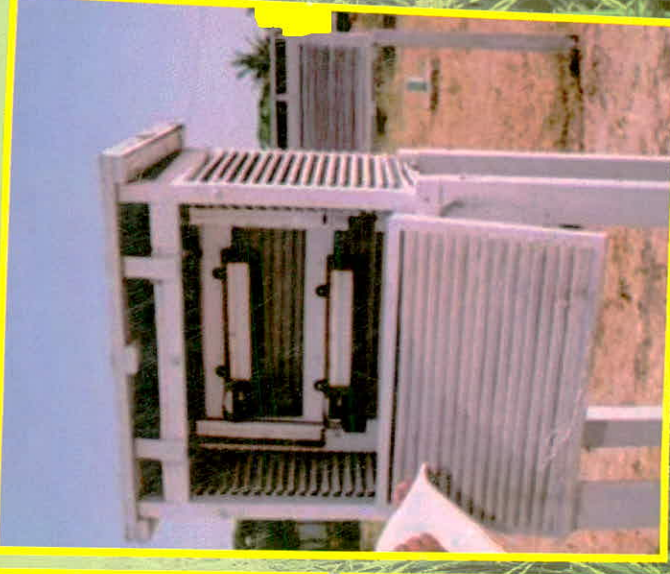
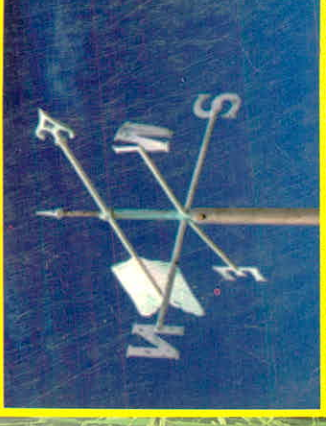
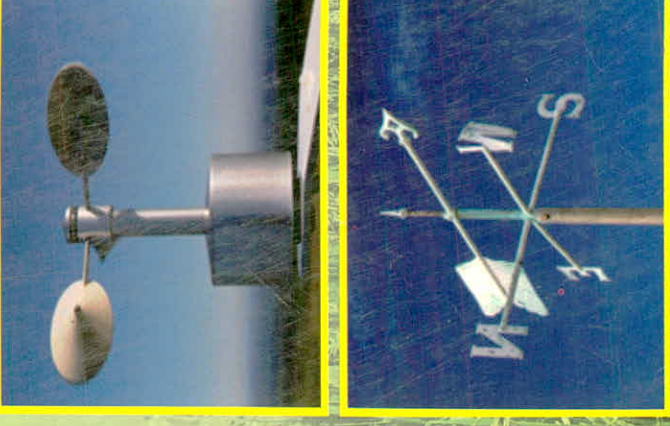


PRACTICAL MANUAL OF AGROMETEROLOGY AND AGRONOMY



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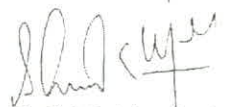
Foreword

This practical manual is meant for undergraduate level students of agriculture course. This book is also useful for officials of agriculture and horticulture departments, who deal with the implementation of technology at village level. This book covers the topics related to basic of agrometeorology and agronomy in a simple form. The topics were dealt along with tables, formulae, figures and illustrations for easy understanding of the subject.

Crop production depends on the climate to a much greater extent than any other single factor of the environment. However, a large number of crops are being grown traditionally in areas without any consideration to the fitness of climate. As a result on one hand, poor yields of the crops are obtained and on the other hand much of the production potential of the climates go unutilized. With staggering increase in food demands and limits on the availability of land and water, the resource base of agriculture needs careful management to increase farm produce from a unit area. Great advances are being made to properly manage some of the variables involved in crop production but successes in the management of climate are still unlimited. Two different approaches are being tried:

One is to control or modify the climate. Here the elements of climate can be controlled with varied degree of success. This is however possible at micro-level and at a very high cost. The second approach is to make an adjustment with the climate to make the best use of it without involving any major expenditure.

The adjustment is made first by determining the agroclimates and then delineating these agroclimates into agroclimatic regions. Agroclimates well understood and wisely integrated into agroclimatic regions can become valuable and handy tools for the practical execution of plans for harnessing the potentials of climates for agricultural production. Further, the effort made by Shri Manish Kumar and A.k. Thakur is highly appreciable.


(S.C. Mukherjee)
Dean

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UNIT- I

Basic Introduction- Meteorology And Agro Meteorology

Crop growth and development are primarily governed by environmental condition ,i.e., climate and soil. Soil provides physical anchorage to crops, is the reservoir of nutrients and water needed by it and is the source of warmth and aeration to roots. The development of the soil profile and its physical and chemical composition have a significant bearing on crop performance .These are either the result of or are greatly affected by weather. Again ,seed materials have to be stored for various lengths of time for raising annual crops The condition of storage invariably permit outside environment to leave an imprint on the vitality and viability of seed material, which in turn, affects the germination and early vigour of crops.

Crops require certain cardinal levels of various factors of environment like air and soil temperatures, length , quality and intensity of light , humidity of soil and air etc ., for optimum physiological functioning .These requirements not only vary from species to species but may also be different for the various stages of development of crops. Deviations from these , resulting from either the in situ climate or from weather ,result in abnormal crop growth and performance. The weather effects can also be physical ,e.g., lodging of crops by high winds , shedding of grains due to heavy rains, etc. Besides the above direct influence , weather may exert an indirect influence through the provision of conditions congenial for outbreak of pests and diseases or by interfering with cultural operations.

Many crops remain , for a considerable fraction of their life -cycle, below the level of the screen in which meteorological measurements are made .Since the soil surface constitutes the source of heat for the atmosphere and exerts a profound fractional effects on wind movements , the air layer close to the ground has many features which are strikingly different from the air layers at higher levels. The special features constitute the ;micro- climate which is modified compared to a flat bare surface by factors like topography ,nature of soil surface , presence of vegetation and type of vegetative cover. The presence of a crop canopy leads to distinct difference in the thermal and humidity regimes of the soil, the air layers immediately above it and the distribution of radiation and wind profile inside the canopy .A study of the physical exchange on the transfer of heat , momentum and moisture in the micro-climate region is called " Micro- meteorology" .Thus success and failure of crops is intimately related to the weather during the crop periods.

Climatology:-

It is defined as a scientific study of climate. It discovers, describes, & interprets the climate on the basis of causes processes that generate them.

OR

Climatology is the science which studies average condition of weather or the state behavior of the atmosphere over a place or region for a long period of time.

Definition Of Meteorology :

Meteorology (from the Greek mete meteoros - lofty-high in the sky) is the study of phenomena of the atmosphere - includes the dynamics, physics, and chemistry of the atmosphere.

OR

Meteorology is the scientific study of the earth's atmosphere and its changes, used especially in forecasting the weather.

OR

More commonly thought of as restricted to the dynamics and thermodynamics of the atmosphere as it affects human life.

Agricultural Meteorology and Its Levels

1. J.W. Smith (1916) has defined Agricultural Meteorology as "Meteorology in its relation to agriculture"
2. It can be defined as the science investigating Meteorology, climates and hydrologic condition, which are significant to agriculture.
3. The meeting of agro meteorologists in Moscow in 1951 defined agro meteorology as a science investigating the meteorological, climatological and hydrological conditions which are significant for agriculture owing to their interaction with the objects and processes of agriculture production.
4. In short Agril. Meteorology is the applied branch of meteorology, which deals with the relationship between climates, weather and life and growth of the cultivated plants and animals.

Levels of Study of Meteorology: Study of meteorology is organized at three levels.

1. Micro scale: A process operating within vegetation canopies near earth surface its size is in few cm and life span is few seconds.
2. Meso scale: The systems are approximately 10km in size and a lifetime is of few hours [up to 5 hrs] eg. Thunder storm.
3. Macro scale: It is divided into two scales.

A) Synoptic scale: These systems have a diameter of few thousand km. and life time of about 5 days eg. Tropical storm, cyclones.

B) Planetary scale: These systems have a diameter of 5000 to 10000km and persist for several weeks eg. Waves in the atmosphere circulation.

UNIT-II

Practical Utility, Importance & Scope Of Meteorology & Agro - Meteorology

Importance of Meteorology

Almost all social, industrial, agricultural, commercial, transports etc. Activities directly or indirectly are affected by weather and climate. The atmosphere affects and sustains human life, animal, micro- organisms, insects, pests, plants, tree's forests and marine culture at all times during every stage of growth and development. Meteorology has therefore, greatest scope on every human enterprise in the modern Life.

Scope of meteorology: 1. Safe Navigation .2. Safe aviation .3. Industry. 4. Animal Production. 5. Fisheries. 6. Irrigation and water resources. 7. Land use planning. 8. Human Life. 8.1 Clothing. 8.2 Housing. 8.3 Food habits. 9. Human health. 10. Commerce.

Importance and Scope of Agro Meteorology : Weather and climate is a resource and considered as basic input or resources in agricultural planning, every plant process related with growth development and yield of a crop is affected by weather. The scope of Agril Meteorology can be illustrated through the following few applications.

- 1. Characterization of agricultural climate:** For determining crop growing season, solar radiation, air temperature, precipitation, wind, humidity etc. are important climatic factors on which the growth, development and yield of a crop depends. Agro-meteorology considers and assess the suitability of these parameters in a given region for maximum crop production and economical benefits.
- 2. Crop planning for stability in production:** To reduce risk of crop failure on climatic part, so as to get stabilized yields even under weather adversity, suitable crops/cropping patterns/contingent cropping planning can be selected by considering water requirements of crop, effective, rainfall and available soil moisture.
- 3. Crop management:** Management of crop involves various farm operations such as, sowing fertilizer application. Plat protection, irrigation scheduling, harvesting etc. can be carried out on the basis of specially tailored weather support. For this the use of operational forecasts, available from agro met advisories, is made e.g.
 - 1) Weeding, harrowing, mulching etc are undertaken during dry spells forecasted.
 - 2) Fertilizer application is advisable when rainfall is not heavy wind speed is <3.0 km/hr and soil moisture is between (30 to 80%) Spraying/dusting is undertaken when there is no rainfall, soil moisture is 90% and wind speed is <2.5km/hr.
- 4. Crop Monitoring:** To check crop health and growth performance of a crop, suitable meteorological tools such as crop growth models. Water balance technique or remote sensing etc. can be used.
- 5. Crop modeling and yield -climate relationship:** Suitable crop models, devised for the purpose can provide information or predict the results about the growth and yield when the current and past weather data is used.
- 6. Research in crop -climate relationship:** Agro-meteorology can help to understand crop-climate relationship so as to resolve complexities of plant process in relation to its micro climate.
- 7. Climate extremities:** Climatic extremities such a frost floods, droughts, hail storms and high winds can be forecasted and so crop can be protected.
- 8. Climate as a tool to diagnose soil moisture stress:** Soil moisture can be exactly determined from climatic water

balance method, which is used to diagnose the soil moisture stress, drought and necessary protective measures such as irrigation, mulching application of antitranspirant, defoliation, thinning etc. can be undertaken.

9. **Livestock production:** Livestock production is a part of agriculture. The set of favorable and unfavorable weather conditions for growth, development and production of livestock is studied in Agril. Meteorology. Thus to optimize milk production, poultry production, the climatic normal are worked out and on the suitable breeds can be evolved or otherwise can provide the congenial conditions for the existing breeds.

10. **Soil formation:** Soil formation process depend on climatic factors like temperature, precipitation, humidity, wind etc, thus climate is a major factor in soil formation and development.

Weather: The state of the atmosphere; mainly with respect to its effects upon human activities. Short term variability of the atmosphere (time scales of minutes to months). Popularly thought of in terms of: temperature, wind, humidity, precipitation, cloudiness, brightness, and visibility.

OR

Weather can be defined as the physical condition or state of the atmosphere at a particular time and place.

Climate: Long term statistical description of the atmospheric conditions, averaged over a specified period of time - usually decades. OR Climate is defined as generalized or average condition of weather of a place or region.

Weather and climate And Its Difference

Sr No	Weather	Climate
1	Instantaneous physical state of atmosphere at particular place.	Normal physical state or generated condition of atmosphere or long term average condition of a place.
2	Weather changes refer to specific instant of time(day or week)	It is generalized over a longer span of time and for a longer area.
3	It is expressed in terms of numerical values of meteorological elements.	It is expressed in terms of time averages and area averages of meteorological elements.
4	Weather is measured in observatory. So the observatory must at a place for which weather is to be described.	This is derived information on regional basis. So scripts of observatories extending over a region are necessary.
5	No statistical treatment is applied to the meteorological elements. They are used as observed and hence always changing.	Application of statistical method over a longer period it's done. It is more or less stable with few random changes.
6	it provides meteorological information.	It constitutes geographical information in respect of weather.
7	Weather of two places having same numerical value must be same.	Climate of the two places having the same averages of weather can not be same, because their distribution over the years may be different.
8	Weather can be categorized as fair, unfair, excellent etc.	Climate is classified as desert climate, marine climate, tropical climate etc.

Climatic Controls: The value of weather elements are modified by the interference of the factors of determining causes like latitude, altitude, etc. Such factors are called as climatic factors of climatic controls.

1. Latitude: The most important influence of latitude is on temperature of a place. Temperature tends to decrease with increase with increase in latitude. Places far away from the equator are colder than those near it. This is because the angle of the Sun's rays decreases as we go to higher latitudes and also the rays have to pass through a greater distance of the atmosphere before they strike the earth's surface.

2. Altitude: Pressure and temperature generally decreases with increase altitude, and the capacity of the air to hold moisture also decreases.

3. Topography: Wind velocity primarily changes with change in topography which may result in change in temperature

4. Mountains: High mountain chains act as a barrier to free flow of winds and divide one type of climatic zone from another. For example moist monsoon current of the Indian sub-continent is not allowed by the Himalayas to crossing into our country in winter.

5. Land and sea distribution: Distribution of land and sea has a profound effect on climate. Places near the sea have moderate climate. On the other hand places far away from the sea are very hot in summer and very cold in winter. So they are said to have an extreme climate.

6. Ocean currents: Ocean currents have a considerable influence on the climate of the coastal regions and Islands near which they flow. The warm currents tend to raise the temperature of the place while the cold currents make a place colder.

UNIT-III

Earth's Atmosphere And Its Composition

Meaning: The dynamic layer surrounding the earth above its surface containing various gases, moisture, aerosols etc. is called atmosphere.

Definitions: 1. Atmosphere can be defined as the gaseous envelope surrounding the earth. 2. Atmosphere can be defined as a grand body from the earth surface to the outer space and composed of number of gases.

The estimated mass of the atmosphere is 5.6×10^{14} metric tones. It extends over about 400 km height and meteorological events and effects occur in it. The thickness of gaseous envelope is equal to 1% of the earth's mean radius.

Usefulness of the atmosphere: 1. It fulfils the biological oxygen demand (BOD) of the animal life. 2. It supplies the necessary precipitation or moisture. 3. It protects the biological life on the planet from harmful extraterrestrial radiations like UV, by absorbing it through ozone. 4. It maintains the warmth of the planet through its green house effect, avoiding the temperature to fall to too extreme limits. (The earth's temperature in the absence of atmosphere would have been $+950^{\circ}\text{C}$ (day), and -1450°C (Night)). 5. It provides the necessary CO_2 which is basic input required to run photosynthesis process in plants to build biomass. 6. It provides the necessary medium for the transport of pollens, seeds, spores and insets. 7. Many physical chemical and hydrological processes responsible for weather and climate occur in atmosphere only. 8. Atmosphere is a big reservoir of nitrogen. Some plants and microbes can fix this nitrogen for plant growth eg, Azolla pinara & Azotobacter.

Composition of the atmosphere: The various constituents of the atmosphere can be divided into following three categories:

Sr.No	Name of constituents		
	1.GASES	2.Moisture	3.Solid impurities or Aerosols
1.	Nitrogen(N_2)	1. Water Vapour	1 Dust particles
2.	Oxygen(O_2)		2. Carbon particles
3.	Argon (Ar)		3 Salt particles
4.	Carbon dioxide (CO_2)		4 Water droplets and ice crystals.
5.	Ozone (O_3)		5. Spores
6.	Sulphur dioxide (SO_2)		6. Pollen grains
7.	Nitrogen dioxide (NO_2)		7. Smoke
8.	Ammonia (NH_3)		
9.	Carbon monoxide(CO)		
10	Neon (Ne)		
11	Helium (He)		
12	Hydrogen(H)		
13	Krypton(K_1)		
14	Xerox(Xe)		
15	Methane)(CH_4)		
16	Nitrous oxide(N_2O)		
17	Radon(Rn)		

Aerosols : There exists different solid particle like dust, organic particles like carbon , inorganic particles like salt and also some liquid particles(Water droplets and crystals) which remain suspended in the atmosphere. These particles are dispersed in the atmosphere and are known as aerosols.

Non Variable and Variable Components

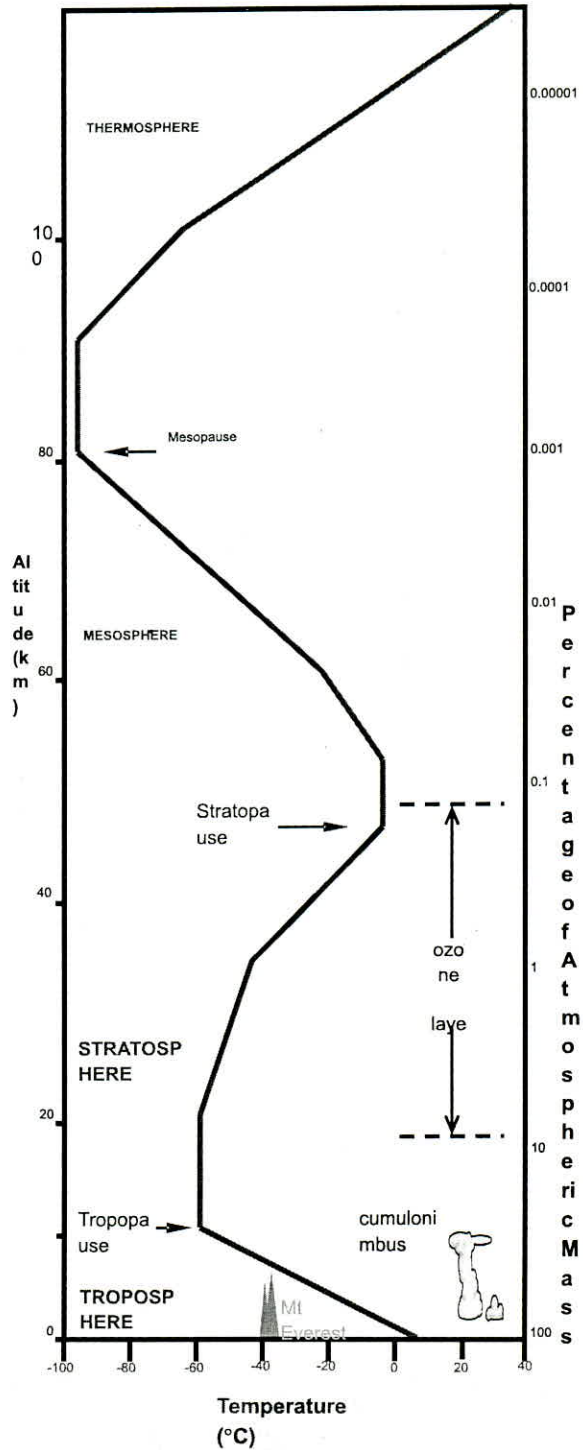
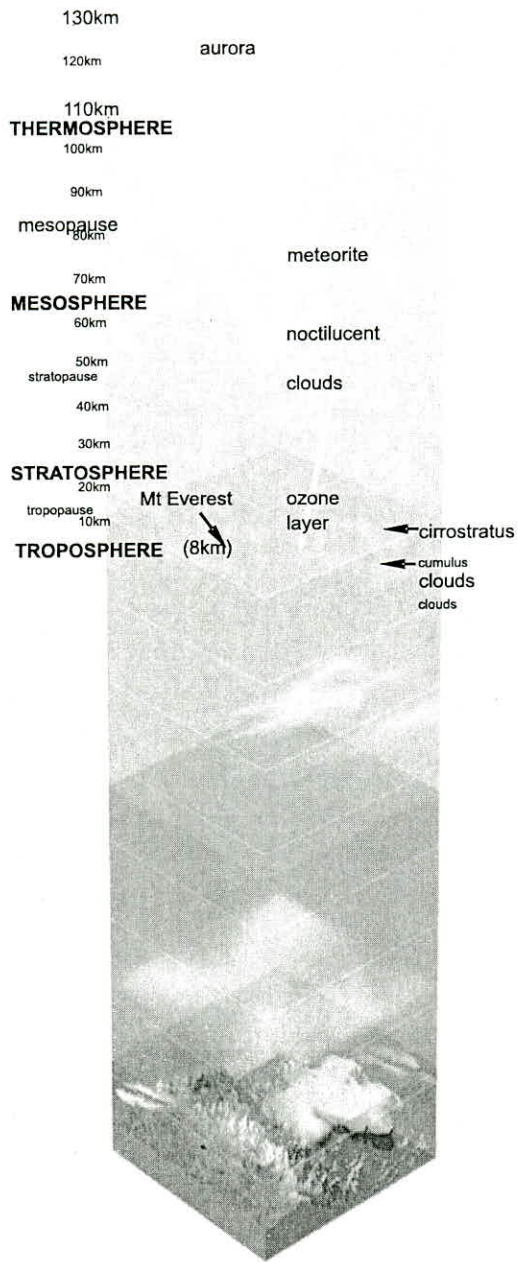
i. Non-variable components: Some gases of the atmosphere remain constant at surface of globe up to the height of 80 to 88 km. This is due to transportation of gases on continental level, diffusion of gases, turbulent mixing and convection. These gases are called non-variable components (permanent constituents), which are as follows:

Sr.No	Constituents	Symbol	Percentage by volume
1	Nitrogen	N ₂	78.084
2.	Oxygen	O ₂	20-946
3	Argon	Ar	0.934
4	Carbon dioxide	CO ₂	0.032
5	Neon	Ne	18.18x10 ⁻⁴
6	Helium	He	5.24x10 ⁻⁴
7	Crypt on	Kr	1.14x10 ⁻⁴
8.	Xenon	Xe	0.087x10 ⁻⁴
9.	Hydrogen	H ₂	0.5x10 ⁻⁴
10.	Methane	CH ₄	1.5x10 ⁻⁴
11.	Nitrous oxide	N ₂ O	0.5 x 10 ⁻⁴
12	Raḍon	Rn	6 x 10 ⁻¹⁸

ii. Variable components: Some gases or components of the atmosphere changes with change with change in time, place, season etc, and these components are called as variable component they are :

S.N.	Constituents	Symbol	Percentage by volume
1	Water vapour	H ₂ O	<4
2.	Ozone	O ₃	<0.07x10 ⁻⁴
3.	Sulphur dioxide	SO ₂	<1x10 ⁻⁴
4.	Nitrogen dioxide	NO ₂	<0.02x10 ⁻⁴
5.	Ammonia	NH ₃	1 race
6.	Carbon monoxide	CO	~0.2x10 ⁻⁴
7.	Dust		<10 ⁻³
8.	Water (liquid & solid)		

Vertical Structure: Temperature



UNIT-IV

Data Acquisition ,techniques, Instruments, Methods (DATIM) And Weather Elements For Observation

GENERAL OBSERVATORIES: An observatory is a specially designed station or place where the regular and simultaneous records of weather data are made by physical measurements using various techniques ,sensor skills, recorders ,instruments etc, using standard methods at hours recorded by the authorized National (IMD) and International agencies (WMD). These observatories are generally established throughout the country by national agency on surface ,water and space as may be required with a aim to understand climate ,climate change and to forecast weather for the safety and prosperity of mankind in the country ,Indian Meteorological Department (IMD) was established during 1875 with its central office at Pune which takes up this responsibility.

AGROMETEROLOGICAL OBSEVATORIES : The station where in physical elements of climate and biological ,agricultural elements generally of phenological or phenometric or both elements taken at a synoptic station may be used in agriculture (plus upper wind ,tem, RH profiles up to 3000m height)

Elements of the Weather

- The weather is made up of different elements, which are measured either by special instruments or are observed by a meteorologist. These measurements are then recorded and used in the making of climate graphs and weather fore casts. The table below shows the weather element details.

Element	Description	How it is measured	Units of measurement
Precipitation	Moisture from the sky e.g. rain, snow etc.	By a Rain Gauge	Millimetres (mm.)
Temperature	How hot or cold it is	By Thermometers, found inside a Stevenson Screen	Degrees celsius (c)
Wind Speed	How fast the wind is blowing	By an Anemometer	Knots, or by the Beaufort Scale
Wind Direction	Where the wind is blowing from	By a Wind Vane	Points of the compass (north, north-west etc), or bearing in

Humidity	The amount of water vapour in the air	By a Hygrometer (wet and Dry Bulb Thermometers)	Relative Humidity (% of water vapour that can be held by the air at the actual temperature)
Air Pressure	The "weight" of the air pushing on the surface of the Earth	By a Barometer	Hectopascals (although most people know it as millibars)
Cloud Cover	The amount of cloud in the sky	It is observed by a meteorologist	Oktas - eighths of the sky
Visibility	How far you can see	It is observed by a meteorologist	Kilometres
Sunshine	The hours of sunshine	By a Sunshine Recorder	Hours and minutes

Common instruments used in Observatory

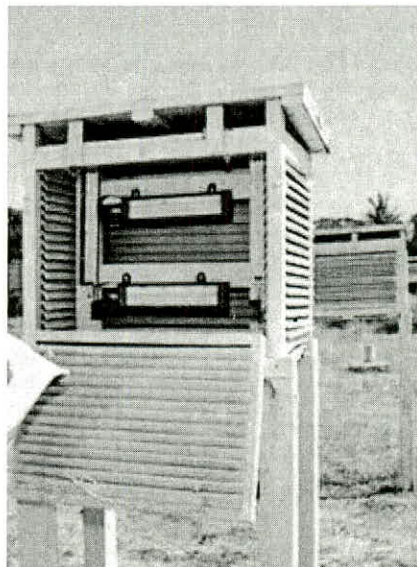
A. Maximum and Minimum Thermometer :

- * It shows the maximum and minimum temperature of air of the day. It consists of two horizontally placed thermometers. One is maximum thermometer, placed in above and another is minimum thermometer placed in below.
- * The maximum thermometer is a mercury thermometer with a constriction in the bore near the bulb. The constriction allows the expanding mercury to pass as the temperature rises, but when cooling occurs the column of mercury breaks at the constriction leaving a part in the bore to register the highest has a larger bore and its fluid is colourless alcohol.
- * A tiny dark index in the shape of a long dumbbell is placed in the bore below the top of alcohol column. As the alcohol contracts with the decreasing temperature the meniscus (concave surface) of the alcohol pulls the index down. When the meniscus moves up the bore, however, it leaves the index behind to register the lowest temperature.

Thermograph: They are automatic self recording thermometers which mark the prevailing temperature continuously on graph paper wound round a drum operated by clock work mechanism. The drum makes one revolution in a day and the automatically marked chart gives the temperature variations taking place during the day.

Unit of Measurement: Three different scales (Namely Fahrenheit, Centigrade, and Kelvin scale) are commonly used in meteorological stations for recording the temperature.

B. Rain Gauge: Rain gauge is a device used for measuring the amount of rainfall. It comprises a funnel with five inches diameter in the mouth, a container to which the funnel is shouldered and finally a metallic cylinder that holds both funnel and container. A measuring flask is used for the measurement of amount of rain water received by container through the funnel. Now-a-days self recording rain gauge is used where amount of rainfall is recorded automatically on graph paper.



Unit of measurement: Rainfall is usually measurement in inches, mm or cm.

C. Dry and wet Bulb Hydrometer: This instrument is simply two thermometers mounted on the same backing. One is mounted a little lower than the other and has its bulb covered with a piece of muslin or wicking can be wetted for observation. It is known as wet bulb thermometer. When the instrument is swung freely in the air or is aerated by a fan, the loss of heat required to evaporate water from the wet-bulb will cause it to show a lower temperature reading. The difference between the reading is called the wet-bulb depression. When the dry-bulb temperature, the wet bulb depression, and the atmospheric pressure are known, any of the standard expressions of humidity can be determined from a series of hygrometric tables. **Function:** It is used to measure the relative humidity of atmosphere.

mercury and a brass scale. The glass tube is kept in a metallic tube. The commonly used barometer in meteorological observatories is Fortin's barometer. The readings taken are corrected for temperature, altitude & latitude.

Barograph: Continuous recording of pressure is made with this instrument.

Unit of measurement: Atmospheric pressure is expressed commonly by the height of the column of mercury in the barometer, either in inches, or millimeters.

E. Wind Vane: Indicates the direction of wind. It consists essentially of a broad arrow head placed in ball bearings to enable the arrow to move freely in the horizontal plane. The arrow indicates the direction of wind.

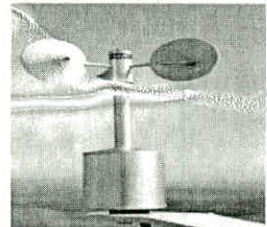
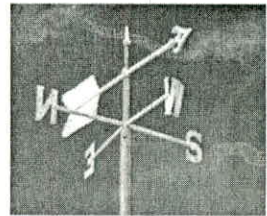
F. Anemometer:

* Anemometers are instruments used for the measurement of wind speed.

* The most common type anemometer is the Robinson Cup Anemometer. Either three or four metal hemispheres are mounted on arms which rotate freely about a vertical axis.

* A system of gears similar to an automobile speed meter translate the rotation generated by the wind to an indicator or recorder for the speed of wind that has passed the instrument.

* Now-a-days digital anemometers are also used for the measurement of wind speed. Digital anemometer gives more precise and accurate reading.



G. Sunshine Recorder:

*Continuous record of bright sun shine hour is obtained by sun-shine recorder.

*It consists of a spherical glass mounted on a stand. When the sun rays fall on the glass, a strip of prepared paper held in a groove at the focus length starts burning. When the sun does not shine, the burn point of the paper the sun light hours (duration) of the sun shine can be recorded.



H. Flux meter: Flux meter is an instrument used for the measurement of intensity of sunshine / solar radiation.

I. Evaporation Pan: Evaporation pan is a device which measures the amount of water evaporated in certain time from a surface. It consists of a round reservoir with a diameter of four inches and depth of ten inches. The tank is filled with water up to two and half inches from the top. The decrease by noting the level of water with the help of a vernier scale.



UNIT-V

Basic Principles Of Agronomy

Principle means a scientific law that explains natural action and agronomic principles are the ways and means for the better management of soil, plants and environment for economically maximum returns per unit area.

Principles of crop management depends largely on the type of farming namely, specialized, diversified, mixed and integrated and also on the physical and technological facilities available, irrigated farming, dry farming and rain fed farming.

The fundamental principles of agronomy may be listed as:

- i. Planning, programming and executing measures for maximum utilization of land, capital, sunshine, rain-water, temperature, humidity, transport and marketing facilities.
- ii. Choice of crop varieties adaptable to the particular agro-climate, land situation, soil fertility, season and method of cultivation and suitable to the cropping systems.
- iii. Proper field management by tillage, preparing field channels and bunds for irrigation and drainage, checking soil erosion and levelling.
- iv. Adoption of multiple cropping and also mixed or inter cropping to ensure harvest even under adverse environmental conditions.
- v. Timely application of proper and balanced nutrients to the crop or crops in sequence and improvement of soil fertility and productivity.
- vi. Choice of quality seed or seed material and maintenance of requisite plant density per unit area with healthy and uniform seedlings.
- vii. Proper water management with respect to crop, soil and environment through conservation and utilization of soil moisture as well as by water that is available in excess.
- viii. Adoption of adequate, need-based, timely and proper plant protection measures against weed's insect-pests, pathogens, as well as climatic hazards correction of deficiencies and disorders.
- ix. Adoption of suitable and proper management practices including inter cultural operations to get maximum benefit.
- x. Adoption of suitable method and time of harvesting of crop to reduce field-damage and to release land for succeeding crop(s) and efficient utilization of residual moisture, plant nutrients and other management practices.
- xi. Adoption of suitable post harvest technologies.

UNIT VI

Crops And Their Classification

Crop : It has some characteristics:

- i. Crop must be cultivated species
- ii. It must have economic value

Definitions of Crop : "Crops are aggregation of individual plants grown on a particular location usually of the same species or variety and have some economic value."

OR

"Crop is a plant or a group of plants that are cultivated with proper care and management for getting raw materials for sustaining the life of human being and livestock."

Agronomic Crops / Field Crops: The crops, which are grown together or collectively with less intensive care, compared to horticultural crops (with intensive care) and harvested in bulk.

Classification of crops:

Classification is an acceptable product of scientific studies and is obviously based on well-defined characteristics or concepts that separate one group from another. Crops are grouped into three main classes according to the range of cultivation. Among these three classes agronomy deals with field crops only. They are :

a) **Gender Crop:** Crop plants that are grown on a small scale with intensive care in gardens such as kitchen gardens, flower gardens and background gardens e.g. onion, brinjal, banana, okra, mango, jackfruits, rose, etc.

b) **Plantation Crops :** Crop plants that are grown on a larger scale on estates. They are permanent in nature (need not be replanted after each harvest) but harvesting continues for a prolonged period from a single planting e.g. tea, coffee, cocoa, rubber etc.

c) **Crop plants** that are grown together or collectively on a vast scale with less intensive care and harvested in bulk, e.g. rice, wheat, maize etc.

Agronomic Classification of Crops :

a) **On the basis of use, agronomic crops are as follows :**

- i. **Cereals (One seeded fruit known as caryopsis):** Cereals are the cultivated grasses grown for their edible starchy grains under graminial family. In general, the longer grains used as staple food are cereals such as rice, wheat, maize, barley etc.
- ii. **Millets :** Millets are the small grained cereals and they have a single cover such as ragi (finger millet), cheena (proso millet) Sawan (barnyard millet), etc.
- iii. **Oil seeds :** Crop seeds that are rich in fatty acids, which are used to extract vegetable oil to meet various requirements e.g. mustard, rape seed, sesame, sunflower, castor, linseed, groundnut, soybean, etc.
- iv. **Pulses :** Seeds of leguminous crop used as food. On splitting they produce dal which are rich in protein such as lentil, gram, grass pea, black gram, pea, cow pea, arhar etc.

- v. **Fibre Crops** : Crop plants grown for fibre yield. Fibre may be obtained from seed such as cotton; stem or bark such as jute, sann-hemp, leaf such as pineapple.
- vi. **Sugar Yielding Crops** : Crops grown for production of sugar and starch e.g. sugar cane, sugar beet, potato, sweet potato, etc.
- vii. **Narcotic Crops** : Crop plants or their products that are used for stimulating, numbing, drowsing or relishing effects such as tobacco, ganja, poppy etc.
- viii. **Beverage Crops** : Products of crops used for mild, agreeable and stimulating liquors meant for drinking such as tea, coffee, cocoa etc.
- ix. **Fodder Crops** : Crop plants or their products which are utilized as feed for animals e.g. maize, berseem, lucerne, napier grass etc.
- x. **Green manuring Crops** : The crop plant which is grown to be incorporated into the soil to increase the fertility of the soil e.g. Dhaincha, sunnhemp, cowpea, etc.

b) On the basis of cultural requirement agronomic crops are as follows:

A. According to suitability of topography

- i. **Upland crops** : They cannot tolerate water stagnation e.g. Arhar, groundnut, sunnhemp, maize, bajra cotton, sesame, napier etc.
- ii. **Medium land crops** : They require sufficient soil moisture but can not tolerate water stagnation e.g. Jute, Potato, Sugar cane, Wheat, Black gram, Burley, Mustard etc.
- iii. **Low Land Crops** : They require an abundant supply of water and can stand prolonged water logged conditions. e.g. Rice, dhaicha, para grass and jute (Capsular's)

B. According to the suitability of the textural groups of soils :

- i. Crops of sandy to sandy loam soils : Sugar-beet, green gram, black gram, sunflower etc.
- ii. Crops of silt to silt loam soils : Jute, sugarcane, maize, cotton, mustard, tobacco, peas.
- iii. Crops of clay to clay loam soils : Rice, wheat, barley, linseed, lentil, chick pea etc.

C. According to the tolerance to the problem soils :

- i. Crops tolerance to acidic soils e.g. wet-rice, mustard
- ii. Crops tolerance to saline soils e.g. wheat, bajra, jowar, barley
- iii. Crops tolerance to alkaline soils e.g. Barley, cotton, chick pea, peas, groundnut, maize
- iv. Crops tolerance to water logged soils e.g. wet-rice, para grass, napier grass
- v. Crops tolerance to soil erosions e.g. groundnut, black gram

D. According to tillage requirements

- i. Crops requiring preparatory tillage e.g. sugarcane, rice, tobacco, maize
- ii. Crops that may not requiring preparatory tillage e.g. black gram, para grass, cow-pea.

E. According to the depth of root system

- i. Shallow-rooted crops: Rice, potato
- ii. Moderately-deep-rooted crops: wheat, groundnut tobacco, barley, chick pea, cow-pea.
- iii. Deep rooted crops : Maize, cotton, jowar, sugar beet.
- iv. very deep-rooted crops: Sugar cane, safflower.

F. According to the tolerance to hazardous weather conditions :

- i. Frost tolerant crops : Sugar beet, wheat
- ii. Cold tolerant crops : Mustard, potato
- iii. Drought tolerant crops : Bajra, jowar, barley, cotton, sesame and all milletes

G. According to the method of sowing or planting :

- i. Direct seeded crops : Upland rice, wheat, mustard, maize, jowar, bajra, groundnut, peas, grams, etc.
- ii. Planted crops : Sugar cane, potato, sweet potato, napier, para grass.
- iii. Transplanted crops : (After raising seedlings in the nursery) Transplanted rice, tobacco, etc.

H. According to the length of field duration :

- i. Very short duration (up to 75 days) crops e.g. Green gram, beet, maize
- ii. Short duration (75 to 100 days) crops e.g. Uplard rice, sunnhemp, sunflower, potato (early)
- iii. Medium duration (100 to 125 days) crops e.g. wheat, jowar, bajra, barley, groundnut, soybean, sesame,, boro rice, jute.
- iv. Long duration (125 - 150 days) crops e.g. Mustard, Kharif rice, mesta, cotton, etc.
- v. Very long duration (150 days) crops e.g. Sugar cane, sugar beet, pigeon pea, napier, para grass.

Special purpose classification of crops :

Crop plants which are grown with the intention of serving purposes in addition to obtaining yield or to meet a particular purpose are grouped into special purposes are grouped into special purpose crops.

1. **Catch crops / Emergency crops / Contingent crops** : These are crops cultivated to 'catch' the forth coming season. They are generally of very short duration quick growing, harvestable or useable at any time of their field duration e.g. green gram, black gram, cow pea, bajra etc.
2. **Restorative crops** : The crops which provide a good harvest along with enrichment or restoration or amelioration of the soil such, such as legumes. They fixed atmospheric nitrogen in root nodules, shed their leaves during ripening and thus restore soil conditions.
3. **Exhaustive crops** : The crop-plants which on growing leave the field exhausted because of more aggressive nature, e.g. sesame, linseed, maize.
4. **Paira crops(uthera)** : These are crop plants which are sown a few days or week before the harvesting of standing nature crop, e.g. Lathyrus in paddy, paira crops in succession may constitute relay cropping.
5. **Smother crops** : The crop plants are able to smother or suppress the population and growth of weed by providing suffocation (curtailing movement of air) and obscuration (of the incidental radiation) by their dense foliage, e.g. mustard, cow pea.

6. **Cover crops** : These crop plants are able to protect the soil surface from erosion (wind, water or both) through their ground covering foliage, e.g. groundnut, black gram.
7. **Nurse crops** : These crop plants help in the nourishment of other crops by providing shade and acting as climbing sticks such as rai in peas, jowar in cow pea.
8. **Barrier crops** : These crop plants help to protect another crop e.g. safflower in gram.
9. **Breake crops** : These crops are grown to break the continuity of the agro-ecological situation of the field under multiple cropping systems, for instance rice-rice, rice-wheat, rice-maize breaks the continuity of a large number of pest (weed, insect, pathogens) due to variations in host ranges and changing of agro-ecological situation.
10. **Trap crops** :These crop plants are grown to trap soil borne harmful biotic agents such as parasitic weeds ,Orobanche and striga that are trapped by solanaceous and sorghum crops.
11. **Mulch crops** :These crop plants are grown to conserve soil moisture by their thick and multilayered foliage and self-seeding nature e.g. cow-pea.
12. **Sod or turf crops** : These crop plants belong to the grass family and have sod type tillers with matted foliage and root close to the soil surface, e.g. Cynodon Dactylon.
13. **Cash crops** : These crop plants are grown for sale to earn hard cash. e.g. Jute, tobacco, cotton and sugarcane.
14. **Cold crops** : These crop plants are essentially cold weather crops belonging to the crucifer family capable of with standing considerable frost such as cabbage, cauliflower.
15. **Leaf crops** : These crop plants are grown to harvest leaves for economic yield e.g. tobacco, spinach.
16. **Erosion restricting crops** : These crop plants are grown to restrict soil erosion. e.g. groundnut.

UNIT VII

Weed Science

- i. **Brief History** : These are 6 stages in the evolutionary of weed control practices (Hay, 1947) such as :
- 10,000 BC : Removing weeds by hands
- 6,000 BC : Use of primitive hand tools to till the land and destroy the weeds.
- 1,000 BC : Animal powered implements like harrows.
- 1,920 AD : Mechanically powered implements and improved animal powered implements like blades, cultivators, finger weeders, rotary hoes, row weeders, etc.
- 1,930 AD : Control of weeds. Using inorganic chemicals and biological weed control.
- 1,947 AD : Use of herbicides for weed control like 2,4-D and MCPA.
- ii. **Definition of weeds** : Weeds are plants which interfere with the use of land for cultivation purpose. Weeds compete with crop plants for nutrient, soil moisture, sunlight and space. OR A plant out of place or an undesirable plant with a negative value .OR A plant, usually herbaceous, which is growing in an area where it is neither desired nor appreciated.
- iii. **Characteristics of weeds**: 1. A concept of growing undesirable location 2. Competitive & aggressive value 3. Of wide & rank growth 4. Persistence & resistance to control or eradication 5. Consisting often large population with abundant rank & extensive growth 6. Useless, unwanted & undesirable 7. Harmful to men, animals, and crops 8. Spontaneous growth appearing without being shown or cultivated 9. High reproductive capacity 10. Unsightly with disfigurement of the land escape 11 Long duration seed dormancy 12. Wide range germination adaptability 13. Weeds can grow & survive field adverse condition 14. Legume weeds can grow accidentally in nitrogen deficient soil 15. Resistance to insects & diseases
- iv. **Special Characteristics of weeds**: 1. Weeds can produce numerous seeds. 2. Ability to survive in adverse condition 3. Ability to propagate vegetatively. 4. Ability to spread vegetatively 5. Persistent to chemical
- v. **Harmful effect of weeds** : 1. They compete successfully with crop for light, water, space & nutrients. 2. They increase grow pest, interfere with crop culture, reduces crop quality, harms human & animal health. 3. Some weed has allelopathic on crop 4. Weed contaminates water body, interfere in non crop land, increases production cost, 5. Weeds decreases crop yield, land value & agricultural product. 6. It inspire the purity of variety 7. Detracts form the beauty of public place 8. It causes accident & pollution. 9. Restrict the movement of water flow & drainage. 10. Increase wastage of water 11. Interfere in pisciculture 12. Impair cultivation of aquatic crop 13. Impair recreation in water bodies
- vi. **Beneficial weeds** : 1. Weeds help in controlling erosion by the soil bonding effects of their roots. 2. Some weeds are used as green fodder, vegetable, medicinal value, thatch, organic matter, mulch & green manuring crop. 3. Certain weeds are used as breeding purpose for fixation of atmospheric N₂ in soil 4. Some weeds are used for beautification of lawn playground & as fuel. 5. Some weeds are used air pollution indication.

vii. Propagation of weeds: 1. Seed 2. Vegetative organ.

viii. Dispersal: 1. Wind 2. Water 3. Animal & man 4. Implements 5. Manures, compost 6. Farm machineries 7. Crop seed 8. Soil 9. Vegetative organ

ix. Crop weed competition

Competition: The tendency of the plant of the same or different species growing together to strive for & capture the common resources. Such as light, water, nutrients and space of the habitat.

Inter- (between or among): The competition amongst individuals of the same species is termed as inter specific competition E.g. crop weed competition.

Intra - (within): The competition amongst individuals of the same species is termed as intra Specific competitions. E.g. intra & intra row competition.

x. Weed management : The rational developments of appropriate technology to minimize the impact of weeds provide systematic management of weed problem & optimize intended land use.

xi. Chemical method of weed control:

Herbicides: 1. Herbicides are chemicals which are used for killing weeds 2. Herbicides are chemicals, used for inhibit the growth of weeds

Classification of herbicides : Several classifications for herbicides applications are used, out of them the most practical approaches are as follow:

A. 1. Selective herbicides : Selective herbicides are those which affect only certain weeds, leaving, and certain crops unharmed. The selective herbicides are used in agricultural and horticultural fields. E.g. 2, 4-D, alachlor, atrazine etc.

2. Non selective herbicides : A non selective herbicide, on the other hand, is one that kills all plants without regard to species. E.g. paraquat, Glyphosate

B. Method of application: 1. Pre planting 2. Pre emergence 3. Post emergence

1. Pre planting or pre sowing application: Herbicide is applied after land preparation & before the crop is planted. g Fluchloralin, Nitrofen.

2. Pre-emergence application: The herbicides are applied after the crop has been sown but before the emergence of the crop or the weeds. This method is adapted to destroy weeds in the earlier stages. It is only possible where a crop is slow in germination & weeds emergence rapidly. Alachlor, simazine.

3. Post emergence application: The herbicides are applied after the emergence of crop & the weeds. These types of spraying can largely be practiced with selective weeds killers. 2,4-D, atrazine.

C. On the basis of mode/mechanism of action.

1. High risk herbicides for resistance development (5-7 years) (groups A & B).eg Acetyl Co-A carboxylase inhibitor & Acetolactate synthase.
 2. Medium risk herbicides (groups C,D,E & F) .eg Photosystem II inhibitors, Photosystem I electron diverters ,Protoporphyrinogen oxidase inhibitors etc.
 3. Low risk herbicides (groups G,H,I,K,L,M,N.O & P) .eg Cell division inhibitors, cell wall synthesis inhibitor & uncouplers etc.
- xii. Formulation herbicide :** 1.The process by which herbicidal compound bare prepared for practical use 2. A preparation containing a herbicide in a form practical use.
- Concentration:** Amount of active ingredient express in percent.
- Emulsion:** Suspension of one liquid as in another liquid without losing is identity.
- Surfactant:** A material which improves emulsifying dispersing spreading wetting properties of liquid.
- Suspension:** Finely divided solid particle aspersed in a solid liquid or gas.
- Wetting agent:** Substance which serves reduce interfacial tension & causes spray solution to make better contract with treated surfaces.
- Wetable powder :** A finely dinied dry herbicide formulation that can be suspended readily in the water.
- Emulsifier:** A chemical which facilitate the formulation of an emulsion. The material that facilitates suspensions of one liquid in another.
- Emulsifiable concentrate :** A homogenous liquid formulation which forms & emulsion or mixing with water.
- Active ingredient :** Is that part of a formulated product that is principally responsible for herbicidal effects. An active ingredient may be a solid, liquid ion & gas .Most technical ingredient can not be used for control of weeds without further processing into a suitable formulation.
- xiii. Advantages of chemical method of weed control:** 1. Herbicide can control weeds before emergence of crop seedling so that crop can germinate and grow in completely weed free environment .this is usually not possible with physical method.2. Weeds can be controlled irrespective of season.3. It kills all weeds in the field.4. Intra row weed control is possible. 5. Control last longer & spiny weed.6. It prevent soil erosion. 7. It increases crop yields & reduces processing cost.8. It requires less time, labour and money.
- xiv. Disadvantages of chemical method :** 1. It requires special technical knowledge about crop ,herbicide, weed , soil, environment& special precautions before application2. It may affect the physical, chemical & biological properties of soil 3. It creates unemployment of labors 4.. It hampers other intercultural operation.5.It requires implements for application of herbicides.7. Very high & low doses are not effective.
- xv. Physiological and biological aspects of herbicide, their absorption, translocation, metabolism and mode of action selectivity of herbicides and factor affecting them.**

The dictionary meaning (Compact Oxford Dictionary the sources word-power guide - 2006.) of above cited terms are as follows :

Physiological : The way in which a living organism or bodily part function. (P.N.666)).

Biological : 1. Relating to biology or living organism, (of a parent or child) related to blood, (of warfare) using harmful micro-organism & (of a detergent) containing enzymes (P.N.-79).

Absorption : The process of absorbing or the action of being absorbed. (P.N. 4)

Metabolism : The chemical process in a living thing by which food is used for tissue growth or energy production (P.N. 56).

Mode of action : Mode -A way in which something occurs or is done (P.N. 574). Action (the process of doing something to achieve an aim ,a thing done , the effect of something such as a chemical & the way in which some thing works or moves (P.N.-9).

Selectivity : 1. Having to do with selection, tends to choose carefully & (or a process or agent) affecting some things and not others. (P.N. 813).

Physiological & biological aspects of herbicides

The specific biochemical process inhibited, often depends upon the chemistry of the herbicide. Both the site

Process / Site	Herbicide group
Photosynthesis	Substituted Ureas; triazines, uracils, bentazon, bipyridillium
Cell division	Carbamates, Dintranilines
Nucleic acid & Protein synthesis	Phenoxy, glyphosate, sulfonyl Ureas, imidazolines
Membrane function	Bipyridiliums, Diphenylethers, dintrophenols
Lipid synthesis	Pyridazinones, Cyclohexanediones, aryloxyphenoxy herbicide

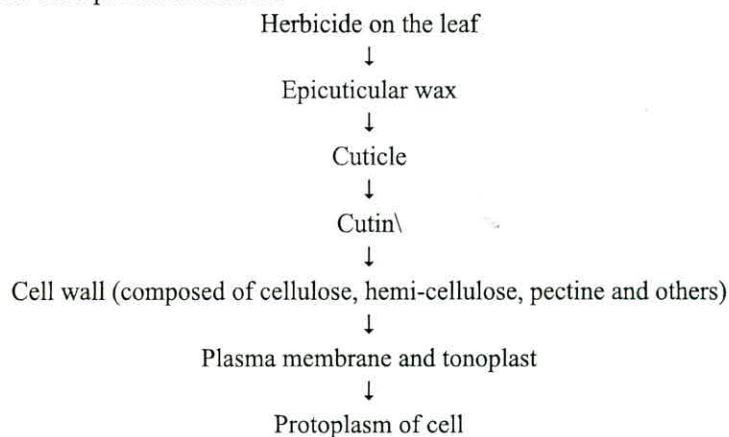
Herbicides movement through plants :

Absorption : Absorption is the process of penetration into the plant tissue. Herbicides are applied by two methods either to the soil or plant foliage and accordingly the herbicide enter into plant by apoplastic or symplastic movement.

Polar-herbicides : Usually hydrophilic or lipophobic in nature and soluble in polar solvents like water and insoluble in apolar / non-polar solvents like (eg, hexene, alcohol)e.g. Maleic hydrazide & Paraquat.

Non-polar herbicide : Usually lipophilic or hydro-phobic in nature and soluble in apolar / non-polar solvents (oily solvent) and insoluble in polar solvents.

The pathway of herbicide absorption is as follows :



❖ Herbicide absorption through plant involve both passive and active process. Passive absorption may include root interception, mass flow and diffusion, which on principle do not require metabolic energy of plants for movement of herbicides in plants.

1. **Root interception** : Contact with roots of ions, molecules or atoms.
2. **Mass flow** : Mass movement of molecules, ions etc. along with water.
3. **Diffusion** : Movement due to concentration gradient from higher to lower concentration without any semi-permeable membrane.

❖ Diffusion is more applicable in foliage applied systemic herbicides, where as all the three process (e.g. root interception, mass flow and diffusion) are applicable to soil applied systemic herbicides.

Herbicide translocation in plants : Once a herbicide is absorbed into the plant system, it moves either apoplastically or symplastically.

Apoplast : System of nonliving interconnecting cell walls, intercellular space and the water filled and air. Filled xylem element (xylem and intercellular space).

Symplast : System interconnected protoplasm that is connected from cell to cell by means of plasmodesmata, excluding the vacuoles. The sieve tubes are the highly specialized components of symplast (phloem).

Four major routes of translocation of herbicides in plants.

- i. No or limited mobility in treated plants : Mainly for contact herbicides with limited or no mobility in treated plants .e.g. bromoxynil, ioxynil, propanil, dinoseb, paraquat and diquat.
- ii. Symplast and symplastic movement : Symplastic movement is a "Source to Sink translocation. Sugar while moving from source to sink through symplast carry along some post-emergence herbicides, namely 2,4-D, glyphosate, which otherwise, cannot move by themselves.
- iii. Apoplastic and apoplastic movement : Herbicide primarily absorbed by roots and move through xylem in plants and translocated along with water (passive transport) or mineral nutrient ions (active transport) and therefore, the movement may or may not require metabolic energy.

- iv. Symplast and apoplast together : Symplast and apoplast together are involved in the translocation of some herbicide (e.g. isoproturon, amitrole, glyphosate, 2,4-D, atrazine) in plants.

S. No.	Apoplast	Symplast
1.	Non-living cells and cell wall continuum of a plant	Living protoplasm (phloem and other living cells) of a plant.
2.	Apo means apart (xylem)	Sym means together (phloem)
3.	Acropetal movement of herbicide (Base to apex)	Basipetal (Apex to Base)
4.	Apoplastic movement may or may not require metabolic energy	Require metabolic energy
5.	Applicable for pre-plant or pre-emergence soil applied systemic herbicides. e.g. Triazines, uracils, dinitroanilines etc	Post-emergence foliage active, systemic herbicide se.g. Glyphosate, Fenoxaprop -p, ethyl 2,4-D.

Difference between mode and mechanism of action of herbicides

S. No.	Mode of Action	Mechanism of Action
1.	Entire chain of action from first time application or contact to final result which could be a death of plant.	Bio-chemical and biophysical reaction, which bring about the ultimate herbicidal effect.
2.	Sum total of anatomical, physiological and bio-chemical responses that bring about the total phytotoxic action in plants.	The certain enzymes cell organelles or cells catalyzing, housing or carrying out the particular bio-chemical reaction like photosynthesis, respiration, lipid bio-synthesis, nucleic acid, amino acid protein bio-synthesis or membrane functions.
3.	The different event may occurred e.g. growth reduction, wilting, yellowing chlorosis, necrosis or leaf burning in sequence.	Molecular reaction such as: i. Inhibition of three aromatic amino acid. ii. Inhibition of three branched of chain amino acid.
4.	Mode of action includes the mechanism of action.	iii. Inhibition of lipid bio-synthesis due to inhibition of acetyl CoA Carboxylase. iv. Inhibition of photosynthesis at PS I, by paraquat, diquat (electron diversion) and at P II by phenylureas, triazines.

Mechanism of action of herbicides: The various physiological and bio-chemical process affected by herbicides are grouped under following categories.

- | | |
|---|-----------------------------------|
| i. Respiration and mitochondrial inhibitors activities. | ii. Photosynthesis inhibitors |
| iii. Protein and nucleic acid biosynthesis inhibitors | iv. Hydrolytic enzymes activities |
| v. Cell division inhibitors | vi. Membrane function disruptors |

Selectivity of herbicides and factor affecting it

Herbicides selectivity is referred as the phenomenon where in a chemical kills the target plant species in a mixed plant population without harming or only slightly affecting the other plants".

The selectivity index of a herbicide is an indication of its safety where :

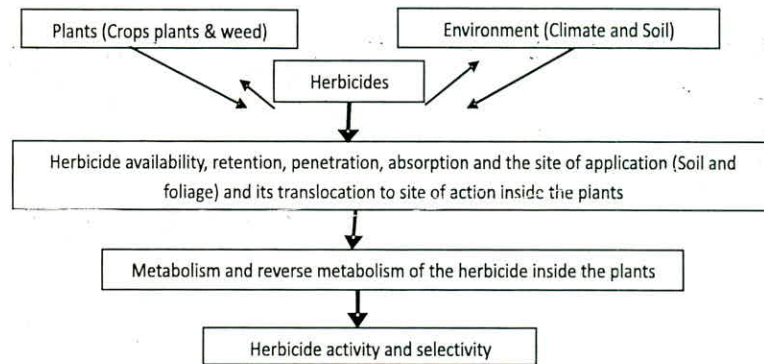
$$\text{Selective index} = \frac{\text{Max}^m \text{ dose tolerated by the crop}}{\text{Min}^m \text{ dose required kill the weed}}$$

The higher the index, the less risk harming the crop by accidental over-dose. An index of 2 is only marginally safe whereas accurate methods are used but indices of 4 or more are desirable if a product is to be recommended for use by relatively unskilled farmers and with simple application equipment (Terry, 1984).

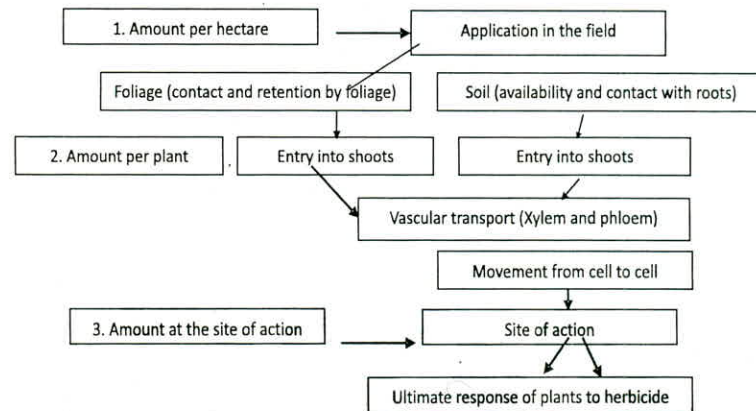
Kind of selectivity : Selectivity is dependent on a complex chain of events beginning from application to disruption of vital functions of the plant. It is mediated mechanically, physically, chemically and metabolically. There are four major types of selectivity.

[i] **Physical selectivity:** (i) Depth protection selectivity of pre-emergence herbicide. (ii) Externally working antidote-mediated selectivity. (iii) Application device protection selectivity of non-selective herbicides. (iv) Selectivity to non-selective herbicides achieved due to other means. [ii] **Chemical selectivity.** [iii] **Biological / Bio-chemical selectivity (True selectivity):** Internally active antidote-mediated selectivity. [iv] Chronological selectivity

Factor effecting selectivity of herbicide: All living plants (crops and weeds) are resultant of interaction of climate, soil, cultural practices and genetical characteristic. However, crops and weeds behavior expressed by chemical nature and mode of action.



Schematic representation of three principal factors (plants, herbicide and environment) interaction towards activity and selectivity of herbicide in plants.



Herbicide movement from the site of application to site of action in plants (Muzik, 1970).

Calibration of hand sprayers

Fill up the sprayer tank to a desired level with water. Operate the sprayer and measure a distance of 100 meters. The speed and pressure must be constant while sprayer. Refill the sprayer to the organic level and determine the amount of water sprayer. Now calculate the volume of liquid required to spray one hectare of land.

$$\text{[Volume required to spray an area of one hect.]} = \frac{([\text{Volume of water used (in liters)} \times 10000])}{([\text{Width sprayed} \times \text{Length}] \text{ (in meters)})} = \text{liters/ha.}$$

Example: Find out the discharge of a sprayer from the following :

- | | | |
|-------|---------------------------|--------------|
| (i) | Distance sprayer (length) | = 100 meters |
| (ii) | Width of spray swath | = 1.5 meters |
| (iii) | Water required to refill | = 5 liters |

Mixing of herbicides

$$\text{Thus, volume required} = \frac{5.0 \times 10000}{1.5 \times 100} = \frac{1000}{3} = 333 \text{ lit}$$

This is done after calculating the quantity of the material required for one hectare which can be determined by the following equation:

$$\text{Volume of liquid formation of the herbicide/ha} = \frac{(\text{Rate of application in kg a.i./ha})}{(\text{Active ingredient percentage of chemical})}$$

Example: Find out the volume of Alachlor needed to spray one hectare from the following details:

1. Rate of application = 0.5 liters a.i./ha
2. Purity of active ingredient of commercial material is 50%

The quantity of wettable powder required for one hectare may be calculated by the following equation.

$$\text{Volume of Alahlor needed/ha} = \frac{(0.50 \text{ kg a.i./ha})}{50 \times 100} = 1 \text{ kg/ha}$$

Example: Find out the quantity of Simazine wettable powder to be sprayed in one hectare area if

$$\text{Quantity of material required per hectare} = \frac{(\text{Rate of application in kg a.i./ha.})}{(\text{Active ingrediant \%})} \times 100$$

1. Rate of application/ha = 3.0 kg. a.i./ha
2. Active ingredient = 80%

$$\text{Thus, the quantity of Simezine/ha} = \frac{3}{80} \times 100 = 3.75 \text{ kg. W.P./ha}$$

UNIT VIII

Bulk Density, Particle Density And One Hectare Furrow Slice Weight

Bulk density: It is defined as the mass per unit volume of total soil including both soil solids and pore space expressed on oven dry basis. This is expressed as mega grams per cubic meter (Mg/m^3). Bulk density of soil divided by density of water is known as apparent specific gravity. The bulk density of a soil is always smaller than its particle density. The bulk density of sandy soil and clayey soil is less than $1.4 Mg/m^3$ and $1.2 Mg/m^3$ respectively may be considered optimum crop growth.

Practical use of Bulk Density : High bulk density values cause restricted root development. The average weight of furrow slice for a hectare is calculated by multiplying the soil volume by its bulk density. One hectare furrow slice of soil is the volume of the soil one-hectare in area and 15 cm in depth.

$$\begin{aligned} \text{Volume of one hectare} &= 10000 \times 15/100 \\ \text{(15 cm depth)} &= 1500 \text{ m}^3 \end{aligned}$$

If the bulk density of surface soil is $1.3 Mg/M^3$ or $1.3 \times 1000 = 1300 \text{ kg/m}^3 = 19,50,000 \text{ kg}$.
A hectare of furrow slice is therefore assumed to weigh 2 million kg.

2 million kg/ hectare is widely used for converting lab data for field use, if soil analysis is reported in ppm. Multiplication by 2 converts ppm to $pp2m$ for use on kg/ha basis. The use of ppm data can be illustrated by a soil containing, for example 5 ppm of available phosphorus. This is equivalent to 10 kg/ha of available phosphorus ($pp2m = ppm \times 2$, i.e. $5 \times 2 = 10 \text{ kg ha}$)

PARTICLE DENSITY

Particle density is the average density of soil particle i.e. excluding pore space. This is expressed as Mega grams per cubic meter (Mg/m^3). It depends upon the type of minerals in the parent material. The amount of organic matter in the soil. Organic matter reduces the value because it is much lighter than mineral matter.

Particle density of soil can be determined by adding densities of the soil constituents. The dominant soils forming minerals are quartz, feldspars, micas and clay mineral. The densities of these minerals range between $2.60-2.75 Mg/M^3$. Hence, in most soils average value of particle density is about $2.65 Mg/M^3$. If minerals like zircon, magnetite and tourmaline, possessing higher densities (more than 2.75) are present, the particle density may exceed.

SOIL POROSITY

The pore space of a soil is the portion of the soil volume occupied by air and water. This when expressed as per cent is known as porosity. Thus a soil with 50% porosity is half solid particle and half pore space. The per cent pore space is calculated from data on bulk density and particle density. Given these two values, the per cent of the soil volume occupied by solids is

$$\begin{aligned} \text{Per cent Solid} &= (\text{bulk density})/(\text{particle density}) \times 100/1 \\ \text{Per cent pore space} &= 100 - \text{per cent solid} \\ \text{Per cent pore space} &= 100 - (\text{bulk density})/(\text{particle density}) \times 100/1 \\ \text{Or usefully per cent pore space} &= (1 - (\text{bulk density})/(\text{particle density})) \times 100 \end{aligned}$$

Thus, increasing bulk density means an increased percent solid and a decrease in percent pore space. Root growth and water penetration are adversely affected with bulk density exceeding $1.5 Mg/M^3$.

Porosity of soil indicates total pore space and not the size and form of individual pores. Macro-pores (non-capillary) allow a ready movement of air & water but do not hold much water. Micro-pores (capillary) can hold more water but the movement of air & water is restricted.

UNIT IX
Calculation Of Fertilizer Dose

To supply 120 : 60 : 40 kg N.P.K. per hectare how much amount of fertilizer will be required from the source such as urea, SSP and muriate of potash.

Solution

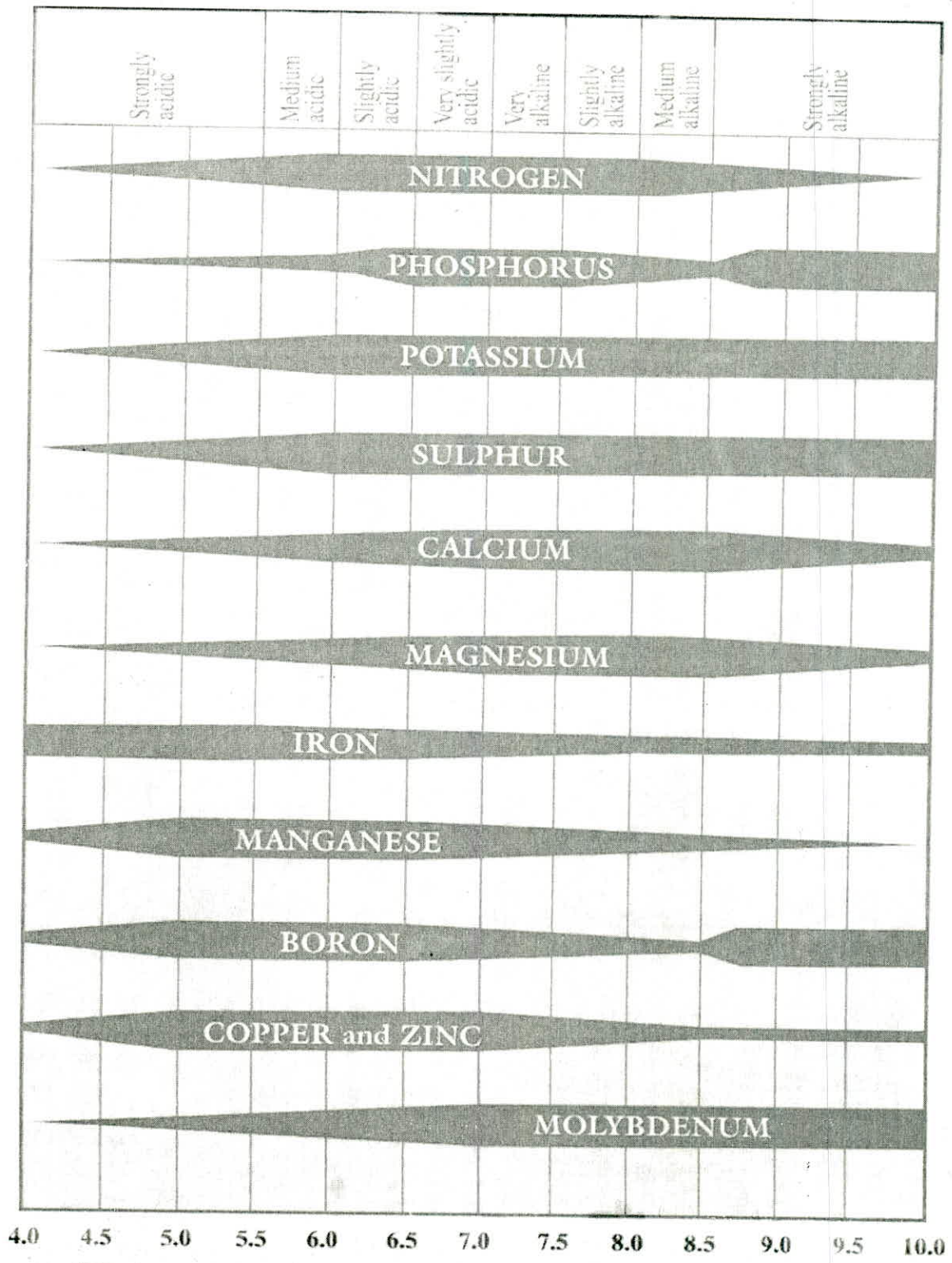
The amount of fertilizers to be applied = $100 / (\text{Nutrient Content in the fertilizers material}) \times \text{recommended dose}$

1. Urea contains 46% N
To supply 46 kg N/ha, 100 urea is necessary
To supply 120 kg N/ha = $(100 \times 120) / (46)$
= 260.9 kg or 261 kg urea is required
2. Single Superphosphate contains 16% P₂O₅
To supply 60kg P₂O₅ = $100 / 16 \times 60$
= 375 kg/ha of SSP
3. Muriate of Potash contain 60 %, K₂O
To supply 40kg K₂O = $100 / 60 \times 40 = 66.4$ OR 67 kg/ha

2. For supplying 120kg N, 80 kg P₂O₅ and 40 kg K₂O how much quantity of Urea, DAP and MOP will required for a one hectare of rice crop.

Solution:

1. Amount of DAP
46kg P₂O₅ remains in 100 kg DAP
1kg P₂O₅ remains in 100 kg DAP = $100 / 46$ kg DAP
80 kg P₂O₅ remains in 100 kg DAP = $(100 \times 80) / 46$ kg DAP = 173.91 kg DAP
2. Amount of Nitrogen available from of 173.91 kg DAP
100 kg DAP content 18 kg of Nitrogen
1kg DAP contain = $100 / 18$ of Nitrogen
173.91 kg DAP contain = $(18 \times 173.91) / 100$ (P)
= 31.30 kg Nitrogen
3. Amount of Urea
The remaining amount of nitrogen (i.e. $120 - 31.30 = 88.7$ kg) is to be supplied through Urea.
46 kg Nitrogen remains in 100 kg Urea
1kg Nitrogen Remains in 100 kg = $100 / 46$ of Urea
88.70 kg Nitrogen remains in = $(100 \times 88.70) / 46$ kg of Urea
= 192.82 kg
4. Amount of Murate of potash (MOP)
60 K₂O remains in 100 kg of MOP
1kg MOP remains in = $100 / 60$ of MOP
40 kg MOP remains in = $(100 \times 40) / 60$ kg of MOP
= 66.66 kg/ha



Effects of soil pH on availability of soil nutrients to plants. Width of bar indicates relative availability of each nutrient with a change in the soil pH.

UNIT X

Seed Rate Calculation

1. Calculation the quantity of maize seed for sowing one hectare area from the following particular:

Spacing	- 75cm x 30cm
Germination p.c. of the seeds	- 90
Purity p.c. of the seeds	- 90
Seeds required for gap filling	- 5 per cent by wt. of seeds required for sowing
Test weight of the seeds	- 250g.

Solution:

$$\text{Seed Rate} = (10,000 \times \text{Test weight in g.} \times 100 \times 100) / (\text{Spacing} \times 1000 \times 1000 \times \text{Germ.p.c.} \times \text{Purity p.c.})$$

$$= (10,000 \times 250 \times 100 \times 100) / (0.75 \times 0.30 \times 1000 \times 1000 \times 90 \times 90) = 13.717 \text{ kg/ha.}$$

Quantity of seed needed for gap filling - at the rate of 5 p.c. of seed weight

$$= (13.717 \text{ kg/ha.}) / 100 = 0.690 \text{ kg/ha.}$$

Answer:

Total quantity if seed required for sowing one hectare area would be - 13.717 kg/ha + 0.690 kg. = 14.407 kg. Or 14.410 kg.

2. Work out the seed requirement of rice in kg/ha if-

A. Transplanted rice:

Spacing of hills	- 20cm x 20cm.
No. of Seedlings/hill	- 3
Germination p.c. of the seed	- 95
Purity p.c. of the seed	- 90
Test weight	- 25g.
No. of damaged seedlings At The time of uprooting (As percentage of uprooted ones)	- 15
No. of seedlings required For gap filling	- 12 per 5 sq. m. area.

B. Upland rice

Approximate spacing/plant	- 20 cm x 3cm.
Germination percentage of the weight	- 95
Purity percentage of the seed	- 90
Test weight	- 25g.
No. of damaged seeds by birds which need to be Replaced by another seed	- 10 seeds/sq. m. area.

Solution:

A. Seed rate for transplanted rice:

Total number of seedling needed to be uprooted from nursery.

$$\text{Seed} = \text{No. of seedling required for transplanting} + \text{No. of damaged seedlings while uprooting} + \text{No. of seedlings required for gap filling.}$$

Thus, No. of seedlings required for transplanting/ha area

$$= (10000 \times \text{No. of seedlings/hill}) / (\text{Spacing/hill})$$

$$= (10000 \times 3) / (0.2 \times 0.2) = 750,000$$

$$\begin{aligned} \text{No. of seedlings damaged while uprooting} \\ = (\text{No of seedlings required for transplanting} \times 15)/100 = 112500 \end{aligned}$$

$$\text{No. of seedlings required for gap filling} = (10000 \times 12)/(5) = 24,000.$$

$$\begin{aligned} \text{Therefore, the total number of seedlings required to be uprooted} \\ = 750000 + 112500 + 24000 \\ = 886,500 \text{ seedlings/ha} \end{aligned}$$

$$\begin{aligned} \text{Seed rate of rice will be} &= (10000 \times \text{no. of seedlings needed/ha} \times \text{Test wt} \times 100 \times 100)/(1000 \times 1000 \times \text{GP} \times \text{PC}) \\ &= 25.92 \text{ kg/ha.} \end{aligned}$$

B. Seed rate for upland rice:

Total number of seeds required: No of seeds required/ha + no. of seeds needed for replacing damaged seeds.

$$\begin{aligned} \text{No. of seeds required/ha} &= 10000/(\text{Spacing}) \\ &= 10000/(1666666.6 \text{ seeds}) \end{aligned}$$

$$\begin{aligned} \text{No. of damaged seeds/ha} &= 10000 \times 10 \\ &= 1000,00 \end{aligned}$$

$$\begin{aligned} \text{Therefore total no. of seeds} &= 1666666.6 + 100000 \\ &= 1766666.6 \text{ seeds/ha.} \end{aligned}$$

$$\begin{aligned} \text{Thus the seed rate/ha would be} \\ &= (\text{Total no. of seeds/ha} \times \text{Test wt} \times 100 \times 100)/(1000 \times \text{GP} \times \text{PC} \times 1000) \text{ kg/ha} \\ &= (1766666.6 \times 25 \times 100 \times 100)/(1000 \times 95 \times 90 \times 1000) \\ &= 51.66 \text{ kg/ha.} \end{aligned}$$

Answer :	Seed rate	A. transplanted rice	25.92kg/ha.
		B. Upland rice	51.66kg/ha.

3. Find out the seed rate of wheat var. Ratan in kg/ha from the following details :

Spacing (approx)	20 cm × 3 cm
Germination percentage	95
Purity percentage	90
Test weight of the seed	46 g.

Solution :

$$\begin{aligned} \text{Seed rate of wheat in kg/ha.} \\ &= (10000 \times 100 \times 100 \times \text{Total weight of seed in g.})/(\text{Spacing in sq.m.} \times \text{Germi.p.c.} \times \text{Purity p.c.} \times 1000 \times 1000) \\ &= (10000 \times 100 \times 100 \times 46)/(0.2 \times 0.03 \times 95 \times 90 \times 1000 \times 1000) \\ &= 89.67 \text{ kg/ha} \end{aligned}$$

Answer:

Seed rate of wheat var. Ratan = 89.67 kg/ha

UNIT XI

Harvest Index And Estimation Of Crop Biological And Economic Yield

The total dry matter production by a crops is known as biological yield and a fraction of biological yield which is useful for man in known as economic yield.

$$\text{Biological yield} \times k = \text{Economic yield}$$

k = Coefficient of effectiveness (Constant) or Harvest index

$$\text{Harvest index} = (\text{Biological yield})/(\text{Economic yield}) \text{ or } \times 100$$

Yield attributes

Economic yield is expressed as a function of factors which contribute to yield. And these yield contributing factors are known as yield attributes.

$$y = a \times b \times c \times d$$

y = Economic yield Cereals

a = Final plant population (At the time of harvest)

b = Number of effective fillers (ear producing shoot)

c = Number of filled grains/ear

d = Test weight

100 grain weight (In case of bold grains)

1000 grain weight (In case of Small sized grains)

Q. Calculate the expected yield of maize grain in t/ha from the details mentioned below:

1. Spacing-75 cm × 30 cm
2. Average no. of cons/plant-2
3. Average no. Grain row/cob-10
4. Average no. seeds/grain row-25
5. Test weight of seeds-250 g.

Solution: Yield of maize grains in t/ha

$$= (10000 \times \text{cobs/plant} \times \text{grain rows/cob} \times \text{grain/cob} \times \text{test wt.in g.}) / (\text{Spacing in sq.m.} \times 1000 \times 1000 \times 100 \times 10) \\ = (10000 \times 2 \times 10 \times 25 \times 250) / (0.75 \times 0.30 \times 1000 \times 1000 \times 100 \times 10)$$

Answer: Yield of maize grain would be 5.56 t/ha

2. What would be the yield of rice grains, if
 - (a) The average ear head density/m²-260
 - (b) Average no. of field grains/panicle-136
 - (c) Test weight-20 g.

Solution:

Yield of rice in t/ha

$$= (10000 \times (\text{ear head density/m}^2) \times (\text{No.of filled garins/earhead}) \times (\text{Test Wt.in.g})) / (1000 \times 10000 \times 100 \times 10) \\ = (100000 \times 260 \times 136 \times 20) / (1000 \times 10000 \times 1000 \times 10) = 7.08 \text{ t/ha.}$$

Answer: Yield of rice would be 7.08 t/ha

UNIT XII

Organic Agriculture

It is a system of farm design and management to create an eco system, which can achieve sustainable productivity without the use of artificial external inputs such as chemical fertilizers and pesticides.

The International Federation for Organic Agriculture Movement's (IFOAM) definition of Organic agriculture is based on:

1. The principle of health.
2. The principle of ecology
3. The principle of fairness and
4. The principle of care

Philosophy : Organic management stresses on optimization of resource use and productivity, rather than maximization of productivity and over exploitation of resources on the cost of resources meant for future generations.

Management Principals : A living soil is the basis of organic farming. A live, healthy soil with proper cropping patterns, crop residue management and effective crop rotation can sustain optimum productivity over the years, without any loss in fertility.

It includes all agricultural systems that promote environmentally sound production of food and fibres. A living soil can be maintained by continuous incorporation of crop and weed biomass, use of animal dung, urine-based manures (FYM, NADEP, vermicompost), biofertilisers and bioenhancers, special liquid formulations (like vermiwash, compost tea etc) during a crop's duration. As a thumb rule, crop residues should be returned to the plot, directly or indirectly. Cattle droppings may be returned to the field as compost. As a strategy, the quantity of biomass removed for human food and fiber, cattle feed or firewood from an organic farm should be replaced with any other bio-waste on the farm. The compost can be further enriched by incorporation of biofertilisers, microbial inoculants, etc. Special composts like biodynamic compost, biodynamic preparations such as BD-500 and BD-501, special formulations like Panchgavya, Dashgavya, Biosol etc are also useful and ensure optimum productivity. For high nutrient demanding crops and for intermittent soil enrichment use of oilcakes, poultry manure, concentrated manures (mixture of oil cakes, poultry manure and rock phosphate) can also be an ideal low-cost option of manuring.

How to achieve: While turning towards organic it is essential that the basic requirements of the system and the area are properly understood and long term strategies are addressed first. To start with, following parameters need to be addressed in first stage:

1. Enrichment of soil : Abandon use of chemicals, use crop residue as mulch ,use organic and biological fertilizers, adopt crop rotation and multiple cropping, avoid excessive tilling and keep soil covered with green cover or biological mulch.

2. Management of temperature : Keep soil covered, Plant trees and bushes on bund.

3. Conservation of soil and rain water : Dig percolation tanks, maintain contour bunds in sloppy land & adopt contour row cultivation, dig farm ponds, maintain low height plantation on bunds.

4. Harvesting of sun energy : Maintain green stand throughout the year through combination of different crops and plantation schedules.

5. Self reliance in inputs : develop your own seed, on-farm production of compost, vermicompost, vermiwash, liquid manures and botanical extracts.

6. Maintenance of life forms : Develop habitat for sustenance of life forms, never use pesticides and create enough diversity.

7. Integration of animals : Animals are important components of organic management and not only provide animal products but also provide enough dung and urine for use in soil.

8. Use of renewable energy : Use solar energy, bio-gas and bullock driven pumps, generator and other machine.



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