pan evaporimeter.
7. Assmann Psychrometer.

Optional instruments

1. Sunshine recorder.
2. Dew gauge.
3. Self-recording rain gauge.
4. Thermo hygrograph.

Auxiliary Agro-meteorological observatory: These types of observatories are equipped with few instruments and collect qualitative data on phenology and insects and diseases of economic importance to important crops of the region.

Essential instruments

1. Maximum and minimum thermometers.
2. Dry bulb and wet bulb thermometers.

Optional instruments

1. Wind vane and anemometer.
2. Dew gauge.
3. Ordinary rain gauge.

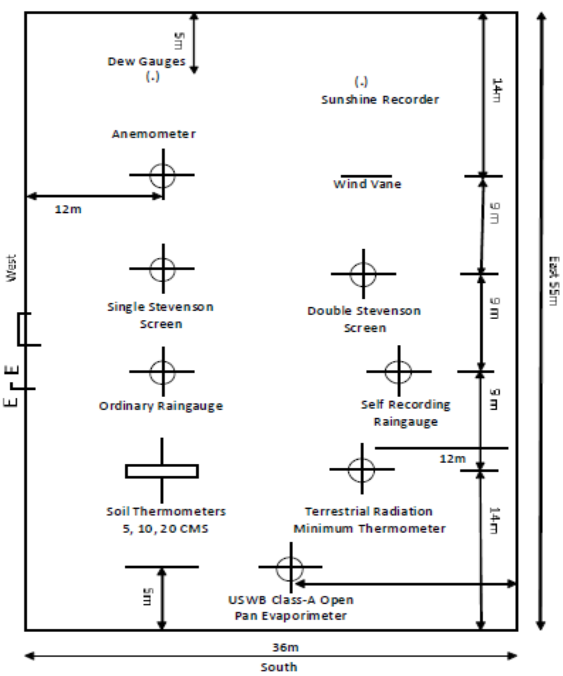
CRITERIA FOR SITE SELECTION

- The site should contain a flat rectangular plot with 55 meters (180 feet) in north-south direction and 36 meters (120 feet) in east-west direction
- The site must be representative of climate, soils and agricultural (cropping) conditions of the area and should be located at the centre of the farm,
- The site must be free from water logging and easily accessible throughout the year,
- Site selected should be away from hills, buildings, streams and trees to avoid shade, shield or channel affects,
- It should be away from steep slopes, water bodies and frequent irrigation.
- The recommendable distance from the obstacles from the raingauge and other instruments are at least twice and 10 times the height of the obstructions, respectively.

Fencing: After the site selection, it should be wire fenced, normally to a height of about 1.5 meter with a gate locking arrangement to protect from theft, animals and rodents which may cause damage to cables.

Surface conditions: The surface of the observatory should be cleaned regularly and be covered with thin grass as barren ground causes increased ground radiation. The grass should be periodically trimmed.

Layout of agromet observatory



Selection of site for observatory: The following basic requirements should be met out in selecting site for establishment of observatory. Proper site selection will ensure that the observations are representative of the place and sufficiently comparable with those of other stations.

1. The site should be representative of the crop-soil-climate conditions of the area.
2. It should be located at the centre of the farm.
3. The site should be free from water logging.
4. It should have easy accessibility during the rainy season.
5. The site should be away from any permanent irrigation sources and tall structures like buildings, hillocks and trees.
6. The site should not have extreme topography and it should be well exposed and levelled.

Recommended layout

- The dimensions for an observatory are length of 55 m and width of 36 m and the longer side running South-North.
- The ground plan for an agromet observatory is given in Fig 1.
- The periphery should be fenced with barbed wires to prevent cattle trespass.
- There should be a gate at appropriate site.
- All tall instruments should be installed at the northern side of the observatory to avoid shade effect.

Time of observation

- The observations are recorded at 07.00 and 14.00 hours local mean time (LMT) all over India.
- However, rainfall and evaporation observations are taken at 08.30 hrs Indian Standard Time (IST) and 14.00 hrs LMT.
- The setting of automatic instruments like thermograph, hydrograph evaporigraph and barographs etc. are done at 08.30 hrs IST.

Major units in general use and measuring instruments

S. No.	Element	Unit	Instrument(s)
1.	Temperature	Degree Celsius (°C)	Thermometer, Hygrograph
2.	Wind speed	kmph, mps, knots	Anemometer, Anemograph
3.	Wind direction	Degrees clockwise from north on the scale 00-36, where 36 is the wind from the north, 09 from the east and 00 refers calm	Wind Vane, Anemograph
4.	Relative humidity	Per cent (%)	Dry and wet bulb thermometers, hygrograph
5.	Precipitation	millimeters (mm)	Rain guage, dewgauge, snowguage
6.	Evaporation	millimeters (mm)	Evaporimeters
7.	Duration of sunshine hours	hours (h)	Sunshine recorder

8.	Cloud cover	Oktas(1/8 of the celestial dome)	Visual, observed in the observatory
9.	Atmospheric Pressure	Inches or millimeters	Barometer

MEASUREMENT OF TOTAL SOLAR RADIATION

Global solar radiation can be measured by converting radiant energy into electro-magnetic force as in thermopiles. Total short-wave radiation or global radiation on a horizontal surface can be measured by Pyranometers.

Pyranometer: In the absence of the instrumentation for observing solar radiation, the solar radiation receiving on the surface of the earth could be estimated by using the relationship between the duration of sunshine and radiation (Table 1). That is, radiation (calories/cm^2 /day) is directly proportional to number of bright sunshine hours. Higher the sunshine hours, larger the radiations received and *vice versa*. This can be given in Angstroms formula as:

Q = QA (a+b n/N); Where Q = the radiation actually received on the surface of the earth (cal/cm^2/day)

QA = Angots value (extra-terrestrial radiation value incident outside the earth's atmosphere

n = actual number of sunshine hours in a day as observed

N = Maximum possible duration of sunshine (depends on the latitude of the place)

a & b = constants depending upon the locations (latitude sun angle)

Case I- when n=N that is actual sunshine equal to maximum possible sunshine under clear sky

Q = QA (a+b n/N) = QA (a+b)

Maximum radiation received on the earth surface.

Case II - n =0, due to continuous overcast conditions throughout the day

Q = QA (a+b 0/N) = QA(a)

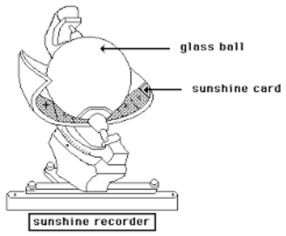
Lowest radiation received due to scattering effect of clouds.

Q is not equal to 0, even if n=0. It is due to the fact that diffused radiation is received even on cloudy days.

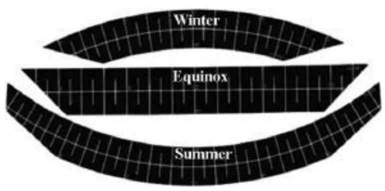
MEASUREMENT OF SUNSHINE DURATION

For the measurement of sunshine duration, following instruments and accessories are required:

i. Campbell-Stokes sunshine recorder.
ii. Sunshine card.
iii. A special plastic scale.



Campbell Stokes sunshine recorder: The Campbell-Stokes Sunshine Recorder consists of a 10 cm diameter glass sphere mounted on a spherical bowl. There are three partially overlapping grooves in the bowl in which three different types of cards are placed. The glass sphere is focused so that an image of the sun is formed on recording paper. Three different recording cards are used depending on the season.



Recording Cards: The cards are made up of a good quality pasteboard of 0.04 mm thickness and are blue in color. This color enables the card to absorb the radiation and gives a good contrast when burned. There are three different types of cards. The short curved are used for winter season, long curved card for summer season and straight cards in equinoxes are used.

Measurement of Sunshine Duration

Cards	Season	Period	Grooves
Short curved	Winter	15th October to end of February	Upper
Long curved	Summer	12th April to 2nd September	Lower
Straight	Equinoxes	3rd September to 14th October; 1st March to 11th April	Middle

Special Plastic Scale: This is a type of time scale used to measure the length of burn to obtain the duration of sunshine. The scale is made up of celluloid and each hour is divided into 10 parts consisting of 0.1h or 6 min. The parallel sunshine scale is used for straight cards and trapezoidal scale is used for long and short curved cards.

Installation and Working: The instrument is installed on a masonry pillar of 10 ft. (3.04 m) above the ground. The sphere is supported on the bowl according to the latitude of the place where the observatory is located.

The focus of the sphere shifts as the sun moves, and a burn trace is left on the recording card at the focal point. A burn trace at a particular point indicates the presence of sunshine at that time, and the recording card is scaled with hour marks so that the exact time of sunshine occurrence can be ascertained. Measuring the overall length of burn traces reveals the sunshine duration for that day. The total length of the burn is measured with the help of the special plastic scale.

Procedure:

1. A suitable card depending on the season is set in the suitable groove.
2. Insert the card in the appropriate groove of the recorder such that the 12 h line coincides with the noon mark engraved on the bowl.
3. After sunset remove the burnt card.

4. Measure the burns using the special plastic scale.
5. Add up the values for all the hours and determine the total duration of sunshine hours for the day.

ESTIMATION OF RADIATION INTENSITY USING BSS (Angstrom Formula)

Various climate models have been developed for use in predicting the monthly average global solar radiation, the popular one being the Angstrom-type regression equation developed by Angstrom in 1924. This relates monthly average daily global radiation to the average daily sunshine hours, and is given by the following expression:

$$\frac{Q}{Qo} = a + b\ \frac{N}{No}$$

where,

Q Monthly average daily global radiation on a horizontal surface (MJ m^{-2} day^{-1}),

Qo Monthly average daily extra-terrestrial radiation on a horizontal surface (MJ m^{-2} day^{-1})

a, b Constants, whose value depends on location and month of observation,

N Monthly average daily number of hours of bright sunshine (BSS)

No Monthly average daily maximum number of hours of possible sunshine (or day length)

Although it is not possible to estimate the daily total amount of global solar radiation on a particular day from the sunshine duration using this method, it does enable rough estimation of a monthly value.

MEASUREMENT OF AIR TEMPERATURE

Temperature of the air is one of the important factors in crop - weather relations. Its measurement helps in understanding the rate and amount of water loss in the process of evaporation from the soil and transpiration from the plant system for a given environment. Temperature is measured using three type of scales namely Fahrenheit, Celsius and Kelvin. The melting point of ice on the three scales is 32°, 0° and 273° and boiling point of water is 212°, 100° and 373°, respectively. The relation between three scales are **°K = °C + 273; °C = 5/9(°F-32) and °F = 9/5(°C+32)**

Temperature Instruments

Maximum thermometer: This is a mercury thermometer and records the highest or maximum temperature reached during past 24 hours or since last setting. Maximum temperature generally occurs in the world between 14.00 to 1600 hrs.

Minimum thermometer: This thermometer records the lowest temperature of air reached during last 24 hours or since last setting. Lowest temperature of the day generally occurs just before sunrise or clear day and after sun rise on cloudy day.

Dry bulb thermometer: This is a mercury thermometer which gives the prevailing temperature of air at 4' 3"to 4' 6"height. It is required to calculate relative humidity and vapour pressure.

Wet bulb thermometer: This is similar to dry bulb thermometer but the bulb of thermometer acts as an evaporating surface. It is used for calculating dew point, relative humidity and vapour pressure.

Thermograph: This instrument continuously records air temperature with passage of time. This is not an accurate instrument but its importance lies in its automatic recording of air temperature.

Infra-red thermometer: This is a sophisticated instrument used for measuring instant temperature. It contains thermocouple and thermistors up to accuracy 0.1 °C and response time less than one second. It is very accurate, rapid, and portable without any contact, temperature is obtained.

Maximum air temperature: The maximum temperature attained by air during the day is measured by a thermometer called maximum thermometer. It is a mercury-in-glass thermometer with a constriction in the bore below the lowest graduation. It allows the mercury to be forced through with rising temperature but prevent it being drawn back with falling temperatures, provided the thermometer is kept at an angle of 10° from the horizontal with the bulb downwards. It allows the mercury in one way as the constriction acts as a valve. The observer resets the thermometer after reading by holding it firmly in hand by the remote end from the bulb and swinging it briskly downwards. The range of maximum thermometer graduation is from -20°C to 55°C.

Minimum thermometer: The minimum temperature attained by air during the day is measured by using a thermometer called minimum thermometer. Minimum thermometer is an alcohol thermometer. Alcohol is sensitive for lower temperature than mercury. Within the liquid, there is a very light dumb bell-shaped glass index which moves freely within the spirit but not readily emerge from the liquid due to surface tension. The thermometer is tilted slightly so that bulb end is upward, the glass index slides along the tube until it reaches the meniscus. But when temperature rises, it remains stationary while the liquid moves ahead in the column. The range of minimum thermometer graduation is from -40°C to 50°C.

MEASUREMENT OF SOIL TEMPERATURE

Soil temperature in simple words is the measurement of the warmth in the soil. Soil temperature is an important factor for plant growth and development. Soil temperature affects the water movement within the soil and plays a vital role in germination of seeds and root system development. The activity of the soil micro-flora, decomposition of organic material and absorption capacity of roots depend on the soil temperature. An increase in soil temperature results in the increased solubility of some major salts.

Soil Thermometer: A soil thermometer is a mercury-in-glass thermometer. The bulb of this thermometer is bent at an angle of 120° while the stem is straight. The range of the thermometer is -20 to +60°C. The site for such measurements should be a level plot of size 180 cm X 120 cm in the observatory and typical of the surrounding soil for which information is required. The standard depths for measurement of soil temperature are 5, 10 and 20 below the surface. Additional depths may however be included. The thermometers are placed 45 cm apart at an inclined depth of 5.8, 11.6 and 23.2 cm to ensure a vertical depth of 5, 10, 15 and 20 cm respectively. In places where ground is covered with snow, it is desirable to measure the temperature of snow cover as well.

Installation

- Minimum soil layer should be disturbed during installation of thermometers inside the soil.
- The bulb of the thermometer should rest in good contact with the firm undisturbed soil.
- While digging the soil for installation, the soil should be removed layer wise and identically layers put in corresponding previous position.
- The zero mark of the thermometer should be at ground level.

Recording Observations: The soil temperature readings are taken read daily at 07.00 and 14.00 h LMT. The following points should be kept in mind while taking the observations:

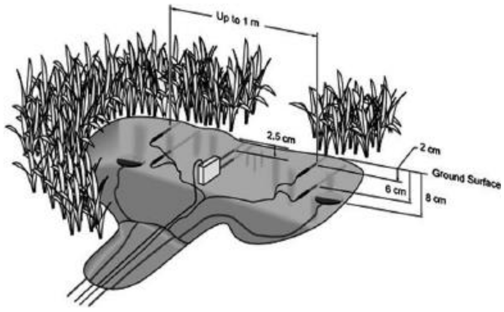
- The line joining the observer's eye and top of the mercury column should be at right angle to the instrument.
- The observer should stand at some distance from the instrument so as not to shadow the ground surface in the vicinity of the instrument.
- Reading should be taken correct to 0.10°C.

Grass Minimum Thermometer: The grass minimum temperature is the lowest temperature reached overnight by a thermometer freely exposed to the sky just above short grass. The grass minimum temperature is measured with a minimum thermometer as described in Section "Minimum Temperature Thermometer". The stem of this thermometer is however encased in a glass jacket in order to protect seal marks on the stem from dew, rain and prevent the stem from cooling rapidly. Grass minimum temperature indicates the chance of occurrence of ground frosts. A ground frost is likely to occur when the instrument records a temperature below 0°C.

Thermometers are mounted on suitable Y-shaped supports so that they are inclined at an angle of about 2° from the horizontal position, with the bulb being lower than the stem. The reading is taken before sunrise. After reading, the instrument is kept indoors to avoid direct exposure to solar radiation. The grass minimum temperature remains lower than the air temperature at screen level.

Computation of Soil Heat Flux: Soil heat flux is measured by means of Soil Heat Flux plates placed at suitable depths in the soil usually 8 cm. Temperature gradient across the plates is measured by means of a thermopile. Each plate is individually calibrated to output flux.

Placement of heat plates and sensors for measurement of soil heat flux



INSTRUMENTS FOR MEASUREMENT OF RELATIVE HUMIDITY

Stationary or simple Psychrometer: It consists of two mercury thermometers with the bulbs of identical form and size. A set of these two thermometers (Dry and Wet bulb) is known as simple Psychrometer. Both are exposed vertically in Stevenson's screen. The dry bulb thermometer indicates the actual temperature at the time of observations and the wet bulb thermometer indicates the temperature of cooled air by converting the bulb to an evaporating surface. With the help of hygrometric table dew point temperature and relative humidity are obtained.

Assmann Psychrometer: Assmann devised this instrument in 1887 in Berlin. This instrument consists of a pair of dry and wet bulb thermometer with the cylindrical bulb forms, fixed vertically. Each bulb is protected from external radiation by two highly polished coaxial tubes. The instrument is designed for measuring the temperature and relative humidity both in the open as well as inside crops. In this psychrometer, the aspiration is provided by means of a clockwork fan by which air is drawn at a speed higher than 10 feet per second (fps).

Whirling Psychrometer: Anago devised this in 1830. This instrument is used to measure the temperature and relative humidity of the air in the open as well as inside crops at various heights. It consists of two thermometers attached horizontally to a rectangular wooden frame. Both the thermometers can be rotated with handle. This psychrometer should be given about 4 rotations per second to obtain desirable wind speed of about 5m per second. By the readings of dry and wet bulb thermometers of Assmann and Whirling psychrometer, dew point temperature, vapour pressure and relative humidity at different heights can be calculated. These two instruments are used to measure microclimatic observations in the laboratory near a microclimatic post. It is a wooden post of 3" X 3" X 3" X 12' size with markings at 1', 2', 4', 8' and 12' heights. It is painted white and by the side of the post is placed a wooden ladder of 8' height.

Hair Hygrometer: Hair hygrometer is used to record humidity at the time of observations. A human hair is used in this instrument. It is circular in size and indicates humidity directly. It is kept in the laboratory to observe humidity in room temperature.

Hair hygrograph: It is an instrument used for continuously recording the relative humidity of the air. Human hair has a property to increase the length with increase in humidity and decrease with decrease in humidity. Thus, the instrument consists of a bundle of cleaned and de-oiled human hair, tied at both the ends and kept tight in the middle by means of a hook attached to one arm of the lever and second arm of the lever is associated with pen arrangement which can make marking on graph paper attached on the clock driven revolving drum. The changes in length of the hair thus, cause a displacement of the hook, which is communicated by second arm of the lever to record the changes on the graph paper. The circular drum rotates once in 24 hrs or once in a week. This instrument is placed inside a Stevenson's screen in the observatory. Its operation is based on the property of de-oiled human hair to vary its length.

MEASUREMENT OF WIND DIRECTION

The instrument used for the measurement of wind is wind vane. The direction from which wind blows is known as the windward side and towards which it bows is known as leeward side.

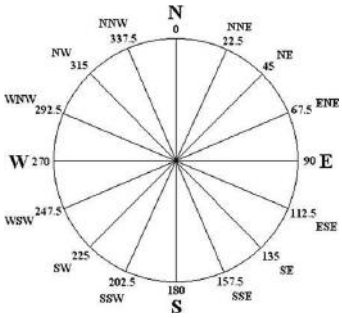
Wind vane: Wind vane consists of a brass-arm, mounted on ball bearing to a vertical axis. To one side of the brass arm there is an arrowhead and on another side there are two flat vanes forming an acute angle (about 20°). The ball bearings are in bearing house where there is an oil hole. The screw below the bearing are in bearing house are tightened to a brass covering known as brass sleeve. Below the wind vane there are 4 direction arms fixed to the vertical axis by means of a brass boss. In between the direction arms there are corner indicators. The direction arms and corner indicators are tightened to the brass boss by means of knots known as check knots. The direction arms are levelled with N, S, E and W. The vertical axis is erected by means of an iron-stand.

Units: Wind direction can be expressed in two ways:

1. By direction (Sixteen point of a compass).
2. By degree (from north, measured in clockwise as N, E, S, W means 360°, 90°, 180° and 270° respectively).

Observation: Watch the wind vane for a few minutes and identify the direction nearest to the sixteen point of the compass.

Wind direction



Measurement of Wind Speed: Wind speed is measured by means of an anemometer. There are two types of rotating anemometers: the cup anemometer, which has three or four cup wheels attached to the rotating axis, and the propeller anemometer, which has propeller blades. Both types rely on the principle that the revolution speed of the cup or propeller rotor is proportional to the wind speed.

Cup Anemometers: A cup anemometer has three or four cups mounted symmetrically around a free-wheeling vertical axis. The difference in the wind pressure between the concave side and the convex side of the cup causes it to turn in the direction from the convex side to the concave side of next cup. The revolution speed is proportional to the wind speed irrespective of wind direction. Wind speed signals are generated with either a generator or a pulse generator.

The cups were conventionally made of brass but in recent years, cups made of light alloy or carbon fiber thermo-plastic have become the common, allowing significant reductions in weight. Beads are set at the edges of the cups to add rigidity and deformation resistance. They also help the cup to avoid the effects of turbulence, allowing the stable measurement of a wide range of wind speeds.

The anemometer is installed on a metal pipe, which is fixed on a wooden post.

The height from the center of the anemometer cups is 10 ft. above the ground level.

Units: A number of different units are used to indicate wind speed. Some of the common units of measurement are

Conversion of units of wind speed	kt	m/s	km/h	mph	ft./s
	1	0.515	1.853	1.152	1.689

i. meters per second (m/s),
ii. kilometers per hour (km/h),
iii. miles per hour (mph),
iv. feet per second (ft./s) and
v. knots (kt).

Wind Rose: Wind direction is normally defined by a wind rose. Wind rose is a graphic display of the distribution of wind direction at a location during a defined period. The characteristic patterns can be presented in either tabular or graphic forms. A wind rose is a set of wind statistics that describes the frequency, direction, force, and speed. In this plot the average wind direction is shown as one of the sixteen compass points, each separated by 22.5' measured from true north. The length of the bar for a direction indicates the percent of time the wind came from that direction. Since the direction is constantly changing, the time percentage for a compass point includes those times for wind direction at 11.25° on either side of the point. The percentage of time for a velocity is shown by the thickness of the direction bar.

Preparation of Wind Rose

i. A circle is first divided into 8, 12, or 16 sectors representing the directions of wind flow.
ii. The percentage of time the wind blows from each direction is determined from wind direction data. **Table** shows a sample frequency data table for preparation of wind rose.
iii. The data is then plotted on a circular graph as a line emanating from the center of the circle. The length of the line is scaled to the percentage obtained from the data, pointing in the given direction.
iv. The wind speed can be included in wind rose diagram. For this purpose, the percent of time that the wind is blowing at given speeds toward each direction needs to be determined. This data is then plotted as scaled blocks on the line showing wind direction.

Sample frequency data for preparation of wind rose

Direction	Frequency	Percentage (%)
N	165	22
NE	65	14
E	142	5
SE	17	3
S	65	9
SW	59	11
W	38	9
NW	150	27
Total	701	100

MEASUREMENT OF RAINFALL BY FRP RAIN GAUGE, SELF-RECORDING RAINGAUGE

- Water in any form falling on the earth is called precipitation.
- The main forms of precipitation falling to the ground are drizzle, rain, snow and hail.
- Rain is the liquid form of precipitation, while snow and hails consist of solid ice crystals. Dew and frost are ground precipitation, which do not fall but form near and ground on the vegetation.
- Rain is an important form of precipitation and is the main source of soil moisture for crop production.

Instruments required

1. Ordinary rain gauge
2. Self-recording rain gauge

Rainfall measurement

- The principle of rainfall measurement is to measure the depth of the layer of the water that has fallen.
- Five millimetre of rain means if that rainfall is collected on flat surface, the height of water would have been 5 mm.

Ordinary rain gauge

- This rain gauge consists of a funnel, provided with a rim, which is circular and exactly 127 mm in diameter. The rim of the rain gauge is 30 cm above the ground level and 25.4 cm above the cemented plat form.
- The rain water collected in receiver is measured with the help of a standard measuring cylinder provided with the instrument. The capacity of the receiver is 4 litres.
- A measuring cylinder calibrated in mm is used to measure the rainfall.
- The measurement is taken daily at 8.30 hrs IST and 14.00 hrs LMT as and when there is rain. The rainfall of last 24 hrs is recorded in the column of observation day.

Measurement of rainfall

- The rainwater from the receiver is carefully poured in to the measuring glass kept on the horizontal surface. The observer maintains his eye at the level of water in the measuring glass.
- Reading is noted from the lower meniscus avoiding parallax.

Care and maintenance

1. The funnel should not get chocked with dirt.
2. The receiver should be always kept clean.
3. The measuring glass should be kept spotless clean.
4. All the parts should be examined regularly for choking and leakage.
5. While replacing the funnel, see that it is pressed down evenly from all sides.

Self-recording raingauge: This is a natural siphon type rain gauge used for measuring the amount, duration and rate of rainfall continuously. The instrument consists of three main parts **Funnel, Recording mechanism and Receiver**

The receiver consists of float and siphoning chamber. Rain water enters the receiver through eight-inch diameter funnel. A pen is mounted on the stem of the float. As the level of water rises in the receiver, the float rises and the pen records continuously the amount of water in the receivers on a chart placed on a rotating drum with clockwork arrangement. The clockwork drum revolves once in 24 hrs or 7 days. Siphoning starts automatically when the pen reaches the maximum point of the chart. If the rain continues, the pen rises again from the zero line on the chart. If there is no rain, the pen traces the horizontal line from where the rain stopped.

Rainy day- If the rainfall of a day is 2.5 mm or more then it is called as a rainy day.

MEASUREMENT OF EVAPORATION

Evaporation is measured by means of evaporimeters. Evaporimeters are pans containing water which are exposed to atmosphere. The loss of water by evaporation is measured at regular intervals. The most common pan evaporimeters used in India for the measurement of evaporation is USWB (United States Weather Bureau) Class a Land Pan (Class A pan evaporimeter).

The Class a land pan is a standard pan with a diameter of 1210 mm and a depth of 255 mm. The depth of water is maintained between 18 and 20 cm. The pan is normally made of unpainted galvanized iron sheet painted white. The pan is placed on a wooden platform of 15 cm height above the ground to allow free circulation of air below the pan. The pan is covered by a wire mesh to avoid birds from drinking water from the pan. Evaporation measurements are made by measuring the depth of water with a hook gauge in a stilling well or by a fixed-point gauge using measuring bucket.

The hook gauge consists of a movable scale fixed with a hook. The rotating head of the hook gauge is divided into 100 divisions so that the level of water may be read correct to 1/100 of an inch. The point of the hook indicates water level. The hook gauge rests on a stilling well of size 10 cm diameter and 30 cm height on which, is placed within the tank. It isolates some amount of the water surface in the pan so that it is not disturbed by waves produced by wind.

In fixed point gauge, a brass pointer is fixed vertically at the center of the cylindrical stilling well. The tip of the rod is located at 6–7 cm below the rim of the pan. There are three small holes at the bottom of the stilling well to permit the flow of water into and out of the well. For taking the reading, the water level is brought to the same fixed point by adding water using a graduated measuring bucket.

The ratio of the area of the bucket to the area of evaporation pan is exactly 1:100. It has is graduated from 0 to 20 along its height. The graduation runs from top to bottom in ascending order. One full cylinder of water rises 2 mm height in the pan. The evaporation can be measured correct to 0.1 mm.

Observations to be Recorded: Evaporation is measured every day at 8:30 am IST. The observations to be recorded are:

1. Temperature of water in the pan.
2. Amount of water added or removed to bring back level to the tip of the pointer.
3. Amount of rainfall during the past 24h.

Evaporation measurement is done for in different conditions.

No Rainfall: When there is no rainfall, measured quantity of water is added to the evaporation pan up to the tip of the pointer using the measuring bucket. The evaporation is equal to the amount of water added to the pan.

Rainfall with Pointer Above the Water Level: When there is rainfall, but the tip of the fixed-point gauge remains above the water level, measured quantity of water is added by measuring bucket till the water level reaches tip of the pointer in the stilling well. Evaporation is estimated as:

Evaporation = Water added + Rainfall during the period

Rainfall with Pointer Below the Water Level: When rainfall is more than evaporation and the water level inside the stilling well is above the tip of the pointer, in this case water is removed from reservoir with the help of measuring bucket until the level of water comes to the tip of the pointer. Evaporation is estimated as:

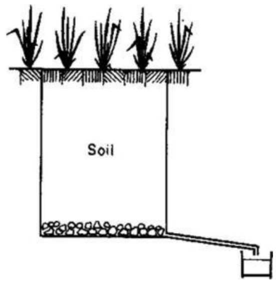
Evaporation = Rainfall during the period - Water removed

Overflow: When there is heavy rainfall, over flow will take place from the pan, evaporation cannot be recorded.

MEASUREMENT OF EVAPOTRANSPIRATION

For determination of evapotranspiration, lysimeters are used. A lysimeter is a special water tight tank containing a block of soil and set in a field of growing plants. The plants grown in the lysimeter are the same as in the field. Evapotranspiration is estimated in terms of the amount of water required to maintain constant moisture conditions within the tank measured either volumetrically or gravimetrically through an arrangement made in the lysimeter. Lysimeters should be designed to accurately reproduce the soil conditions, moisture content, type and size of the vegetation of the surrounding area. They should be so buried that the soil is at the same level inside and outside the container. There are three types of lysimeters:

Non-weighing Type Lysimeters: Non-weighing (percolation-type) lysimeters can be used only for measuring volumetric changes in water balance weekly or biweekly. They do not provide accurate daily estimates. A simple non-weighing lysimeter is shown in Fig. Irrigation water is applied to the lysimeter. A layer of pebbles is placed at the bottom to facilitate easy drainage. Excess water is collected from below at a suitable distance.



Weighing Type Lysimeters: Weighing lysimeters provide precise information on soil moisture changes for daily or even hourly periods. This lysimeter is mainly composed of an inner tank, which is placed inside another tank. The outer tank is in contact with the surrounding soil. The inside container can be isolated from the outer tank and is weighed by scales. A heavy liquid like $ZnCl_2$ can be used to float the tank in water and the water gain or loss is estimated in terms of water displaced. This lysimeter is most commonly used for ET measurement but it has some important limitations. The restricted root growth, the disturbed soil structure in the lysimeter causing changes in water movement and possibly the tank temperature regime, resulting in condensation of water on the walls of the container. Harrold and Dreilbelbis (1967) estimated that errors due to dew formation were in the order of 250 mm per annum. Other limitations include the ‘bouquet effect’ whereby the canopy of the plants grown in the lysimeter is above and extends over the surrounding crop, resulting in a higher evapotranspiration rate. In spite of these limitations, it is the best technique for precise studies on evapotranspiration.

Floating Type Lysimeters: In this lysimeter, soil is placed in a hollow-walled tank that floats in water inside a slightly larger reservoir tank. A loss or gain of weight in the floating tank results in a change of water level in the reservoir tank and stilling well. This level is recorded by a sensitive water-level recorder. Any overflow from an excessive weight on the floating tank is retained in an overflow tank at the recorder.