FCI Phase-2
AG-III (Agriculture) Capsule
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Chapter-3 (Agriculture):- General Agricultural, Statics of Indian Agriculture (Cereals & Pulses), Elementary entomology, Plant Protection, Agricultural Economics, Crops Forecasting

Chapter - 1 (Botany)

Plant Tissues

Plants are multicellular eukaryotes with tissue systems made of various cell types that carry out specific functions. Plant tissue systems fall into one of two general types: meristematic tissue and permanent (or non-meristematic) tissue. Cells of the meristematic tissue are found in meristems, which are plant regions of continuous cell division and growth. Meristematic tissue cells are either undifferentiated or incompletely differentiated, and they continue to divide and contribute to the growth of the plant. In contrast, permanent tissue consists of plant cells that are no longer actively dividing.

Meristematic tissues consist of three types

Apical meristems contain meristematic tissue located at the tips of stems and roots, which enable a plant to extend in length.

Lateral meristems facilitate growth in thickness or girth in a maturing plant.

Intercalary meristems occur only in monocots, at the bases of leaf blades and at nodes (the areas where leaves attach to a stem). This tissue enables the monocot leaf blade to increase in length from the leaf base; for example, it allows lawn grass leaves to elongate even after repeated mowing.

Permanent Tissue

Permanent tissues in a plant are those tissues that contain nondividing cells. The cells are also modified to perform specific functions in the plants. The cells of the permanent tissue are derived from the meristematic tissue.
The permanent tissue cells are also fully differentiated. The cells are large and a definite shape and size. You can see intercellular spaces being present in between the cells. Large vacuoles are also present inside these cells. The metabolism that occurs in the cells of the permanent tissue is fairly at a lower rate.

**Types of Permanent Tissues**

**Permanent tissues can be classified into two types. They are:**

i) Simple permanent tissue

ii) Complex Permanent tissue

**Simple Permanent Tissues**

These tissues are simple. They are made up of only one type of cell. Here, all the cells that make up the tissue are similar and have the same structure, with the same type parts. Simple permanent tissues are again classified into three main types. They are parenchyma, collenchyma, and sclerenchyma.

**Parenchyma** – The cells of this tissue are living, with thin cell walls. Cells can be oval or round in shape. They have a large central vacuole and a dense cytoplasm. The parenchyma tissue is located in the soft parts of the plant such as cortex and pith. It mainly acts as a packing tissue, providing mechanical support. It also helps in the storage of food. Based on the specific functions, parenchyma can be further classified into Aerenchyma and Chlorenchyma.

**Collenchyma** – These cells are living cells and have an elongated shape. The corners of the cell wall are thickened. There is very little intercellular space present. The collenchyma tissue can be located in the leaf stalks, below the epidermis etc. Its main function is to provide flexibility to the plants as well as mechanical support.

**Sclerenchyma** – The cells of the sclerenchyma tissue are dead. The cell wall is very thick due to the deposition of lignin. The cells of this tissue can be in different shapes and sizes.

**Complex Permanent Tissue**

The complex permanent tissues are made up of more than one type of cell. They coordinate together to perform the same specialized functions in the plant body. They are classified into two types – Xylem and Phloem

**Xylem** – The xylem tissue is responsible for the conduction of water and minerals from the roots to the leaves and stem. It also provides support to the plants. It has four elements. They are tracheids, vessels, xylem parenchyma and xylem fibres.

**Phloem** – This complex permanent tissue helps in the translocation of food that is prepared by photosynthesis in the leaves to various parts of the plant. Phloem consists of four elements. They are sieve tubes, companion cells, phloem fibres and phloem parenchyma.

**Dermal Tissue**

The dermal tissue of the stem consists primarily of epidermis, a single layer of cells covering and protecting the underlying tissue. Woody plants have a tough, waterproof outer layer of cork cells commonly known as bark, which further protects the plant from damage. Epidermal cells are the most numerous and least differentiated of the cells in the epidermis. The epidermis of a leaf also contains openings known as stomata, through which the exchange of gases takes place (Figure 2). Two cells, known as guard cells, surround each leaf stoma, controlling its opening and closing.
and thus regulating the uptake of carbon dioxide and the release of oxygen and water vapor. Trichomes are hair-like structures on the epidermal surface. They help to reduce transpiration (the loss of water by aboveground plant parts), increase solar reflectance, and store compounds that defend the leaves against predation by herbivores.

**Vascular Tissue**

The xylem and phloem that make up the vascular tissue of the stem are arranged in distinct strands called vascular bundles, which run up and down the length of the stem. When the stem is viewed in cross section, the vascular bundles of dicot stems are arranged in a ring. In plants with stems that live for more than one year, the individual bundles grow together and produce the characteristic growth rings. In monocot stems, the vascular bundles are randomly scattered throughout the ground tissue.

**Ground Tissue**

Ground tissue is mostly made up of parenchyma cells, but may also contain collenchyma and sclerenchyma cells that help support the stem. The ground tissue towards the interior of the vascular tissue in a stem or root is known as pith, while the layer of tissue between the vascular tissue and the epidermis is known as the cortex.

**Organs and Organs System**

**Plant Organs**

Like animals, plants contain cells with organelles in which specific metabolic activities take place. Unlike animals, however, plants use energy from sunlight to form sugars during photosynthesis. In addition, plant cells have cell walls, plastids, and a large central vacuole: structures that are not found in animal cells. Each of these cellular structures plays a specific role in plant structure and function.

In plants, just as in animals, similar cells working together form a tissue. When different types of tissues work together to perform a unique function, they form an organ; organs working together form organ systems. Vascular plants have two distinct organ systems: a shoot system, and a root system. The shoot system consists of two portions: the vegetative (non-reproductive) parts of the plant, such as the leaves and the stems, and the reproductive parts of the plant, which include flowers and fruits. The shoot system generally grows above ground, where it absorbs the light needed for photosynthesis. The root system, which supports the plants and absorbs water and minerals, is usually underground.

**Stems**- Stems are a part of the shoot system of a plant. They may range in length from a few millimeters to hundreds of meters, and also vary in diameter, depending on the plant type. Stems are usually above ground, although the stems of some plants, such as the potato, also grow underground. Stems may be herbaceous (soft) or woody in nature. Their main function is to provide support to the plant, holding leaves, flowers and buds; in some cases, stems also store food for the plant. A stem may be unbranched, like that of a palm tree, or it may be highly branched, like that of a magnolia tree. The stem of the plant connects the roots to the leaves, helping to transport absorbed water and minerals to different parts of the plant. It also helps to transport the products of photosynthesis, namely sugars, from the leaves to the rest of the plant.

**Stem Anatomy**

**Parenchyma cells**
Collenchyma cells

Sclerenchyma cells

**ii) Leaves** - Leaves are the main sites for photosynthesis: the process by which plants synthesize food. Most leaves are usually green, due to the presence of chlorophyll in the leaf cells. However, some leaves may have different colors, caused by other plant pigments that mask the green chlorophyll.

The thickness, shape, and size of leaves are adapted to the environment. Each variation helps a plant species maximize its chances of survival in a particular habitat. Usually, the leaves of plants growing in tropical rainforests have larger surface areas than those of plants growing in deserts or very cold conditions, which are likely to have a smaller surface area to minimize water loss.

**iii) Roots** - The roots of seed plants have three major functions: anchoring the plant to the soil, absorbing water and minerals and transporting them upwards, and storing the products of photosynthesis. Some roots are modified to absorb moisture and exchange gases. Most roots are underground. Some plants, however, also have adventitious roots, which emerge above the ground from the shoot.

**Types of Root Systems**

Root systems are mainly of two types. Dicots have a tap root system, while monocots have a fibrous root system. A **tap root system** has a main root that grows down vertically, and from which many smaller lateral roots arise. Dandelions are a good example; their tap roots usually break off when trying to pull these weeds, and they can regrow another shoot from the remaining root). A tap root system penetrates deep into the soil.

In contrast, a **fibrous root system** is located closer to the soil surface, and forms a dense network of roots that also helps prevent soil erosion (lawn grasses are a good example, as are wheat, rice, and corn). Some plants have a combination of tap roots and fibrous roots. Plants that grow in dry areas often have deep root systems, whereas plants growing in areas with abundant water are likely to have shallower root systems.

**Genetics**

Plant genetics is the study of genes, genetic variation, and heredity specifically in Plants. It is generally considered a field of biology and botany, but intersects frequently with many other life sciences and is strongly linked with the study of information systems. Plant genetics is similar in many ways to animal genetics but differs in a few key areas.

The discoverer of genetics was Gregor Mendel, a late 19th-century scientist and Augustinian friar. Mendel studied "trait inheritance", patterns in the way traits are handed down from parents to offspring. He observed that organisms (most famously pea plants) inherit traits by way of discrete "units of inheritance". This term, still used today, is a somewhat ambiguous definition of what is referred to as a gene. Much of Mendel's work with plants still forms the basis for modern plant genetics.

**DNA:**
Deoxyribonucleic acid (DNA) is a nucleic acid that contains the genetic instructions used in the development and functioning of all known living organisms and some viruses. The main role of DNA molecules is the long-term storage of information. DNA is often compared to a set of blueprints or a recipe, or a code, since it contains the instructions needed to construct other components of cells, such as proteins and RNA molecules. The DNA segments that carry this genetic information are called genes, and their location within the genome are referred to as genetic loci, but other DNA sequences have structural purposes, or are involved in regulating the use of this genetic information.

Geneticists, including plant geneticists, use this sequence of DNA to their advantage to better find and understand the role of different genes within a given genome. Through research and plant breeding, manipulation of different plant genes and loci encoded by the DNA sequence of the plant chromosomes by various methods can be done to produce different or desired genotypes that result in different or desired phenotypes.

**Plant Specific Genetics:**

Plants, like all other known living organisms, pass on their traits using DNA. Plants however are unique from other living organisms in the fact that they have Chloroplasts. Like mitochondria, chloroplasts have their own DNA. Like animals, plants experience somatic mutations regularly, but these mutations can contribute to the germ line with ease, since flowers develop at the ends of branches composed of somatic cells. People have known of this for centuries, and mutant branches are called "sports". If the fruit on the sport is economically desirable, a new cultivar may be obtained.

**Modern ways to genetically modify plants:**

"Gene gun" method

The gene gun method is also referred to as "biolistics" (ballistics using biological components). This technique is used for in vivo (within a living organism) transformation and has been especially useful in monocot species like corn and rice. This approach literally shoots genes into plant cells and plant cell chloroplasts. DNA is coated onto small particles of gold or tungsten approximately two micrometres in diameter. The particles are placed in a vacuum chamber and the plant tissue to be engineered is placed below the chamber. The particles are propelled at high velocity using a short pulse of high pressure helium gas, and hit a fine mesh baffle placed above the tissue while the DNA coating continues into any target cell or tissue.

Agrobacterium method

Transformation via Agrobacterium has been successfully practiced in dicots, i.e. broadleaf plants, such as soybeans and tomatoes, for many years. Recently it has been adapted and is now effective in monocots like grasses, including corn and rice. In general, the Agrobacterium method is considered preferable to the gene gun, because of a greater frequency of single-site insertions of the foreign DNA, which allows for easier monitoring. In this method, the tumor inducing (Ti) region is removed from the T-DNA (transfer DNA) and replaced with the desired gene and a marker, which is then inserted into the organism. This may involve direct inoculation of the tissue with a culture of transformed Agrobacterium, or inoculation following treatment with micro-projectile bombardment, which wounds the tissue.

**Plant Classification**

Taxonomy is the Science of classification which makes the study of wide variety of organisms easy and helps us to understand the interrelationships among different groups of organisms. In Plant Kingdom the first level of
classification depends whether plant body is differentiated, have special tissues for transportation, ability to bear seeds and whether the seeds are enclosed within fruits or not.

Classification of Plant Kingdom

Thallophyta: Various types of microorganisms like algae, fungi and bacteria have been kept under it. Algae are classified into three categories: Red, Brown and Green algae.

Chief characteristics of algae are:
- Cell wall of algae is made up of cellulose.
- Sex organs of algae are unicellular.
- Algae store their food in the form of starch.

Reproduction: Vegetative, Asexual and Sexual reproduction.

Economic Utilities: It is useful in the form of food stuffs, agriculture, in trade and business, in biological research, as the fodder of domestic animals, in the form of medicines and in the formation of land. But there are many algae which act like pollutants and contaminate the drinking water. Also, watery equipments are rottened by the algae. Celphaleuros algae produce a disease called red rust in the tea plants.
(I) Bryophyta: Plants are found at land and water but are amphibians like Liver warts, Horn warts, Moss etc. These plants are also autotrophic as chloroplasts are present.

Economic Utilities: These plants have good absorption capacity of water and thus can be used as flood preventive measure. Also used in stopping soil erosion. Moss plant is used as a fuel called peat energy and as antiseptics.

(II) Tracheophyta: These plants have well developed vascular tissues and divided in to xylem and phloem. Further it is divided in to three subgroups: Pteridophyta, Gymnosperms and Angiosperm.

**Pteridophyta:** In these plants there are lack of seeds and flowers.
Examples: Club Mosses, horsetails, ferns etc.

**Characteristics:**

- These plants are sporophyte. As spores of these plants are produced in sporangia.

- The leaves in which sporangia produces is called sporophyll.

- On Gametophyte there exist male and female sex organ.

- Alternation of genes is also appeared.

- Zygospores are formed through zygote.

**Utilities:** This plant is used as fodders for the domestic animals, while the seed is used as medicines.

<table>
<thead>
<tr>
<th>Algae</th>
<th>Fungi</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. They contain photosynthetic pigments.</td>
<td>1. Photosynthetic pigments are absent.</td>
</tr>
<tr>
<td>2. Autotrophic</td>
<td>2. Heterotrophic</td>
</tr>
<tr>
<td>3. Most of them are aquatic in habitat.</td>
<td>3. Most of them are terrestrial.</td>
</tr>
<tr>
<td>4. The cell wall is made up of Cellulose.</td>
<td>4. The cell wall is made up of chitin.</td>
</tr>
<tr>
<td>5. It contains starch as a stored food material.</td>
<td>5. It contains glycogen and oil as the stored food material.</td>
</tr>
</tbody>
</table>

**Gymnosperm:** The plants whose seeds are completely uncoated and there is complete lack of ovary.

Examples: Cycas, Pinus (Pines), Cedrus (Deodar) etc.

**Characteristics:**
- These plants are perennial and xerophytic.

- Have clear cut annual rings.

- Undergo wind-pollination and have polyembryony-characteristics.

- One or more cotyledons in an embryo exists with radicle and plumule.

**Economic Utilities:** Used in the form of food, timber & medicine. For decorative and domestic use. In making volatile oils & also used in the form of tanning and resin.

**Angiosperm:** This is the most-important subgroup of plants, whose seeds are coated and developed in an organ or ovary. Our major food, fibre, spice and beverage crops are flowering plants (angiosperms). Also used as medicinal plants and the respondent flavour species, latex products like rubber etc. These plants are also utilised in making perfumes, soaps and cosmetics from their oils.

**Characteristics:**

- The reproductive organ of this plant is flower and double fertilization takes place.

- Are saprophytic, symbiotic and parasitic. Some are autotrophic also.

- Normally appear on land but few are aquatic.

- The vascular tissues are extremely well developed.

Further Angiosperm is classified into two categories:

**Monocotyledonae (monocot):** Leaves of these plants are much longer rather than broad. Stems of monocot lack cambium and hence they increase little in girth except palm tree. Examples: Maize, wheat, rice, onion, sugarcane, barley, banana, coconut etc.

**Characteristics:**

- In the seed of these plants one cotyledon is found.

- Their leaves have parallel venation.

- The roots of these plants are not developed.

- The flowers are trimerous i.e have three or multiple of three petals.

- In the vascular part, cambium doesn't exist.
Dicotyledonae (Dicot): These plants have two seed leaves. Have veins forming a network in their leaves. Almost have all the hardwood tree species, pulses, fruits, vegetables etc. Examples: Pea, potato, sunflower, rose, banyan, apple, neem etc.

Characteristics:

- In the seed of these plants two cotyledons are found.
- In the vascular part cambium exists.
- The flower of the plant has multiples of four or five petals.
- These dicots plants have secondary growth.

Ecology

Ecology Definition - Ecology is the branch of biology that studies how organisms interact with their environment and other organisms. Every organism experiences complex relationships with other organisms of its species, and organisms of different species. These complex interactions lead to different selective pressures on organisms. The pressures together lead to natural selection, which causes populations of species to evolve. Ecology is the study of these forces, what produces them, and the complex relationships between organisms and each other, and organisms and their non-living environment.

Types of Ecology

Molecular Ecology

At the molecular level, the study of ecology focuses on the production of proteins, how those proteins affect the organism and the environment, and how the environment in turn affects the production of various proteins. In all known organisms, DNA gives rise to various proteins, which interact with each other and the environment to replicate the DNA. These interactions lead to some very complex organisms. Molecular ecologist study how these proteins are created, how they affect the organism and environment, and how the environment in turn affects them.

Organismal Ecology

Taking a step back, the study of organismal ecology deals with individual organisms and their interactions with other organisms and the environment. While organismal biology is a division of ecology, it is still a huge field. Each organism experiences a huge variety of interactions in its lifetime, and to study all of them is impossible. Many scientist studying organismal ecology focus on one aspect of the organism, such as its behavior or how it processes the nutrients of the enviroment.

Population Ecology

The next level of organism organization, populations, are groups of organisms of the same species. Due to the wide variety of life on Earth, different species have developed many different strategies for dealing with their conspecifics, or organisms of the same species. Some species directly compete with conspecifics, while other organisms form close social bonds and work cooperatively to secure resources. A branch of ecology, social ecology, studies organisms like bees and wolves, which work together to provide for the colony or pack. The complex interactions between these organisms and there environment leads to different selective forces than in animals that compete with conspecifics.
In fact, scientist hypothesize that the increased success found in human society may have been what lead humans to be so communicative. Population ecologist study populations of organism and the complex interactions they have with the environment and other populations.

**Community Ecology**

Different populations that live in the same environment create communities of organisms. These communities create niches, or various spaces, for organisms to occupy. For instance, several niches can be found in a wheat field. The wheat exists on the sun’s rays and the nutrients in the soils. Various insects live off of the nutrients collected by the wheat. Certain bacteria occupy a niche in the roots, where they convert nitrogen for the plant. Community ecologist study these complex interactions and the selective pressures they produce. Sometimes, organisms in communities will begin to experience coevolution where two or more species both evolve in response to each other. This can be seen in many species, from bees and the flowers they pollinate to predators and the prey they eat.

**Ecosystem Ecology**

The largest scale of organismal organization is the ecosystem. An ecosystem is network of interconnected biological communities. The largest ecosystem, the biosphere, encompasses all ecosystems inside of it. Ecosystem ecologist study the complex patterns produced by interacting ecosystems and the abiotic factors of the environment. They may study water, nutrients, or other chemical that cycle through the ecosystem. Ecosystem ecology is a very complex and large-scale science that includes many disciplines.

**Related Biology Terms**

**Primary Production** – The process of converting inorganic energy, such as sunlight, into biological energy, usually glucose.

**Niche** – A role or position that a creature can role within an ecosystem.

**Nutrient cycling** – The process through which different elements pass from organism to organism, and are used in different ways or returned to the environment.

**Biosphere** – The sum of all ecosystems on the planet, acting as one ecosystem.

**Diversity**

In biology, diversity may pertain to the variation of life forms present in different ecosystems. Specifically termed as biodiversity, its scope includes (but not limited to) the following:

(1) **Genetic diversity** - Genetic diversity refers to both the vast numbers of different species as well as the diversity within a species.

(2) **Ecosystem diversity** - Ecosystem diversity refers to the diversity of a place at the level of ecosystems.

(3) **Species diversity** - Species diversity pertains to the effective number of species represented in a data set.
(4) **Phylogenetic diversity** - Phylogenetic diversity measures the diversity that incorporates phylogenetic difference between species.

(5) **Crop diversity** - Crop diversity refers to the variance in genetic and phenotypic characteristics of plants used in agriculture.

(6) **Functional diversity** - Functional diversity pertains to the elements of biodiversity that have an effect on the function of the ecosystem.

Diversity in biological sense thus measures the variety of organisms in a particular ecosystem. It tends to cluster in hotspots.

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**Photosynthesis**

Photosynthesis is the process used by plants, algae and certain bacteria to harness energy from sunlight and turn it into chemical energy. Here, we describe the general principles of photosynthesis and highlight how scientists are studying this natural process to help develop clean fuels and sources of renewable energy.

**Types of photosynthesis**

There are two types of photosynthetic processes:

i) **Oxygenic photosynthesis**

ii) **Anoxygenic photosynthesis**

The general principles of anoxygenic and oxygenic photosynthesis are very similar, but oxygenic photosynthesis is the most common and is seen in plants, algae and cyanobacteria.

**Oxygenic photosynthesis** - Oxygenic photosynthesis, light energy transfers electrons from water (H2O) to carbon dioxide (CO2), to produce carbohydrates. In this transfer, the CO2 is "reduced," or receives electrons, and the water becomes "oxidized," or loses electrons. Ultimately, oxygen is produced along with carbohydrates.

Oxygenic photosynthesis functions as a counterbalance to respiration by taking in the carbon dioxide produced by all breathing organisms and reintroducing oxygen to the atmosphere.

Oxygenic photosynthesis is written as follows:

$$6\text{CO}_2 + 12\text{H}_2\text{O} + \text{Light Energy} \rightarrow \text{C}_6\text{H}_12\text{O}_6 + 6\text{O}_2 + 6\text{H}_2\text{O}$$

Here, six molecules of carbon dioxide (CO2) combine with 12 molecules of water (H2O) using light energy. The end result is the formation of a single carbohydrate molecule (C6H12O6, or glucose) along with six molecules each of breathable oxygen and water.

**Anoxygenic photosynthesis** - Anoxygenic photosynthesis does not produce oxygen — hence the name," said David Baum, professor of botany at the University of Wisconsin-Madison. "What is produced depends on the electron donor. For example, many bacteria use the bad-eggs-smelling gas hydrogen sulfide, producing solid sulfur as a byproduct."
Though both types of photosynthesis are complex, multistep affairs, the overall process can be neatly summarized as a chemical equation.

Anoxygenic photosynthesis reactions can be represented as a single generalized formula:

$$CO_2 + 2H_2A + \text{Light Energy} \rightarrow [\text{CH}_2\text{O}] + 2A + H_2O$$

The letter A in the equation is a variable and H2A represents the potential electron donor. For example, A may represent sulfur in the electron donor hydrogen sulfide (H2S), explained Govindjee and John Whitmarsh, plant biologists at the University of Illinois at Urbana-Champaign, in the book "Concepts in Photobiology: Photosynthesis and Photomorphogenesis" (Narosa Publishers and Kluwer Academic, 1999).

**The photosynthetic apparatus**

The following are cellular components essential to photosynthesis.

**Pigments**

Pigments are molecules that bestow color on plants, algae and bacteria, but they are also responsible for effectively trapping sunlight. Pigments of different colors absorb different wavelengths of light. Below are the three main groups.

**Chlorophylls:** These green-colored pigments are capable of trapping blue and red light. Chlorophylls have three subtypes, dubbed chlorophyll a, chlorophyll b and chlorophyll c. According to Eugene Rabinowitch and Govindjee in their book "Photosynthesis"(Wiley, 1969), chlorophyll a is found in all photosynthesizing plants. There is also a bacterial variant aptly named bacteriochlorophyll, which absorbs infrared light. This pigment is mainly seen in purple and green bacteria, which perform anoxygenic photosynthesis.

**Carotenoids:** These red, orange or yellow-colored pigments absorb bluish-green light. Examples of carotenoids are xanthophyll (yellow) and carotene (orange) from which carrots get their color.

**Phycobilins:** These red or blue pigments absorb wavelengths of light that are not as well absorbed by chlorophylls and carotenoids. They are seen in cyanobacteria and red algae.

**Antennae**

Pigment molecules are associated with proteins, which allow them the flexibility to move toward light and toward one another. A large collection of 100 to 5,000 pigment molecules constitutes "antennae," according to an article by Wim Vermaas, a professor at Arizona State University. These structures effectively capture light energy from the sun, in the form of photons.

**Reaction centers**

The pigments and proteins, which convert light energy to chemical energy and begin the process of electron transfer, are known as reaction centers.

**The photosynthetic process**

The reactions of plant photosynthesis are divided into those that require the presence of sunlight and those that do not. Both types of reactions take place in chloroplasts: light-dependent reactions in the thylakoid and light-independent reactions in the stroma.
Light-dependent reactions (also called light reactions): When a photon of light hits the reaction center, a pigment molecule such as chlorophyll releases an electron.

"The trick to do useful work, is to prevent that electron from finding its way back to its original home," Baum told Live Science. "This is not easily avoided, because the chlorophyll now has an 'electron hole' that tends to pull on nearby electrons."

The released electron manages to escape by traveling through an electron transport chain, which generates the energy needed to produce ATP (adenosine triphosphate, a source of chemical energy for cells) and NADPH. The "electron hole" in the original chlorophyll pigment is filled by taking an electron from water. As a result, oxygen is released into the atmosphere.

Light-independent reactions (also called dark reactions and known as the Calvin cycle): Light reactions produce ATP and NADPH, which are the rich energy sources that drive dark reactions. Three chemical reaction steps make up the Calvin cycle: carbon fixation, reduction and regeneration. These reactions use water and catalysts. The carbon atoms from carbon dioxide are "fixed," when they are built into organic molecules that ultimately form three-carbon sugars. These sugars are then used to make glucose or are recycled to initiate the Calvin cycle again.

**Respiration**

Respiration is an intracellular process of oxidation-reduction reactions by which cells release energy from organic compounds (e.g., sugars) to generate ATP (to do other metabolic processes) through a series of chemical reactions involving the transfer of electrons. In respiration, glucose is oxidized and thus releases energy. Oxygen is reduced to form water. The carbon atoms of the sugar molecule are released as carbon dioxide (CO2).

\[ C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy (36 ATP)} \]

**Difference between Photosynthesis and Respiration**

<table>
<thead>
<tr>
<th>Photosynthesis</th>
<th>Respiration</th>
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<tbody>
<tr>
<td>Produces food</td>
<td>Uses food</td>
</tr>
<tr>
<td>Stores energy</td>
<td>Releases energy</td>
</tr>
<tr>
<td>Uses water</td>
<td>Produces water</td>
</tr>
<tr>
<td>Uses carbon dioxide</td>
<td>Produces carbon dioxide</td>
</tr>
<tr>
<td>Releases oxygen</td>
<td>Uses oxygen</td>
</tr>
<tr>
<td>Occurs in sunlight</td>
<td>Occurs in the dark as well as light</td>
</tr>
</tbody>
</table>
It is basically an energy releasing and supplying process. The energy released in respiration is of two types:

(a) **Chemical energy**, i.e. ATP. It is utilized for the cellular activities.

(b) **Heat energy**. It is mostly lost. Depending upon the availability of oxygen as an oxidant, respiration is of two types:
1. aerobic respiration, in which oxygen is used in the respiratory breakdown of organic substrate, and
2. anaerobic respiration, in which oxygen is not used in the respiratory breakdown of organic substrate.

Respiration can be divided into the following stages (image 904):
- The process of respiration is completed in two phases:
  
  In **aerobic** as well as **anaerobic** respiration, **initial sequence of events are the same, therefore collectively known as glycolysis**.

1. **Glycolysis**
   - Glycolysis is the breakdown of a 6-carbon glucose molecule into two molecules of 3-carbon pyruvate; it takes place in the cytoplasm (cytosol) of all living cells, and are common to both types of respiration. Therefore, glycolysis is also known as cytoplasmic respiration.

Reactions in Phase II depend upon whether O2 is utilized or not. Respiration is of two types:

- **Aerobic respiration**:
  - When free or molecular oxygen participates in the respiratory breakdown of organic substrate, it is called aerobic respiration. (In this process, free molecular oxygen acts as the final electron acceptor.)

- **Anaerobic respiration**:
  - When the respiratory breakdown of organic substrate takes place without participation of free molecular oxygen, it is called anaerobic respiration. In anaerobic respiration, pyruvate is used in fermentation.

Chemical equation for anaerobic respiration:

\[ C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + \text{Energy} \]

**Glycolysis (also known as E.M.P. pathway = Embden - Meyerhof - Parnas Pathway)**: Glycolysis (glyco = sugar; lysis = splitting) splits a 6-carbon sugar, glucose, into two molecules of 3-carbon pyruvate in a series of steps, each catalyzed by a particular enzyme. Glycolysis takes place in the cytoplasm (cytosol) of all living cells, not in mitochondria, and does not require the presence of oxygen. Therefore, glycolysis is also known as cytoplasmic respiration.

**The various steps of glycolysis are**:

1. **Phosphorylation of glucose**
   - This is called the preparatory phase of glycolysis. The reactions are:
     - In this step, 6-C glucose is converted into glucose-6-phosphate. One ATP is used in the reaction.
     - The next step involves isomerization of glucose 6-phosphate into Fructose 6-phosphate.
2. **Splitting of fructose-1, 6-diphosphate**:
   - The molecule of 6-C fructose-1, 6-diphosphate is broken down into two molecules of 3-C triose phosphates. One is 3-phosphoglyceraldehyde (3-PGAL) and the other is dihydroxy acetone phosphate (DHAP). These are isomers of each other, with each molecule having the formula C3H4O2-phosphate.
   - However, further reactions in glycolysis utilize only PGAL. Therefore, DHAP is also converted into PGAL.
   - Thus, two molecules of 3-PGAL are formed from the splitting of one molecule fructose-1, 6-diphosphate.

3. **Formation of 3-C pyruvic acid**:
   - 3-PGAL in combination with one inorganic phosphate (derived from H3PO4) and coenzyme NAD (nicotinamide adenine dinucleotide) is converted into 1, 3 diphosphoglyceric acid (1, 3 diPGA). This is an oxidation and phosphorylation reaction. The reduced coenzyme NADH2 is formed in the process. Hydrogen is then removed from the triose phosphate (PGAL) and transferred to the carrier molecule NAD (nicotinamide adenine dinucleotide) and the reduced NAD (NADH2) is used during oxidative phosphorylation. The NADH+ accepts 2 electrons and one proton [one hydrogen ion]; the second hydrogen ion remains free.
   - In the next step, 1, 3-diPGA undergoes dephosphorylation to form 3-phosphoglyceric acid (3-PGA). Phosphate removed from each diPGA is transferred to by ADP to form ATP. Two ATP molecules are formed at this step.
   - 3-PGA is transformed into 2-PGA.
   - In the next step, 2-PGA is converted into 2-phosphoenol pyruvic acid (2-PEP) with the loss of water (dehydration).
   - Substrate-level phosphorylation In the final step of glycolysis, 2-PEP is dephosphorylated to form 3-C pyruvic acid, which is the end product of glycolysis. The reaction produces 2 ATP.

**Anaerobic respiration**: Fermentation In anaerobic respiration When oxygen is not available, pyruvate is converted to either ethanol or lactic acid:

**Alcoholic fermentation**: Alcoholic fermentation is common in bacteria and yeast cells (unicellular fungus). In some plant cells and yeasts, alcoholic fermentation produces CO2 and ethanol. The conversion of pyruvate to acetaldehyde generates CO2 and the conversion of acetaldehyde to ethanol regenerates NAD+.

**Lactic acid fermentation**: This pathway is common for animal cells, bacteria, fungi, and protist cells and lactic acid bacteria. During one form of anaerobic glycolysis or fermentation, L-lactate is produced from pyruvate via the enzyme lactate dehydrogenase. This conversion also oxidizes one molecule of NADH to NAD+, and this is the reason for the conversion: NAD+ has to be regenerated so that glycolysis can continue.

**Aerobic respiration**: Aerobic respiration (when oxygen is present) comprises a series of enzymatic reactions. In which 3-c pyruvic acid (the end product of glycolysis) is broken down step by step to form the end products CO2, H2
O and ATP energy of aerobic respiration In eukaryotes, these processes occur in the mitochondria, while in prokaryotes they occur in the cytoplasm. It involves two stages:

A. The T.C.A. (Tricarboxylic acid) cycle (Krebs cycle or citric acid cycle) occurs in the matrix.
B. Electron transport chain and oxidative phosphorylation occur deep in the cristae.

Formation of 2-C Acetyl Co-A : The Transition Reaction: The two pyruvate molecules formed from a single glucose molecule in glycolysis is transported to the matrix of the mitochondria undergoes oxidative de-carboxylation i.e

- The two 3-carbon pyruvate molecules are oxidized by dehydrogenation to two 2-carbon acetyl groups (CH3CO).
- Two molecules of CO2 are released from pyruvic acid.
- These two-carbon molecules are oxidized—that is, electrons are removed and used to form a total of two NADH molecules (to be used later).
- The two 2-carbon compound produced is attached to Coenzyme A (CoA-CoA) to produce acetyl CoA and the cycle begins.
- The NADH so formed is channelled into the respiratory chain in the mitochondrial membrane.

Electron transport chain and oxidative phosphorylation

Electron transport chain: In aerobic respiration, glucose is oxidized, and its electrons are passed to the electron transport chain in the inner mitochondrial membrane. The enzymes necessary for the transfer of electrons are present in the inner mitochondrial membrane in an ordered manner and also function in a specific sequence. The ten NADH that enter the electron transport originate from each of the earlier processes of respiration: two from glycolysis, two from the transformation of pyruvate into acetyl-CoA, and six from the citric acid cycle. The two FADH2 originate in the citric acid cycle. Electron flow through the mitochondrial electron transport chain which includes Complexes I, II, III, and IV. The electron transport chain also involve NADH and FADH, which act as electron transporters as they flow through the inner membrane space.

- Complex I, (NADH:CoQ oxidoreductase,) is composed of NADH dehydrogenase with FMN as cofactor, plus non-heme-iron proteins having at least 1 iron sulfur center. In complex I, electrons are passed from NADH to the electron transport chain, where they flow through the remaining complexes. Complex I is the first coupling site in the mitochondrial membrane meaning that the redox reaction is coupled to a proton pumping activity across the membrane. It is the energy stored in the electrochemical proton gradient that is used for ATP synthesis by the H+ATPase. NADH is oxidized to NAD in this process.
- Complex II (succinate dehydrogenase or succinate:CoQ oxidoreductase) Complex II oxidizes FADH, garnering still more electrons for the chain.
- The difference in free energy, of electron flow through Complexes I and II, accounts for the fact that a pair of electrons originating from NADH and passing to oxygen supports production of 3 equivalents of ATP, while 2 electrons from succinate support the production of only 2 equivalents of ATP.
- Complex III (Cytochrome-c reductase) which mainly composed of the heme proteins known as cytochromes b and c1 and a non-heme-iron protein, known as the Rieske iron sulfur protein. Reduced CoQ (CoQH2) diffuses...
in the lipid phase of the membrane and donates its electrons to Complex III. At complex III, no additional electrons enter the chain, but electrons from complexes I and II flow through it.

**Oxidative phosphorylation** is the process by which NADH and FADH2 are oxidized and ATP is formed.

The energy released by the electrons as they pass through the electron transport chain is used to actively transport (pump) hydrogen ions across a membrane—across the inner mitochondrial membrane into the intermembrane space in mitochondria. As electrons are pulled from NADH and FADH2, protons (H+) also are released, and the protein complexes pump them into the intermembrane space. Inner mitochondrial membrane is impermeable to hydrogen ions (protons), they accumulate there, and thus both a proton gradient (H+ gradient) and an electrochemical gradient are established between the inner membrane space and the matrix. This diffusion is called **chemiosmosis or proton motive force (PMF)**. This potential is the sum of the concentration difference of protons across the membrane and the difference in electrical charge across the membrane. The 2 electrons from NADH generate a 6-proton gradient. In aerobic respiration, the transport protein is an enzyme called ATP synthase with inner channels through which hydrogen ions (protons) diffuse. As the protons move down the gradient, their energy binds a phosphate group to ADP, an oxidative phosphorylation, making ATP.

**NADH enters the ETS chain at the beginning, yielding 3 ATP per NADH. FADH2 enters at Co-Q, producing only 2 ATP per FADH2.**

**Net production of ATP per glucose molecule:** Glycolysis produces two ATPs. It does not produce any CO2 or H2O. Formation of acetyl-CoA produces two molecules of CO2. The citric acid cycle produces two ATPs and the remaining four molecules of CO2. Electron transport and chemiosmosis produce the 12 molecules of H2O and 32 to 34 ATPs. Altogether, a maximum of 36 to 38 ATPs are produced per glucose molecule.

**BIOCHEMISTRY**

Biochemistry is a field of biology that studies the chemical reactions within living organisms. Life can be reduced down to thousands of chemical reactions that continuously occur to keep an organism alive. Biochemistry studies the very important chemical pathways that have allowed for life to live and evolve to the incredible diversity we now have on Earth.

All life is built from four groups of molecules referred to as the ‘molecules of life’. These include proteins, carbohydrates, lipids and nucleic acids. These four molecule group make up the vast majority of living tissue and are involved in vital processes such as respiration and photosynthesis.

**PROTEINS**

Proteins are the building blocks of life and are the most common molecule found in cells. They are hugely diverse and important. Proteins include compounds such as hormones, enzymes, and antibodies.

**LIPIDS**

Lipids are a group of molecules that include fats, oils and some steroids. They are built from molecules called ‘fatty acids’ and can be bonded to a wide range of other compounds. Almost all lipids are insoluble in water.

**RESPIRATION**
Respiration is a process that occurs in cells. Through respiration, cells convert the energy of glucose and other molecules into cellular energy. Cells are then able to use this energy to perform functions such as build proteins, replicate DNA and breakdown wastes.

CARBOHYDRATES

A carbohydrate is either a sugar or the combination of multiple sugars. They are vital for life on Earth and perform a range of functions such as providing energy, structural support and cellular communication.

PHOTOSYNTHESIS

Photosynthesis is arguably the most important set of chemical reactions in terms of the evolution of life on Earth. Photosynthesis is a process which uses energy from the sun to convert carbon dioxide into sugars and oxygen.

Coordination in Plants

You see plants all around you. But, are they of the same size or height? Of course not! You see big trees, medium-sized shrubs, and even plant saplings. This tells us that plants exhibit some growth changes as well as some movements. This coordination in plants is attributed to the presence of plant hormones. Unlike animals, plants do not have any muscular system or nervous system. But, they are still able to show movement and also coordination. These movements are always controlled and not haphazard. Let us learn more about coordination in plants.

What is coordination in plants?

Coordination is the ability to use different parts of the plant together, smoothly and efficiently. In plants, coordination is due to the result of a chemical system, wherein plant hormones or phytohormones have a major role.

Movement in plants

Plants exhibit two types of movements.

i) Growth-dependent movements called the Tropic Movements. (towards or away from a stimulus)

ii) Non-growth dependent movements called the Nastic Movements. (independent of stimulus)

Tropic movements

These can be classified again into 5 types. They are:

i) Phototropism (light)

ii) Geotropism (gravity)

iii) Hydrotropism (water)

iv) Chemotropism (chemicals)

v) Thigmotropism (touch)
Phototropism – It is the movement of plants in response to light. The shoot system of a plant exhibits this characteristic. The shoot moves towards the light.

Geotropism – It is the movement of a plant part towards the soil. This is a characteristic of the root system. The roots always move in the direction of the earth's gravity.

Hydrotropism – It is the movement of a plant towards the water. The stimulus here is water.

Chemotropism – It is the movement of plants in response to a chemical stimulus. A classic example of this type of movement is the growth of the pollen tube towards the ovule, during fertilization, in a flower.

Thigmotropism – It is a directional movement in plants in response to touch. For e.g. the plant tendrils climb around any support which they touch.

Nastic Movements

Nastic movements in plants are not directional movements. They are not dependent on stimulus and are growth independent. For example, the leaves of a touch me not plant (Mimosa pudica), fold up immediately when touched. These kinds of changes occur due to the changes in the amount of water in the leaves. Depending on the quantity, they either swell up or shrink.

Plant hormones or phytohormones

They are responsible for the control and coordination of plants. There are different types of hormones, which affect the growth of a plant. Phytohormones are chemical compounds which are released by stimulated cells. These hormones are diffused around the plant cells. They have a role to play in the cell division, cell enlargement, cell differentiation, fruit growth, falling of leaves, ripening of fruits, ageing of plants etc.

The different types of phytohormones are:

i) Auxins

Auxins – They help in the cell growth at the shoot tips. By elongating the cells, they help in the growth process.

ii) Gibberellins

Gibberellins – These hormones are responsible for the cell growth in the stem, seed germination, and flowering.

iii) Cytokinins

Cytokinins – They promote cell division in plants. They also promote the opening of the stomata and delay ageing in leaves.

iv) Abscisic acid

Abscisic acid – This hormone inhibits the growth of the plant. And therefore, it promotes dormancy in seeds and buds. The detachment of fruits, flowers, and falling of leaves etc. are promoted by this hormone.
Animal Tissues

Tissues are groups of similar cells that perform a particular function. We will be examining human tissues as an example of animal tissues.

Human bodies, like most animal bodies, are made up of four different types of tissue:

Epithelial tissue forms the outer layer of the body and also lines many of the body’s cavities where it has a protective function.

Connective tissue assists in support and protection of organs and limbs and depending on the location in the body it may join or separate organs or parts of the body.

Muscle tissue enables various forms of movement, both voluntary and involuntary.

Nerve tissue is responsible for the carrying of electrical and chemical signals and impulses from the brain and central nervous system to the periphery, and vice versa.

Epithelial tissue - Epithelial tissues are formed by cells that cover surfaces (e.g. skin) and line tubes and cavities (e.g. digestive organs, blood vessels, kidney tubules and airways). Epithelial tissue usually consists of a single layer of cells, however in certain cases there may be more than one layer. All epithelial tissues are free surfaces attached to the underlying layers of a basement membrane.

There are different types of epithelial tissue which are named according to the number of layers they form and the shape of the individual cells that make up those layers. Simple epithelium refers to a single layer of cells. Stratified epithelium refers to two or more layers of cells. Squamous epithelium refers to flattened cells, cuboidal epithelium refers to cells that are cube-shaped and columnar epithelium refers to vertically elongated cells. Ciliated epithelium refers to epithelial cells that contain many tiny hair-like projections.

General functions of epithelial tissue

i) Provides a barrier between the external environment and the organ it covers.

ii) Specialised to function in secretion and absorption.

iii) Protects organisms from microorganisms, injury, and fluid loss.

iv) Excretes waste products such as sweat from the skin.

Muscle tissue enables various forms of movement, both voluntary and involuntary.

There are three types of muscle tissue:
Skeletal and cardiac muscle are striated. Striated muscle cells are striped, with regular patterns of proteins responsible for contraction. Striated muscle contracts and relaxes in short bursts, whereas smooth muscle contracts for longer.

1. **Skeletal muscle** is a voluntary muscle. It is striated in appearance. Skeletal muscle tissue has regularly arranged bundles. It is anchored by tendons and is used to effect skeletal muscle movement, such as locomotion, and maintain posture. The muscles have a reflex action but can also respond to conscious control.

2. **Smooth muscle** is an involuntary, non-striated muscle with tapered ends. It is found within the walls of blood vessels such as arteries and veins. Smooth muscle is also found in the digestive system, urinary tract and in the trachea. It is responsible for involuntary rhythmic contractions of peristalsis, required for moving food down the alimentary canal, and for the dilation and construction of blood vessels to control blood pressure.

3. **Cardiac muscle** is the major tissue making up the heart. It is an involuntary muscle that is striated in appearance. However, unlike skeletal muscle, cardiac muscle connects at branching, irregular angles. The connected branches help with coordinated contractions of the heart.

**Nerve tissue** - Cells making up the central nervous system and peripheral nervous system are classified as nervous tissue. In the central nervous system, nervous tissue forms the brain and spinal cord. In the peripheral nervous system the nervous tissue forms the cranial nerves and spinal nerves, which include the sensory and motor neurons.

The function of nerve tissue is to transmit nerve impulses around the body. Nerves consist of a cell body (soma), dendrites, which receive impulses, and axons which send impulses. The axons of neurons are surrounded by a myelin sheath. The myelin sheath consists of layers of myelin, a white fatty substance. The myelin sheath's main function is to insulate nerve fibres and it also increases the speed of the impulses transmitted by the nerve cell. There are three types of nerve cells: sensory neurons, interneurons and motor neurons.

**Connective tissue** - Connective tissue is a biological tissue that is important in supporting, connecting or separating different types of tissues and organs in the body. All connective tissue is made up of cells, fibres (such as collagen) and extracellular matrix. The type of intercellular matrix differs in different connective tissues. There are different types of connective tissues with different functions.

**Blood**

Blood is regarded as a specialised form of connective tissue because it originates in the bones and has some fibres. Blood is composed of red blood cells, white blood cells and platelets. These components are suspended in a yellow fluid known as plasma.

**Red blood cells**: called erythrocytes are made in the red bone marrow. They do not have a nucleus and are biconcave in shape. Their biconcave shape makes them flexible so that they can squeeze through narrow capillaries. It also gives them a bigger surface to volume ratio, so that they absorb and release gases faster. Red blood cells have a short life span of approximately 120 days. Red blood cells contain the protein known as haemoglobin. Haemoglobin contains
the pigment known as heme that has an iron (Fe) at its centre that combines with oxygen. Haemoglobin releases oxygen as required and takes up carbon dioxide. Red blood cells transport oxygen from the lungs to the tissues and returns carbon dioxide from the tissues to the lungs.

**White blood cells:** Are commonly known as leukocytes and are produced in the yellow bone marrow and lymph nodes. The cells have one or more nuclei. White blood cells are slightly larger than red blood cells and are more irregular in shape. Their main function is to protect the body from diseases. There are several types of white blood cells.

**Platelets:** Also known as thrombocytes are produced in the bone marrow and are fragments of bone marrow cells. They have no nuclei. Platelets assist in the clotting of blood and prevent excessive bleeding.

**Plasma:** Plasma is the pale-yellow component of blood that allows the rest of the components of blood to float in suspension. It makes up about \((\text{55}\%\)\) of total blood volume. It contains dissolved proteins, hormones, urea and carbon dioxide. Its main functions are to transport nutrients, cells and metabolic waste products and maintain blood volume.

**WHAT ARE CELLS?**

Cells are the functional units of life, in which all of the chemical reactions necessary for the maintenance and reproduction of life take place. They are the smallest independent units of life. There are two basic types of cells: prokaryotes and eukaryotes. The prokaryotes lack nuclei and other membrane-bound organelles. These simpler (prokaryotic or prokaryotes; "before nucleus") cells are classified into two domains: Archaea and Eubacteria. The Archaea have unique characteristics but also share features with Eubacteria and the third domain, Eukarya. Eukaryotic cells are larger and more complex than prokaryotic cells. Since animals and protista are composed of eukaryotic cells.

All eukaryotes ("true nucleus") have cells with a membrane-bound nucleus containing DNA. In addition, eukaryotic cells contain many other structures called organelles ("little organs") that perform specific functions. Eukaryotic cells also have a network of specialized structures called microfilaments and microtubules organized into the cytoskeleton, which gives shape to the cell and allows intracellular movement.

**All eukaryotic cells have three basic parts**

1) The plasma membrane is the outer boundary of the cell. It separates the internal metabolic events from the environment and allows them to proceed in organized, controlled ways. The plasma membrane also has specific receptors for external molecules that alter the cell's function.

2) Cytoplasm (Gr. kytos, hollow vessel + plasm, fluid) is the portion of the cell outside the nucleus. The semifluid portion of the cytoplasm is called the cytosol. Suspended within the cytosol are the organelles.

3) The nucleus (pl., nuclei) is the cell control center. It contains the chromosomes and is separated from the cytoplasm by its own nuclear envelope. The nucleoplasm is the semifluid material in the nucleus.

**Heredity & Variation**

Heredity - Heredity or Hereditary is the process of passing the traits and characteristics from parents to offsprings. The offspring cells get their features and characteristics aka genetic information from their mother and father.
Heredity and genetics are the reason you look so much like your parents. Genetics is a branch of science that studies the genes, genetic variation, and heredity in living organisms.

**Gregor Mendel- The Father of Genetics**

Acquiring characteristics or traits from one generation to the other is nothing but inheritance. Here, both the parents contribute equally to the inheritance of traits. It was Gregor Mendel, known as the Father of Genetics, who conducted immense research and studied this inheritance of traits.

It was with his research on plant breeding and hybridization that he came up with the laws of inheritance in living organisms. He conducted his experiments on pea plants to show the inheritance of traits in living organisms.

He observed the pattern of inheritance from one generation to the other in these plants. And thus he came up with Mendel’s Laws of Inheritance, which can be summarized under the following headings:

- Law of Dominance
- Law of Segregation
- Principle of Independent Assortment

**Know Some Terms**

- **Gene** – It is the basic unit of inheritance. It consists of a sequence of DNA, which is the genetic material. A point to be noted here is that genes can mutate and can take two or more alternative forms.

- **Alleles** – The alternative forms of genes which arise as a result of mutation. They are found in the same place on the chromosome and effect the same characteristic or trait but in alternative forms.

- **Chromosomes** – These are thread-like structures of nucleic acids and protein that are found in the nucleus of most living cells. They carry the hereditary or genetic information in the form of genes.

- **Genotype** – It is the complete heritable genetic identity of an organism. It is the actual set of alleles that are carried by the organism. This includes even the alleles that are not expressed, which means even the alleles that do not influence a specific trait that they code for.

- **Phenotype** – It is the description of the actual physical characteristics of an organism, the way the genotype is expressed.

- **Dominant alleles** – When an allele affects the phenotype of an organism, then it is a dominant allele. It is denoted by a capital letter. For example, “T” to express tallness.

- **Recessive alleles** – An allele that affects the genotype in the absence of the dominant allele is called a recessive allele. It will express itself in the small letter. For example – “t” for tallness.

- **Homozygous** – Each organism has two alleles for every gene. (Each chromosome has one each) If both the alleles are same then it is called homozygous. If tallness is the trait, then it is expressed as “TT”
• **Heterozygous** – If the two alleles are different from each other, then they are heterozygous in nature. If tallness is the trait, then it is expressed as "Tt".

### Mendel's Experiments

#### Monohybrid Cross

It is the cross between two pea plants which have one pair of contrasting characters. For Example, a cross between a tall pea plant and a short (dwarf) plant.

#### Dihybrid Cross

It is the cross between two plants which have two pairs of contrasting characters. This takes into consideration alternative traits of two different characters. For example, a cross between one pea plant with round and green seeds and the other pea plant having wrinkled and yellow seeds.

### Variation

Variation, in biology, any difference between cells, individual organisms, or groups of organisms of any species caused either by genetic differences (genotypic variation) or by the effect of environmental factors on the expression of the genetic potentials (phenotypic variation). Variation may be shown in physical appearance, metabolism, fertility, mode of reproduction, behaviour, learning and mental ability, and other obvious or measurable characters.

#### Important Point

Genotypic variations are caused by differences in number or structure of chromosomes or by differences in the genes carried by the chromosomes. Eye colour, body form, and disease resistance are genotypic variations. Individuals with multiple sets of chromosomes are called polyploid; many common plants have two or more times the normal number of chromosomes, and new species may arise by this type of variation. A variation cannot be identified as genotypic by observation of the organism; breeding experiments must be performed under controlled environmental conditions to determine whether or not the alteration is inheritable.

Environmentally caused variations may result from one factor or the combined effects of several factors, such as climate, food supply, and actions of other organisms. Phenotypic variations also include stages in an organism’s life cycle and seasonal variations in an individual. These variations do not involve any hereditary alteration and in general are not transmitted to future generations; consequently, they are not significant in the process of evolution.

### Animal Classification

In order for us to understand how all living organisms are related, they are arranged into different groups. The more features that a group of animals share, the more specific the group is. Animals are given scientific names so that people all around the world can communicate about animals, no matter what language they speak (these names are traditionally Latin words). Animals belong to a number of different groups, starting with the animal kingdom.

#### Kingdom
All living organisms are first placed into different kingdoms. There are five different kingdoms to classify life on Earth, which are Animals, Plants, Fungi, Bacteria, and Protists (single-celled organisms).

**Phylum**

The animal kingdom is divided into 40 smaller groups, known as phylum. Here, animals are grouped by their main features. Animals usually fall into one of five different phylum which are Cnidaria (invertebrates), Chordata (vertebrates), Arthropods, Molluscs and Echinoderms.

**Class**

The phylum group is then divided into even smaller groups, known as classes. The Chordata (vertebrates) phylum splits up into Mammalia (Mammals), Actinopterygii (Bony Fish), Chondrichthyes (Cartilaginous Fish), Aves (Birds), Amphibia (Amphibians) and Reptilia (Reptiles).

**Order**

Each class is divided into small groups again, known as orders. The class Mammalia (Mammals), splits into different groups including Carnivora, Primate, Artiodactyla and Rodentia.

**Family**

In every order, there are different families of animals which all have very similar features. The Carnivora order breaks into families that include Felidae (Cats), Canidae (Dogs), Ursidae (Bears), and Mustelidae (Weasels).

**Genus**

Every animal family is then divided into small groups known as genus. Each genus contains animals that have very similar features and are closely related. For example, the Felidae (Cat) family contains genus including Felis (small Cats and domestic Cats), Panthera (Tigers, Leopards, Jaguars and Lions) and Puma (Panthers and Cougars).

**Species**

Each individual species within the genus is named after its individual features and characteristics. The names of animals are in Latin so that they can be understood worldwide, and consist of two words. The first word in the name of an animal will be the genus, and the second name indicates the specific species.

**Example 1 - Tiger**

Kingdom: Animalia (Animal)

Phylum: Chordata (Vertebrate)

Class: Mammalia (Mammal)

Order: Carnivora (Carnivore)

Family: Felidae (Cat)

Genus: Panthera

Species: Panthera tigris (Tiger)
Example 2 - Orang-utan

Kingdom: Animalia (Animal)
Phylum: Chordata (Vertebrate)
Class: Mammalia (Mammal)
Order: Primates
Family: Hominidae (Great Apes)
Genus: Pongo
Species: Pongo pygmaeus (Orang-Utan)

Microorganism

A microorganism is a living thing that is too small to be seen with the naked eye. Examples of microorganisms include bacteria, archaea, algae, protozoa, and microscopic animals such as the dust mite.

These microorganisms have often been under-appreciated and under-studied. Indeed, until Anton von Leeuwenhoek invented the microscope, we did not know they existed! Until that time, it was thought that phenomena such as illness and food spoilage were caused by “vapors” or “spontaneous generation.”

Types of Microorganisms

**Bacteria** – now sometimes called “eubacteria” or “true bacteria” to differentiate them from archaeabacteria – are the type of microorganism you probably hear about the most.

This is because they're the type most likely to make you sick. Bacteria are the cause of most skin infections, and can also cause food poisoning, pneumonia, strep throat, and many other illnesses.

However, bacteria are also very helpful to humans. “Good bacteria” in our digestive tracts help us to extract nutrients from our food, and help to fight pathogens that could hurt us.

**Archaea**, or archaeabacteria, were once thought to be part of the bacteria family. However, recent research has shown that they are much different from eubacteria, and may even be more closely related to us than they are to modern bacteria.

Archaea can be found in many of the same places as bacteria – in water, in soil, and inside our digestive tracts, where they help us to stay healthy.

However, archaeabacteria can also be found in some unusual places – many are able to live in environments that are very hot, very cold, very acidic, or very salty.

This makes them a common finding inside hot springs and other places where other organisms cannot easily survive.

Animals
Several types of animals come in microscopic varieties, including:

i) Arthropods (dust mites, spider mites, microscopic crustaceans)

ii) Rotifers (a type of zooplankton)

iii) Loricifera (microscopic animals that live in ocean sediments)

iv) Nematodes

**Protozoa** - Protozoa are a diverse group of unicellular eukaryotic organisms. Like bacteria and archaea, they are single-celled; but their cells resemble those of animals and plants more than those of bacteria or archaea.

Several dangerous human diseases including malaria, toxoplasmosis, giardia, African "sleeping sickness," and Chagas disease are caused by protozoa.

**Fungi** - Though some microscopic fungi can infect humans just like bacteria or protozoa, there's one microscopic fungus that most humans like a lot: yeast!

Yeast is the fungus that is responsible for making baked goods rise; and for producing alcoholic beverages such as beer, wine, and liquor.

Yeast feeds on sugars found in foods and converts it into carbon dioxide – and, yes, ethyl alcohol. The carbon dioxide can make our breads and cakes fluffy; and the alcohol can build up to intoxicating levels, if yeasts are bottled with a high concentration of sugar.

**Molds** - Molds are microorganisms that share some properties of fungi, but are not true fungi.

These include pathogenic molds that infect plants and have caused devastating crop failures such as the Great Irish Famine of the 1840s.

They also include the fantastically weird class of slime molds – single-celled organisms that are capable of cooperation so impressive that, during one stage of their life cycle, many slime mold cells gather together and operate like a single organism.

Slime mold intercellular cooperation is so impressive that scientists have been using slime molds to study intelligence and problem-solving!

**Algae** - Microscopic algae were once thought to be plants, but recent studies have shown that algae don’t fit into the plant family. Instead, these single-celled photosynthetic organisms are thought to be relatives of the lineage that led to land plants.

Throughout history, algae have been important photosynthesizers. They likely evolved before land plants did, and helped to pump oxygen into Earth’s atmosphere along with their ancestors, the cyanobacteria.

Today algae can both help and hurt humans – some species clean water and produce oxygen, while others produce dangerous toxins that can end up in our seafood and drinking water.

**Others**
There are many other microscopic organisms that scientists are struggling to neatly classify. Once, many microorganisms were lumped into one category called “protists,” but many scientists now believe this system was only useful for explaining that the organism didn’t fit into any other kingdom.

Organ System

Organs

A single tissue does not usually work alone. The efficiency is greatly increased when two or more tissues function together. An organ may be defined as an association of tissues for performing a special function.

The lung, for example, is an organ for carrying out respiration; it is composed mainly of epithelial and connective tissues. Similarly, the human hand is an organ for manipulating and grasping objects; it consists of all the four kinds of tissues.

Organ Systems:

An isolated organ cannot work satisfactorily. Several organs act together in the metazoan body for effectsing a particular important function. Such a group of organs is known as an organ system. The body of a fish or a frog is comparable to a huge factory with several separate departments.

Each department is entrusted with a special kind of job and the various departments act in co-operation with one another. The organ systems, just mentioned, are the various departments of the animal machinery. Each system performs its own part and the benefit is shared by the others.

Insects & Rodents

Insect, (class Insecta or Hexapoda), any member of the largest class of the phylum Arthropoda, which is itself the largest of the animal phyla. Insects have segmented bodies, jointed legs, and external skeletons (exoskeletons). Insects are distinguished from other arthropods by their body, which is divided into three major regions: (1) the head, which bears the mouthparts, eyes, and a pair of antennae, (2) the three-segmented thorax, which usually has three pairs of legs (hence “Hexapoda") in adults and usually one or two pairs of wings, and (3) the many-segmented abdomen, which contains the digestive, excretory, and reproductive organs.

General Features

In numbers of species and individuals and in adaptability and wide distribution, insects are perhaps the most eminently successful group of all animals. They dominate the present-day land fauna with about 1 million described species. This represents about three-fourths of all described animal species. Entomologists estimate the actual number of living insect species could be as high as 5 million to 10 million. The orders that contain the greatest numbers of species are Coleoptera (beetles), Lepidoptera (butterflies and moths), Hymenoptera (ants, bees, wasps), and Diptera.

Appearance and habits
The majority of insects are small, usually less than 6 mm (0.2 inch) long, although the range in size is wide. Some of the feather-winged beetles and parasitic wasps are almost microscopic, while some tropical forms such as the hercules beetles, African goliath beetles, certain Australian stick insects, and the wingspan of the hercules moth can be as large as 27 cm (10.6 inches).

**Distribution and abundance**

Scientists familiar with insects realize the difficulty in attempting to estimate individual numbers of insects beyond areas of a few acres or a few square miles in extent. Figures soon become so large as to be incomprehensible. The large populations and great variety of insects are related to their small size, high rates of reproduction, and abundance of suitable food supplies. Insects abound in the tropics, both in numbers of different kinds and in numbers of individuals.

**Importance**

**Role in nature**

Insects play many important roles in nature. They aid bacteria, fungi, and other organisms in the decomposition of organic matter and in soil formation. The decay of carrion, for example, brought about mainly by bacteria, is accelerated by the maggots of flesh flies and blowflies. The activities of these larvae, which distribute and consume bacteria, are followed by those of moths and beetles, which break down hair and feathers. Insects and flowers have evolved together. Many plants depend on insects for pollination. Some insects are predators of others.

**Agricultural significance**

**Ecological factors**

Many insects are plant feeders, and, when the plants are of agricultural importance, humans are often forced to compete with these insects. Populations of insects are limited by such factors as unfavourable weather, predators and parasites, and viral, bacterial, and fungal diseases, as well as many other factors that operate to make insect populations stable. Agricultural methods that encourage the planting of ever larger areas to single crops, which provides virtually unlimited food resources, has removed some of these regulating factors and allowed the rate of population growth of insects that attack those crops to increase. This increases the probability of great infestations of certain insect pests. Many natural forests, which form similar giant monocultures, always seem to have been subject to periodic outbreaks of destructive insects.

**Damage to growing crops**

Insects are responsible for two major kinds of damage to growing crops. First is direct injury done to the plant by the feeding insect, which eats leaves or burrows in stems, fruit, or roots. There are hundreds of pest species of this type, both in larvae and adults, among orthopterans, homopterans, heteropterans, coleopterans, lepidopterans, and dipterans. The second type is indirect damage in which the insect itself does little or no harm but transmits a bacterial, viral, or fungal infection into a crop. Examples include the viral diseases of sugar beets and potatoes, carried from plant to plant by aphids.

**What are Rodents?**
This order includes Mice, Rats, Beavers, Guinea Pigs, Capybaras and Squirrels. Rodentia is the single largest group of mammals in the world with around 2016 species recognised from 28 families. Most of the non flying mammals are rodents. They are native to every continent in the world, excluding Antarctica and New Zealand. With this they have adapted to a range of environments ranging from ground-dwelling, arboreal, semi-aquatic and burrowers.

**Rodents are now found in all continents except Antarctica. The main characteristics of rodents are:**

Rodents have a single pair of incisors in each jaw, and the incisors grow continually throughout life. They have no canines and typically only a few molars at the rear of the jaws.

Rodents gnaw with their incisors by pushing the lower jaw forward, and chew with the molars by pulling the lower jaw backwards.

Breeding is both fast and prolific

They adapt quickly to environmental changes

Mostly, they are small animals, hence able to hide from predators. (The Capybara is the largest, weighing up to 100 pounds)

Rodents have large prominent incisors (teeth), which grow continually (both on top and bottom). The enamel on these teeth is very hard, enabling them to gnaw

They have a large gap beside the incisors (instead of canine teeth) allowing them to manoeuvre the incisors

Many have the ability to hibernate in extreme cold or estivate in hot conditions

Some of them, like the Rat-kangaroo and jerbos have developed long hind legs that allow them to jump in a similar way to Kangaroos. This is convergent evolution as these groups are not related taxonomically to Marsupials kangaroos (Family Macropodidae).

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**Chapter – 3(Agriculture)**

**GENERAL AGRICULTURE**

**DEFINITION OF AGRICULTURE**

The term agriculture is derived from the Latin words “ager” or “agri” meaning “soil” and ‘cultra’ meaning ‘cultivation’

Agriculture is a very broad term encompassing all aspects of crop production, Livestock farming, fisheries, forestry etc.

Agriculture may be defined as the art, the science and the business of producing crops and livestock for man’s use and employment.
Agriculture is the cultivation of lands for production of crops for a regular supply of food and other needs for progress of the nation.

Agriculture is influenced by a large number of factors, some of which can be controlled by man (soil and irrigation) which others are beyond the control (climate).

**IMPORTANCE EVENTS OF AGRICULTURE IN INDIA**

1788 First attempt at cotton crop improvement in Bombay province

1827 First agricultural society at Calcutta

1864 First model agricultural farm at Saidapet, Tamil Nadu

1871 Department of Agriculture created

1878 Higher Education in Agriculture at Coimbatore

1880 First Report of Famine Commission (Famine during 1876-77)

1893 Second report of Famine Commission

1901 Third report of Famine Commission

1901 First Irrigation Commission

1902 Introduction of large scale cultivation of groundnut

1903 Imperial Agricultural research Institute at Pusa, Bihar

1904 Introduction of Cambodia cotton

1912 Imperial Sugarcane Breeding Station at Coimbatore

1926 Royal Commission on Agriculture

1929 Imperial (Indian) Council of Agricultural Research at Delhi

1936 IARI shifted to Delhi

1942 Grow More Food Campaign

1946 Central Rice Research Institute

1947 Fertilisers and Chemicals, Travancore

1956 Project for Intensification of Regional Research on Cotton, Oilseeds and Millets (PIRRCOM)

1960 Intensive Agriculture District Programme (IADP)

1963 National Seed Corporation

1965 Intensive Agriculture Area Programme (IIAP)

1965 National Demonstration Programme

1965 All India Coordinated Rice Improvement Project, Hyderabad

1966 HYV Programme
AGRONOMY

The term “Agronomy” is derived from Greek words “Agros” meaning “field” and “nomos” meaning “to manage.”

Agronomy is a branch of agricultural science which deals with principles and practices of soil, water and crop management.

Agronomy deals with methods which provide favourable environment to the crop for higher productivity.

Scope of Agronomy

Agronomy is a dynamic discipline with the advancement of knowledge and better understanding of plant and environment, agricultural practices are modified and new practices developed for high productivity, for example availability of chemical fertilizer has necessitated the generation of knowledge on the method, quantity and time of application of fertilizers. Similarly availability of herbicides for the control of weeds has led to development of knowledge about selectivity, time and method of application of herbicides. To overcome the problems different management practices are developed.
Population pressure is increasing but area under cultivation is static, therefore more number of crops have to be grown on the same piece of land to increase the yield. As a result, intensive cropping has come into practice.

New technology has to be developed to overcome the effect of moisture stress under dryland conditions. As new varieties of crops with high yield potential become available package of practices have to be developed to exploit their full potential.

Restoration of soil fertility, preparation of good seed bed, use of proper seed rates, correct dates of sowing for each improved variety, proper conservation and management of soil moisture and proper control of weeds are agronomic practices to make our limited land and water resources more productive.

CROPPING SYSTEMS – DEFINITION & TYPES

Cropping pattern: - It means the proportion of area under various crops, at a point of time in a unit area. It indicates the yearly sequence and spatial arrangement of crops and fallow in an area. Decrease keeping the field vacant

Cropping System: It is an order in which the crops are cultivated on a piece of land over a fixed period this is cropping system.

Mono-cropping: or Monoculture refers to growing of only one crop on a piece of land year after year.

Ex: Rice – Rice (In Godavari belt) Groundnut every year in Anantapur dist.

Disadvantage in Mono-cropping

• Improper use of moisture and nutrients from the soil
• Control of crop associated pests and weeds become a problem.

Crop rotation: It is a process of growing different crops in succession on a piece of land in a specific period of time with an object to get maximum profit from least investment without impairing soil fertility.

Principles of crop rotation:

1. The crops with tap roots should be fall by those which have a fibrous root system
2. The leguminous crops should be grown after non leguminous crops.
3. More exhaustive crops should be followed by less exhaustive crop.
4. Selection of crops should be demand based.
5. Selection of crops should be problem based.
6. The crops of the same family should not be grown in succession because the act like alternate hast for insects, pests and disease pathogens.
7. An ideal crop rotation is one which provides maximum employment to the family and farm labour, the machines and equipment's are efficiently used then all the agriculture operations are done simultaneously.

Multiple cropping
Growing two or more crops on the same piece of land in one agriculture year is known as ‘Multiple cropping’.

It is the intensification of cropping in time and space dimensions i.e., more number of crops within a year and more number of crops on the same piece of land.

It includes intercropping, mixed cropping and sequence cropping.

**Inter Cropping:**

It is growing two or more crops simultaneously on the same piece of land with a definite row pattern. Ex: Setaria + Redgram in 5:1 ratio

Groundnut + Redgram in 7:1 ratio (a). Additive series

(b). Replacement series

**Mixed Cropping**

It is the process of growing two or more crops together in the same piece of land. This system of cropping is generally practiced in areas where climatic hazards such as flood, drought, frost etc. are frequent and common.

**Sequence cropping**

It can be defined as growing of two or more crops in sequence on same piece of land in a farming year. Depending on number of crops grown in a year. It is called double, triple and quadruple cropping involving two, three and four crops respectively.

**Relay cropping:**

It is analogous to a relay race where crop hands over land to next crop in quick succession. Ex: Maize – Early Potato – Wheat – Mungo

**Overlapping system of cropping:**

In this the succeeding crop is sown in standing proceeding crop thus in this system before harvesting one crop the seeds of next crop are sown. Ex: Maize potato onion bendi in North India.

**Ratoon cropping:** It refers to raising a crop with re growth coming out of roots or stalks after harvest of the crop. Ex: Sugarcane.

**Multi Storeyed System:** Growing of plants of different heights in same field at the same time is termed as multi-storeyed cropping. Ex: Coconut – Piper - banana – Pineapple.

**Difference between intercropping and mixed cropping**

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<th>SNO</th>
<th>INTERCROPPING</th>
<th>MIXED CROPPING</th>
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The main objective is to utilize the space left between two rows of main crop especially during early growth period of main crop.

Main objective is to get at least one crop under any climatic hazards (flood, drought or frost) conditions.

More emphasis is given to the main crop and subsidiary crops are not grown at the cost of main crop thus there is no competition between main and subsidiary crop.

All crops are given equal care and there is no competition between main and subsidiary crop. Almost all the crops compete with one another.

Subsidiary crops are of short duration and they are harvested much earlier than main crop.

The crops are almost of same duration.

Both the crops are sown in rows. The sowing time may be the same or the main crop is sown earlier than subsidiary crop.

Crops may be broad casted and sowing time for all the crops is the same.

DRYLAND FARMING-INTRODUCTION AND DEFINITION AND IMPORTANCE

Dry farming: is cultivation of crops in regions with annual rainfall less than 750 mm. Crop failure is most common due to prolonged dry spells during the crop period. These are arid regions with a growing season (period of adequate soil moisture) less than 75 days. Moisture conservation practices are necessary for crop production.

Dryland farming: is cultivation of crops in regions with annual rainfall more than 750 mm. In spite of prolonged dry spells crop failure is relatively less frequent. These are semi-arid tracts with a growing period between 75 and 120 days. Moisture conservation practices are necessary for crop production. However, adequate drainage is required especially for vertisols or black soils.

Rain fed farming: is crop production in regions with annual rainfall more than 1150 mm. Crops are not subjected to soil moisture stress during the crop period. Emphasis is often on disposal of excess water. These are humid regions with growing period more than 120 days.

United Nations Economic and Social Commission for Asia and the Pacific distinguished dryland agriculture mainly into two categories: dryland and rain fed farming. The distinguishing features of these two types of farming are given below.

FARMING SYSTEMS
Farming system is a complex inter-related matrix of soil, plants, animal implements, power, labour, capital and other inputs controlled in part by farm families and influenced by varying degrees of political, economic, institutional and social forces that operate at many levels. In other words it is defined as unique and reasonably stable arrangement of farm enterprises that the household manages according to its physical, biological, economic and socio-cultural environment in accordance with the household’s goals, preferences and resources. Conceptually it refers to a set of elements or components that are interrelated which interact among themselves. At the centre of the interaction is the farmer exercising control and choice regarding the type and result of interaction.

**Farming systems concept**

In farming system, the farm is viewed in a holistic manner. Farming enterprises include crops, dairying, poultry, fishery, sericulture, and piggery, apiary tree crops etc. a combination of one or more enterprises with cropping when carefully chosen, planned and executed, gives greater dividends than a single enterprise, especially for small and marginal farmers. Farm as a unit is to be considered and planned for effective integration of the enterprises to be combined with crop production activity, such that the end-products and wastes of one enterprise are utilized effectively as inputs in other enterprise. For example the wastes of dairying viz., dung, urine, refuse etc. are used in preparation of FYM or compost which serves as an input in cropping system. Likewise the straw obtained from crops (maize, rice, sorghum etc.) is used as a fodder for dairy cattle.

**Principles of farming system**

- Minimization of risk
- Recycling of wastes and residues
- Integration of two or more enterprises
- Optimum utilization of all resources
- Maximum productivity and profitability
- Ecological balance
- Generation of employment potential
- Increased input use efficiency
- Use of end products from one enterprise as input in other enterprise

**Characteristics of farming system**

- Farmer oriented & holistic approach
- Effective farmers participation
- Unique problem solving system
- Dynamic system
- Gender sensitive
- Responsible to society
- Environmental sustainability
- Location specificity of technology
- Diversified farming enterprises to avoid risks due to environmental constraints
- Provides feedback from farmer
Objectives of farming system

Productivity - Farming system provides an opportunity to increase economic yield per unit area per unit time by virtue of intensification of crop and allied enterprises. Time concept by crop intensification and space concept by building up of vertical dimension through crops and allied enterprises.

Profitability - The system as a whole provides an opportunity to make use of produce/waste material of one enterprise as an input in another enterprise at low/no cost. Thus by reducing the cost of production the profitability and benefit cost ratio works out to be high.

Potentiality - Soil health, a key factor for sustainability is getting deteriorated and polluted due to faulty agricultural management practices viz., excessive use of inorganic fertilizers, pesticides, herbicides, high intensity irrigation etc. In farming system, organic supplementation through effective use of manures and waste recycling is done, thus providing an opportunity to sustain potentiality of Production base for much longer time.

Balanced food - In farming system, diverse enterprises are involved and they produce different sources of nutrition namely proteins, carbohydrates, fats & minerals etc. form the same unit land, which helps in solving the malnutrition problem prevalent among the marginal and sub-marginal farming households.

Environmental safety - The very nature of farming system is to make use or conserve the by product/waste product of one component as input in another component and use of bio-control measures for pest & disease control. These eco-friendly practices bring down the application of huge quantities of fertilizers, pesticides and herbicides, which pollute the soil water and environment to an alarming level. Whereas IFS will greatly reduce environmental pollution.

Meeting fodder crises - In IFS every inch of land area is effectively utilized. Alley cropping or growing fodder legume along the border or water courses, intensification of cropping including fodder legumes in cropping systems helps to produce the required fodder and greatly relieve the problem of non- availability of fodder to livestock component of the Farming system.

ORGANIC FARMING
Organic farming “is a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators, and livestock feed additives. To the maximum extent feasible, organic agriculture systems rely upon crop rotations, crop residues, animal manure, legumes, green manure, off-farm organic wastes, mechanical cultivation, mineral bearing rocks, and aspects of biological pest control to maintain soil productivity, tilt, to supply plant nutrients, and to control insects, weeds, and other pests”. (USDA, 1980).

The concept of the soil as a living system which must be “fed” in a way that does not restrict the activities of beneficial organisms necessary for recycling nutrients and producing humus is central to this definition.

**Principles of organic farming**

1. To produce food of high nutritional quality in sufficient quantity
2. To interact in a constructive and life enhancing way with all natural systems and cycles
3. To encourage and biological cycles with in the farming system, involving micro-organisms, soil flora and fauna, plants and animals and careful mechanical intervention
4. To maintain and increase long-term fertility of soils
5. To promote the healthy use and proper care of water, water resources and all life therein
6. To help in the conservation of soil and water
7. To use, as far as is possible, renewable resources in locally organized agricultural systems
8. To work, as far as possible, within a closed system with regard to organic matter and nutrient elements
9. To work, as far as possible, with materials and substances which can be reused or recycled, either on the farm or elsewhere
10. To give all livestock conditions of life which allow them to perform the basic aspects of their innate behaviour
11. To maintain all forms of pollution that may result from agricultural practices
12. To maintain the genetic diversity of the production system and its surroundings including the protection of wild life habitats
13. To allow everyone involved in organic production and processing a quality of life confirming to the UN Human Rights Charter, to cover their basic needs and obtain an adequate return and satisfaction from their work, including a safe working environment
14. To consider the wider social and ecological impact of the farming system
15. To produce non-food products from renewable resources, which are fully degradable
16. Weed, disease and pest control relaying primarily on crop rotation, natural predators, diversity, organic maturing, resistant varieties, and limited (preferably minimal) thermal, biological and chemical intervention

**Crops Season**
1. The Kharif Season:

Crops are sown at the beginning of south-west monsoon and harvested at the end of the south-west monsoon.

**Sowing Season: May to July.**

Harvesting Season: September to October.

Important Crops: Jowar, Bajra, Rice, Maize, Cotton, Groundnut, Jute, Hemp, Tobacco etc.

2. The Rabi Season:

Crops need cool climate during growth period but warm climate during the germination of seed and maturation.

**Sowing Season: October to December Harvesting Season: February to April**


3. The Zaid Season:

These Crops are raised throughout the year due to artificial irrigation.

1. **Zaid Kharif Crops:**

Sowing Season: August to September Harvesting Season: December-January

Important Crops: Rice, Jowar, Rapeseed, Cotton, Oilseeds.

2. **Zaid Rabi Crops:**


Important Crops: Watermelon, Tori, Cucumber & other vegetables.

**Cereal Crops**

Rice, Wheat and millets are consumed as important staple food all over the world. Cereals provide essential carbohydrates which are important source of energy for working. Cereals are monocotyledonous plants and are grown on large scale by Indian farmers. The economy of huge number of Indian farmers is largely dependent on cereals.

**Pulse Crops**

Pulse crops are legumes. The word legume is derived from the Latin word ‘legere’, with means ‘to gather’. Pulses are important in crop rotations and crop mixtures practiced by farmers, as they help in maintaining the soil fertility. Pulses are rich in protein and they meet the major share of the protein requirements of the predominantly vegetarian population of India.

**Oil seed crops**

Importance of oilseeds crop in Indian farming:

- They can be grown on all kinds of soil.
- Important constituent of the crop rotation with millets and pulses.
Valuable cash crops and bring ready cash to the farmers.

They are a source of foreign exchange.

They provide raw material for many industries e.g. paints, varnishes,

Soaps, lubricating oils etc.

They contribute vegetable oils and fats to Indian diet.

The edible oil cakes provide concentrates for the cattle.

The non-edible oil cakes are used as manures and some oil cakes like

Cash, fiber and spice corps

Sugarcane is the important cash crop grown in India. Sugarcane is cultivated in UP, Bihar, Maharashtra, Karnataka and AP. on large scale. Sugarcane is the most important source of sugar and jaggery. The sugar factories have transformed the total scenario in the sugarcane tracts. Cotton is the most extensively grown commercial crop and the most important of all fibre crops of the world. Likewise turmeric is an important spice crop grown on commercial scale as a source of farm income. It is cultivated in the states of AP, Tamilnadu, Maharashtra, Orissa, Kerala and Assam.

Crop Area Statistics

As the data from a 20 per cent sample is large enough to estimate crop area with a sufficient degree of precision at the all-India, State and district levels, crop area forecasts and final area estimates issued by the Ministry of Agriculture should be based on the results of the 20 per cent Timely Reporting Scheme (TRS) villages in the temporarily settled States and Establishment of an Agency for Reporting Agricultural Statistics (EARAS) scheme villages in the permanently settled states. In the case of the North-Eastern States, Remote Sensing methodology should be used for this purpose after testing its viability.

The patwari and the supervisors above him should be mandated to accord the highest priority to the work of the girdawari and the patwari be spared, if necessary, from other duties during the period of girdawari.

The patwari and the primary staff employed in Establishment of an Agency for Reporting Agricultural Statistics (EARAS) should be imparted systematic and periodic training and the fieldwork should be subjected to intensive supervision by the higher-level revenue officials as well as by the technical staff.
For proper and timely conduct of the girdawari, the concerned supervisory staff should be made accountable.

Timely Reporting Scheme (TRS) and Establishment of an Agency for Reporting Agricultural Statistics (EARAS) scheme should be regarded as programmes of national importance and the Government of India at the highest level should prevail upon the State Governments to give due priority to them, deploy adequate resources for the purpose and ensure proper conduct of field operations in time.

Crop Production

- In view of the importance of reliable estimates of crop production, the States should take all necessary measures to ensure that the crop cutting surveys under the General Crop Estimation Survey (GCES) are carried out strictly according to the prescribed programme.
- Efforts should be made to reduce the diversity of agencies involved in the fieldwork of crop cutting experiments and use as far as possible agricultural and statistical personnel for better control of field operations.
- A statistical study should be carried out to explore the feasibility of using the Improvement of Crop Statistics (ICS) data for working out a correction or adjustment factor to be applied to official statistics of crop area to generate alternative estimates of the same. Given the past experience of the Land Utilisation Surveys of the NSS and the controversies they created, the Commission is of the view that the objective of redesigning of the ICS, at present, should be restricted to working out a correction factor.
- The two series of experiments conducted under the National Agricultural Insurance Scheme (NAIS) and the General Crop Estimation Survey (GCES) should not be combined for deriving estimates of production as the objectives of the two series are different and their merger will affect the quality of general crop estimates.
- Crop estimates below the level of district are required to meet several needs including those of the National Agricultural Insurance Scheme (NAIS). Special studies should be taken up by the National Statistical Office to develop appropriate "small area estimation" techniques for this purpose.

Crop Forecasts

- The Ministry of Agriculture and the National Crop Forecasting Centre (NCFC) should soon put in place an objective method of forecasting the production of crops.
- The National Crop Forecasting Centre (NCFC) should be adequately strengthened with professional statisticians and experts in other related fields.
- The programme of Forecasting Agricultural output using Space, Agro-meteorology and Land based observations (FASAL), which is experimenting the approach of Remote Sensing to estimate the area under principal crops should be actively pursued.
- The States should be assisted by the Centre in adopting the objective techniques to be developed by the National Crop Forecasting Centre (NCFC).

Production of Horticultural Crops

- The methodology adopted in the pilot scheme of "Crop Estimation Survey on Fruits and Vegetables" should be reviewed and an alternative methodology for estimating the production of horticultural crops should be developed taking into account information flowing from all sources including market arrivals, exports and growers associations. Special studies required to establish the feasibility of such a methodology should be taken up by a team comprising representatives from Indian Agricultural Statistics Research Institute (IASRI), Directorate of Economics and Statistics, Ministry of Agriculture (DESMOA), Field Operations Division of National Sample Survey Organisation (NSSO (FOD)) and from one or two major States growing horticultural...
crops. The alternative methodology should be tried out on a pilot basis before actually implementing it on a large scale.

- A suitable methodology for estimating the production of crops such as mushroom, herbs and floriculture needs to be developed and this should be entrusted to the expert team comprising representatives from Indian Agricultural Statistics Research Institute (IASRI), Directorate of Economics and Statistics, Ministry of Agriculture (DESMOA), Field Operations Division of National Sample Survey Organisation (NSSO (FOD)) and from one or two major States growing these crops.

Land Use

- The nine-fold classification of land use should be slightly enlarged to cover two or three more categories such as social forestry, marshy and water logged land, and land under still waters, which are of common interest to the centre and States, and which can easily be identified by the patwari through visual observation.
- State Governments should ensure that computerisation of land records is completed expeditiously.

Irrigation Statistics

- In view of wide variation between the irrigated area generated by the Ministry of Agriculture and the Ministry of Water Resources, the State Governments should make an attempt to explain and reduce the divergence, to the extent possible, through mutual consultation between the two agencies engaged in the data collection at the local level.
- The State Directorates of Economics and Statistics (DESs) should be made the nodal agencies in respect of irrigation statistics and they should establish direct links with the State and Central agencies concerned to secure speedy data flow.
- Statistical monitoring and evaluation cells with trained statistical personnel should be created in the field offices of the Central Water Commission (CWC) in order to generate a variety of statistics relating to water use.
- The Central Statistical Organisation (CSO) should designate a senior level officer to interact with the Central and State irrigation authorities in order to promote an efficient system of water resources statistics and oversee its activities.

Land Holdings and Agricultural Census

- The Agricultural Census should henceforth be on a sample basis and the same should be conducted in a 20 per cent sample of villages.
- There should be an element of household enquiry (besides re-tabulation) in the Agricultural Census in the temporarily settled States.
- Computerisation of land records should be expedited to facilitate the Agricultural Census operations.
- There should be adequate provision for effective administrative supervision over the fieldwork of Agricultural Census and also a technical check on the quality of data with the help of the State statistical agency.
- The post of the Agricultural Census Commissioner of India at the Centre should be restored and should be of the level of Additional Secretary to be able to interact effectively with the State Governments. Further, this post should be earmarked for a senior statistician.
- The Census Monitoring Board should be revived to oversee the Agricultural Census operations.

Agricultural Prices
The Ministry of Agriculture should prepare a well-documented manual of instructions on collection of wholesale prices of agricultural commodities.

- The agricultural price collectors should be given thorough training in the concepts, definitions and the methods of data collection, and the training courses should be repeated periodically.
- Workshops and training courses should be made an integral part of quality improvement. The quality of data should be determined on the basis of systematic analysis of the price data of agricultural commodities both by the Centre and the States.
- Latest tools of communication technology like e-mail should be availed of to ensure timely data flow of agricultural prices.
- A system should be developed to secure a simultaneous data flow of agricultural prices from lower levels to the State as well as the Centre.
- The State agencies at the district level and below should follow up cases of chronic non-response relating to collection of data on agricultural prices.
- The number of essential commodities for which agricultural prices are collected should be reduced to an absolute minimum, especially the non-food crops, in consultation with Ministry of Consumer Affairs and Cabinet Committee on Prices.
- The centres of agricultural price collection should, as far as possible, be the same for the essential commodities as those for wholesale prices.

**Agricultural Market Intelligence**

The functions, activities and the staff requirements of the Agricultural Market Intelligence Units should be re-evaluated and appropriate measures taken to streamline the units.

**Cost of Cultivation of Principal Crops**

- In view of the importance of the Cost of Cultivation Studies in the price administration of agricultural commodities and several studies relating to farm economy, the present programme should continue.
- Focused attention should be paid to the proper organisation and management of the Cost of Cultivation Studies.
- A review of the number of centres, methodology, sample size, the existing schedule and questionnaire, etc. of the Cost of Cultivation Studies should be undertaken.
- The Directorate of Economics and Statistics, Ministry of Agriculture (DESMOA) should minimise the delay in bringing out the results of the Cost of Cultivation Studies.

**Livestock Numbers**

- The quinquennial Livestock Census should henceforth be taken in a 20 per cent sample of villages instead of a cent per cent coverage.
- The Livestock Census should include some minimum information about the household (size, occupation, etc.) in addition to the head count for more meaningful analysis of the census data.
- There should be a concerted effort towards better organisation and management of the Livestock Census operation through comprehensive training of the field staff and regular supervision over their work by both administrative and technical personnel.
- Information Technology tools should be used at various stages of the Livestock Census for rapid processing and preparation of the final reports as well as improving the quality of the data.
Integration of Livestock and Agricultural Censuses

- The Livestock and Agricultural Censuses should be integrated and taken together in a 20 per cent sample of villages.
- Before effecting the integration of Livestock and Agricultural Censuses a limited pilot investigation be undertaken to firm up the procedures of integration.
- The periodical National Sample Survey Organisation’s survey on land and livestock holdings be synchronised with Agricultural and Livestock Censuses in order to supplement as well as help in the crosscheck of information from the two sources.

Livestock Products

- The Integrated Sample Surveys should be continued and efforts should be made to fill up the existing data gaps.
- The Indian Agricultural Statistics Research Institute (IASRI) should be entrusted with the task of developing appropriate methodologies for filling up the remaining data gaps relating to estimates of mutton, pork, poultry meat, and meat by-products.

Fisheries Statistics

- The survey design for estimating production of marine fisheries should be modified taking into account the current distribution of landing sites and the volume of catch at different sites. The field staff engaged in collection of data should be imparted regular training and their work should be adequately supervised.
- The survey methodology for estimating production of inland fisheries especially with regard to running water sources (rivers and canals) should receive urgent attention and the Indian Agricultural Statistics Research Institute (IASRI) along with the Central Inland Fisheries Research Institute (CIFRI) should be provided with adequate support to develop this programme on a priority basis.
- The States should improve the recording of area under still water by appropriate modification of land use statistics.
- The discrepancies between the two sources of data namely, Livestock Census and State reports with regard to data on fishermen, fishing craft and gear should be reconciled by adoption of uniform concepts and definitions and review of these statistics at the district and State levels.

Forestry Statistics

- Remote Sensing techniques should be extensively used to improve and develop forestry statistics.
- The State Forest Departments should be adequately supported by the establishment of appropriate statistical units to oversee the collection and compilation of forestry statistics from diverse sources on forest products including timber and non-timber forest products.
- Arrangements should be made for storage and speedy transmission of forestry data through Information Technology devices.
- In view of the unavoidable nature of the divergence between statistics from the two sources – land records and State Forest Departments – because of different coverage and concepts, the two series should continue to exist; but the reasons for divergence should be clearly indicated to help data users in interpreting the forestry statistics.
- A Statistics Division in the Ministry of Environment and Forests with adequate statistical manpower should be created for rationalisation and development of proper database on forestry statistics.
Marketable Surplus and Post-Harvest Losses

- The existing methodology in conducting the surveys on marketable surplus and post-harvest losses of food grains should continue in future surveys of this type.
- The agencies designated for the collection of information on marketable surplus and post-harvest losses of food grains should be provided additional manpower, wherever necessary, for the conduct of these surveys.

Market Research Surveys

- The Directorate of Marketing and Inspection (DMI) should establish a Statistical Cell either independently or within Market Research and Planning Cell (MRPC) with sufficiently trained statistical personnel to undertake comprehensive analysis of survey data and aid the decision-making process.
- The Statistical Cell of Directorate of Marketing and Inspection (DMI) should identify the problems and deficiencies in the market research surveys carried out by different institutions and develop a standard methodology for uniform adoption.

Index Numbers in Agriculture

- A review of the item basket for the construction of Index Numbers of Area, Production and Yield should be undertaken immediately.
- The item basket for the construction of Index Numbers of Area, Production and Yield should be different for different States.
- The present arrangements for the construction and release of Index of Terms of Trade should continue.

Recording of Area under Mixed Crops

- The rates used to apportion the areas of constituent crops of major crop mixtures should be fixed for the recognised mixtures at sub-district and district levels and updated periodically.
- Data available from surveys conducted under schemes like Improvement of Crop Statistics (ICS) over the years should be used for deciding the crop mixtures and their ratios.

Input Statistics

- The Directorate of Economics and Statistics, Ministry of Agriculture (DESMOA) should collect, compile and maintain a complete database on State-wise production, sale of tractors, power tillers, harvesters and other agricultural implements, density of such implements per hectare, investment made, level of mechanisation, adoption of water saving devices, etc.
- A Farm Management Survey on an all-India basis should be conducted on a regular basis preferably at an interval of five years.
- The Directorate of Plant Protection Quarantine and Storage (PPQ&S) being the apex body for plant protection should act as a depository of information on plant protection. Efforts should be made to design, develop and maintain a comprehensive database on plant protection for effective long-term uses.
- The Statistics and Computer Unit of the Directorate of Plant Protection, Quarantine and Storage (PPQ&S) should be strengthened both in terms of statistical and computer personnel as well as computer equipment.
Information collected through General Crop Estimation Survey (GCES) and the scheme for Improvement of Crop Statistics (ICS) should be compiled to generate estimates on various inputs such as fertilisers, pesticides, multiple cropping, etc.

Plant Protection

What is plant protection and why it is so important?

Ever since humans have relied on planted crops as the main source of food, plant diseases, insects, rodents, weeds and other pest* organisms have been a constant threat to food supply.

*The term 'pest' is used throughout this website to refer to all biotic agents that cause diseases of crops and other valued plants, insects, plant-parasitic nematodes, mites and vertebrates that feed upon them, and weeds that compete with them.

The biblical locust plagues, the potato blight epidemic that killed millions of people in Ireland in the 1850s, and the complex of pests that have attacked rice crops throughout Asia for thousands of years are just some examples of the devastation that pests can cause. More recently, while estimates of potential global losses due to insect and vertebrate pests, diseases and weeds varies from crop to crop, it has been estimated that these pests possibly cause up to 40% of the world’s production of food by reducing crop yield and causing losses in storage [Oerke, E-C (2006). Crop losses to pests. The Journal of Agricultural Science: 144:31–43.]

An integrated approach to plant protection

The mission of the International Association for the Plant Protection Sciences (IAPPS) is to promote and support an integrated, scientific approach to plant protection. Embracing a wide range of research approaches, technologies and practices, IAPPS aims to encourage the development and implementation of plant protection practices that provide farmers with ecologically sustainable and socially acceptable means of preventing and controlling pests, obtaining an economically profitable yield and, at the same time, assuring the resilience and long term viability of crop production and protection systems.

The process of plant protection

A fundamentally important starting point for plant protection is the ability to anticipate the emergence and spread of noxious organisms and to prevent their introduction and spread before they become agricultural pests in specific crops and regions. In this regard, international biosecurity measures and rapid and efficient sharing of information across continents and countries becomes of paramount importance for preventing new invasions.

In dealing with existing problems, the various steps in plant protection are quite similar to those of human medicine.

The first step is to ensure a correct diagnosis of a problem has been made, which involves a proper identification of the organisms responsible for the damage symptoms observed. The legacy of classic taxonomy, anchored on worldwide collections of invertebrates, micro-organisms and plant collections, is the primary resource base for comparing collected specimens with referenced ones. Modern information technology and biotechnological tools have allowed
the development of modern and time-saving field and lab identification tools for known threats which can be detected before they invade new areas.

The second step is to assess the extent of the damage and the yield or revenue loss likely to result from this damage, which enables the grower to make informed decisions on whether to invest resources in combating the pest.

If the farmer decides to take action to reduce pest attack, the third step is to consider the various options available for controlling pests, including host plant resistance, cropping system and cultivation practices that reduce pest populations, the conservation and introduction of antagonistic organisms, such as parasites and predators of pests, and active interventions through the application of chemically- or biologically-based pesticides.

The main disciplines involved in plant protection

As the science of plant protection has developed it has been necessary for an increasing number of disciplines to become involved so that the full dimensions of plant protection problems are appreciated and a range of tools and approaches developed that enable these problems to be resolved in an economic and sustainable way. Scientists from the following disciplines need to be involved:

i) **Biologists** working on pest organisms such as insects, diseases, nematodes and weeds are required for identifying pest species, and understanding their population dynamics and the natural factors that influence their abundance.

ii) **Agronomists** are involved in determining the impact that pest attack has on the yield and quality of crops and the role of plant tolerance and compensation in ameliorating the damage caused by pests.

iii) **Chemists and engineers** are required to develop new pesticides and bio-pesticides and to design pesticide application technologies that effectively deliver the pesticide to the target pest.

iv) **Genetic engineers** are increasingly involved in developing molecular identification techniques and genetically modified crops that have in-built resistance to pest attack.

v) **Information Technology and communication** experts are involved in developing on-line identification aids and providing new communication technologies.

vi) **Social scientists**, including economists and sociologists, investigate the various on-farm and off-farm factors that affect the feasibility and economic outcomes of crop protection strategies, including the information, training and political opportunities and constraints to improved plant protection.

Aims of IAPPS

The prime aim of IAPPS is to promote the application of an integrated approach to research and the application of the plant protection sciences. With an increasing world population and the need for more increased food production, effective and sustainable plant protection practices will have an increasingly important role to play. An integrated approach to plant protection that includes a scientific understanding of pest population dynamics, the role of natural control mechanisms, how various management practices can be combined to achieve better outcomes, etc. provides the best means of achieving effective and resilient plant protection strategies.

**Plant protection in organic farming**

**PRINCIPLES OF ORGANIC AGRICULTURE**
Principle of Health: Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible

Principle of Ecology: Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them

Principle of Fairness: Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities

Principle of Care: Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment

Plant protection

› Conventional

› Integrated

› Organic

Plant protection

Organic: i) Prevent pest, disease and weed problems through optimized cropping system as a whole

ii) No total destruction of pests and pathogens (economic threshold: balanced operation)

iii) Curative agricultural system against pests and diseases

› Resilient, tolerant crop

› Crop variety and rotation

› Appropriate husbandry practices

Integrated

› Combined application of biological, biotechnological, chemical, cultural or plant-breeding measures

› Environmental consideration (useful organisms and interactions)

› Limited chemical plant protection products

› Substitution of harmful chemicals with less harmful "green" chemicals

Conventional

› Avoidance of plant damage by eliminating/killing pests (economic loss)

› Use of different "killing" compounds (-cide, fungicide, bactericide, insecticide, acaricide etc.)

› No agro-technical, biological and other plant protection methods

Plant protection: Conventional
Pest \( \Rightarrow \) damage threshold \( \Rightarrow \) treatment

Economic threshold

Depending on yield and product price

Impact of natural regulatory mechanisms is not relevant for threshold

Reciprocal relation with pest and parasitoids is not relevant

E.g. Use of widely effective insecticide against the larvae of the cabbage moth has negative effects on parasitoids of aphids. As a result, heavy aphid infestation can build up, which makes more insecticide inserts needed (Daniel 2014)

**Plant protection strategies**

**Aim of organic plant protection**

- Remove reasons/encouraging conditions for occurrence of harmful organisms

**Prevention (indirect method)**

- Preventative measures and indirect methods of plant protection
- Based on cultivation methods and selecting cultivars
- Promoting environmentally-friendly farming system

**Protection (direct method)**

- Physical: mechanical and thermic (not selective)
- Biocontrol

**Plant protection strategies in organic farming**
Crop rotation

i) Growing different crops on the same land in a regular recurring sequence
Succeeding crop belongs to a different family than the previous one

ii) Rotating crops is one of the key principles of conservation agriculture

Advantages

i) It improves the soil structure It increases soil fertility

ii) It helps control weeds, pests and diseases

iii) It produces different types of output

iv) It reduces risk
Biopesticides vs Chemical pesticides

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biopesticides</strong></td>
<td>less toxic</td>
<td>slow effect</td>
</tr>
<tr>
<td></td>
<td>generally affect only the target pest</td>
<td>lack persistence and wide spectrum activity</td>
</tr>
<tr>
<td></td>
<td>and closely related organisms effective in very small quantities</td>
<td>rapidly degraded by UV lights</td>
</tr>
<tr>
<td></td>
<td>often decompose quickly</td>
<td>not available easily</td>
</tr>
<tr>
<td></td>
<td>difficult for insects to develop resistance to these pesticides</td>
<td></td>
</tr>
<tr>
<td><strong>Chemical pesticides</strong></td>
<td>high efficacy low cost easy application</td>
<td>broad-spectrum activity and environmental persistence effects on non-target organisms secondary pests pesticide resistance toxicity</td>
</tr>
</tbody>
</table>

Protection: Products for organic agriculture

**Fungicides – mainly chemical and mineral substances**

<table>
<thead>
<tr>
<th>Product Description</th>
<th>Fungicide (up to 6 kg/ha per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper in the form of copper hydroxide, copper oxychloride, (tribasic) copper sulphate, cuprous oxide, copper octanoate</td>
<td></td>
</tr>
<tr>
<td>Lime sulphur (calcium polysulphide)</td>
<td>Fungicide, insecticide, acaricide</td>
</tr>
</tbody>
</table>
### Protection: Products for organic agriculture:

#### Insecticides

*mainly substances of crop or animal origin (plant extracts and oils)*

<table>
<thead>
<tr>
<th>Insecticides</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Azadirachtin extracted from Azadirachta indica</strong> <em>(Neem tree)</em> – <em>(commercial product in Bulgaria - NeemAzal)</em></td>
<td>Insecticide (especially sucking insects – aphids, thrips)</td>
</tr>
<tr>
<td><strong>Gelatine</strong></td>
<td>Insecticide</td>
</tr>
<tr>
<td><strong>Plant oils (e.g. mint oil, pine oil, caraway oil). Rapeseed oil</strong></td>
<td>Insecticide, acaricide, fungicide and sprout inhibitor.</td>
</tr>
<tr>
<td><strong>Natyral pyrethrum (Pyrethrins extracted from Chrysanthemum cinerariaefolium)</strong></td>
<td>Insecticide (its effectiveness is not selective – it also damages populations of useful organisms)</td>
</tr>
<tr>
<td>Substances produced by microorganisms</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td><strong>Spinosad</strong>&lt;br&gt;(commercial product on this base in Bulgaria: Syneis, Laser)</td>
<td>Insecticide (based on a compound found in the bacterial species Saccharopolyspora spinosa (S. spinosa))&lt;br&gt;Only where measures are taken to minimize the risk to key parasitoids and to minimize the risk of development of Resistance</td>
</tr>
<tr>
<td><strong>Microbial preparations (Biocontrol)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Bacillus thuringiensis</strong>&lt;br&gt;(commercial products in Bulgaria: Dipel, Foray etc.)</td>
<td>Bacteria attacking caterpillars of butterflies.</td>
</tr>
<tr>
<td><strong>Virus products</strong>&lt;br&gt;(commercial products in Bulgaria: Madex granulovirus (CpGV) as the active ingredient)</td>
<td>Codling and Fruit Moths</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other substances</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty acid potassium salt (soft soap)</td>
<td>Insecticide</td>
</tr>
<tr>
<td>Lime sulphur (calcium polysulphide)</td>
<td>Fungicide, insecticide, acaricide</td>
</tr>
</tbody>
</table>
### Agricultural Economics

#### Introduction

India's agricultural sector, which contributed 16 percent of the country's GDP in 2017, supports the livelihoods of 43.9 percent of the population. Employment in this sector has decreased by 10 percentage points within a decade, from 53.1 percent in 2008 to 43.9 percent in 2018. The sector is facing manifold problems such as crop failures, non-remunerative prices for crops, and poor returns on yield. Agrarian distress is so severe, that it is pushing many farmers to despair; about 39 percent of the cases of farmer suicides in 2015 were attributed to bankruptcy and indebtedness.

#### Agriculture in Indian Economy

- Indian is an agriculture based country, where more than 50% of population is depend on agriculture. This structures the main source of income. The commitment of agribusiness in the national income in India is all
the more, subsequently, it is said that agriculture in India is a backbone for Indian Economy. The contribution of agriculture in the initial two decades towards the total national output is between 48% and 60%. In the year 2001-2002, this contribution declined to just around 26%. The aggregate Share of Agriculture and Allied Sectors, Including agribusiness, domesticated animals, and ranger service and fishery sub segments as far as rate of GDP is 13.9 percent during 2013-14 at 2004-05 prices. Agricultural exports constitute a fifth of the total exports of the country. In perspective of the overwhelming position of the Agricultural Sector, gathering and support of Agricultural Statistics expect incredible significance.

- According to the fourth Advance Estimates of Production of food grains for 2013-14, aggregate food grain production is assessed to be 264.77 million tons (MT).

- Export of spices from India are relied upon to reach US$ 3 billion by 2016-17, on the back of imaginative promoting strategies, inventive bundling, quality in quality and an in number appropriation system. The Indian flavors business is pegged at Rs 40,000 crore (US$ 6.42 billion) every year, of which the marked portion represents 15%.

- The National Food Security Mission (NFSM) was launched from Rabi, 2007-08. The fundamental targets of the National Food Security Mission (NFSM) is to expand production of rice, wheat, pulses and coarse cereals through region extension and efficiency upgrade in a supportable way in the recognized locale of the nation; restoring soil ripeness and profitability at the individual ranch level; and improving farm level economy (i.e. ranch benefits) to restore confidence amongst the farmers. The Mission met with a staggering achievement and accomplished the focused on extra generation of rice, wheat and heartbeats. The Mission is being kept amid Twelfth Five Year Plan with new focuses of extra generation of sustenance grains of 25 million tons including 10 million tons of rice, 8 million tons of wheat, 4 million tons of pulses and 3 million tons of coarse cereals by the end of twelfth five year plan.

- Training is an important procedure of capacity building of people as to enhance the execution. Consequently, training needs appraisal is imperative to the training process. It serves to recognize present issues and future difficulties to be met through training and improvement. It is obliged to figure out the needs of individual trainee on which proficient skills ought to be assembled to do the relegated occupation in the associations.

- The 6% of agricultural production is converted in to processed food, which is focused to achieve 20% in coming future. The business is work escalated and contributes around 50% for industrial production. Multi-National Food Companies have assumed a part of making business sector draw and rivalry. Selection of inventive and experimental bundling strategies by food industry has empowered the assembling of sheltered and quality sustenance.

**Conclusion**

Most of the Indians are directly or indirectly depending on the agriculture. Some are directly attached with the farming and some other people are involved in doing business with these goods. India has the capacity to produce the food grains which can make vast difference in Indian Economy. To achieve targeted mark by the government it needs to provide support in case of land, bank loans and other machineries to the small farmers along with the big farmers with this we can expect some improvement in Indian economy.

**Agricultural Economics Research Association (India)- AERA (India)**
The Agricultural Economics Research Association (India), a registered society, came into being in 1987, and on date has around 957 life members, 110 ordinary members, 122 institutional members and 33 honorary life members from India and abroad. Through it journal Agricultural Economics Research Review the Association contributes towards improving quality of research in agricultural economics and rural development. To encourage young professional, the journal also publishes abstracts of the Master's and Doctoral dissertations in agricultural economics. Besides, the Association regularly organizes annual conference on the issues of contemporary importance and undertakes sponsored research in agricultural economics and rural development. The Association is now widely recognized for its professional contributions and credibility. Its journal Agricultural Economics Research Review is highly rated by the National Academy of Agricultural Science, New Delhi.

**Indicative Outlines of Subjects Selected for Discussion at the 79th Annual Conference of the Indian Society of Agricultural Economics**

The 79th Annual Conference of the Indian Society of Agricultural Economics will be held sometime in November/December 2019.

**The following subjects are selected for discussion:**

1. Coping with Risks and Climate Change through Conservation of Natural Resources with Particular Reference to Agriculture: Appropriate Technologies and Practices
2. Doubling Farmer's Income from Demand Perspective

Research Papers on the above themes are invited from members and other paperwriters for discussion at the Conference. The scope of each of the three themes is spelt out in the enclosed Indicative Outlines below. The Indicative Outlines are also available on the Society’s website [www.isaeindia.org](http://www.isaeindia.org). The soft copy of the paper (not exceeding 3500 words or 10 pages), with its Summary not exceeding 250 words need to be submitted. The last date for the receipt of the papers at the Society’s office is June 30, 2019.

**Importance of Agriculture in Indian Economy**

During Independence there was extremely low productivity per hectare and per worker.

However, the previous trend of stagnant agriculture was completely changed due to the introduction of economic planning since 1950-51, and with special emphasis on agricultural development, particularly after 1962.

(i) A steady increase in the area under cultivation is noticed.

(ii) A substantial growth in the food crops is marked.

(iii) During the plan period there had been a constant increase in the yield per hectare.

**Importance of Agriculture in Indian Economy:**

Though industry has been playing an important role in Indian economy, still the contribution of agriculture in the development of Indian economy cannot be denied.
1. **Agricultural influence on national income:** The contribution of agriculture during the first two decades towards the gross domestic product ranged between 48 and 60%. In the year 2001-2002, this contribution declined to only about 26%.

2. **Agriculture plays vital role in generating employment:** In India at least two-thirds of the working population earn their living through agricultural works. In India other sectors have failed generate much of employment opportunity the growing working populations.

3. **Agriculture makes provision for food for the ever increasing population:** Due to the excessive pressure of population labour surplus economies like India and rapid increase in the demand for food, food production increases at a fast rate. The existing levels of food consumption in these countries are very low and with a little increase in the capita income, the demand for food rise steeply (in other words it can be stated that the income elasticity of demand for food is very high in developing countries).

Therefore, unless agriculture is able to continuously increase it marketed surplus of food grains, a crisis is like to emerge. Many developing countries are passing through this phase and in a bid to ma the increasing food requirements agriculture has been developed.

4. **Contribution to capital formation:** There is general agreement on the necessity capital formation. Since agriculture happens be the largest industry in developing country like India, it can and must play an important role in pushing up the rate of capital formation. If it fails to do so, the whole process economic development will suffer a setback.

To extract surplus from agriculture the following policies are taken:

(i) Transfer of labour and capital from farm non-farm activities.

(ii) Taxation of agriculture should be in such a way that the burden on agriculture is greater than the government services provided to agriculture. Therefore, generation of surplus from agriculture will ultimately depend on increasing the agricultural productivity considerably.

5. **Supply of raw material to agro-based industries:** Agriculture supplies raw materials to various agro-based industries like sugar, jute, cotton textile and vanaspati industries. Food processing industries are similarly dependent on agriculture. Therefore the development of these industries entirely is dependent on agriculture.

6. **Market for industrial products:** Increase in rural purchasing power is very necessary for industrial development as two-thirds of Indian population live in villages. After green revolution the purchasing power of the large farmers increased due to their enhanced income and negligible tax burden.

7. **Influence on internal and external trade and commerce:** Indian agriculture plays a vital role in internal and external trade of the country. Internal trade in food-grains and other agricultural products helps in the expansion of service sector.

8. **Contribution in government budget:** Right from the First Five Year Plan agriculture is considered as the prime revenue collecting sector for the both central and state budgets. However, the governments earn huge revenue from agriculture and its allied activities like cattle rearing, animal husbandry, poultry farming, fishing etc. Indian railway along with the state transport system also earn a handsome revenue as freight charges for agricultural products, both-semi finished and finished ones.
Agriculture remains the primary sector of the Indian economy. While it accounts for merely 16 percent of the country’s GDP, approximately 43.9 percent of the population depends on it for their livelihood. In recent years, indebtedness, crop failures, non-remunerative prices and poor returns have led to agrarian distress in many parts of the country. The government has come up with various mechanisms to address these issues: insurance, direct transfers and loan waivers, among them. However, these mechanisms are ad hoc, poorly implemented and hobbled by political dissension. In February 2016 the government launched the crop insurance scheme, Pradhan Mantri Fasal Bima Yojana (PMFBY) to reverse the risk-averse nature of farmers. While the PMFBY has improved upon its predecessors, it faces structural, logistical and financial obstacles. This paper makes an assessment of the performance of the PMFBY in terms of adaptability and the achievement of the objective of “one nation, one scheme.”

The Rationale for Crop Insurance

Indian agriculture has been progressively acquiring a ‘small farm’ character. The total number of operational holdings in the country increased from 138 million in 2010–11 to 146 million in 2015–16, i.e. an increase of 5.33 percent. Small and marginal farmers with less than two hectares of land account for 86.2 percent of all farmers in India but own only 47.3 percent of the crop area. Semi-medium and medium landholding farmers who own two to 10 hectares of land, account for 13.2 percent but own 43.6 percent of the crop area, which supports the claim that the average landholding size has declined from 1.15 hectares in 2010–11 to 1.08 hectares in 2015–16. To be sure, a small landholding is not automatically a deterrent to productive farming. In China, for example, despite a small average land size of 0.6 hectare, farmers have achieved higher productivity due to efficient practices involving mechanisation and R&D, in turn leading to increased surpluses. In India, such small average holdings do not allow for surpluses that can financially sustain families. India’s primary failure has been its inability to capitalise on technology and efficient agricultural practices, which can ensure surpluses despite small landholdings.

Pradhan Mantri Fasal Bima Yojana (PMFBY): An Overview

The PMFBY has made several improvements compared to its predecessors, the National Agricultural Insurance Scheme and the Modified National Agricultural Insurance Scheme. One of the highlights of the PMFBY is the absence of any upper limit on government subsidy, even if the balance premium is 90 percent. The scheme was implemented in February 2016 and was allocated an initial central-government budget of INR 5,500 crore for 2016–17. It has increased by 154 percent, as announced in the Interim Budget of 2019. This massive increase in the outlay for the scheme shows that it is important for the government to insure all farmers and guarantee financial support and flow of credit to them in the event of crop-yield loss.

Features of the PMFBY

Coverage of Farmers: The scheme covers loanee farmers (those who have taken a loan), non-loanee farmers (on a voluntary basis), tenant farmers, and sharecroppers.

Coverage of Crops: Every state has notified crops (major crops) for the Rabi and Kharif seasons. The premium rates differ across seasons.

Premium Rates: The PMFBY fixes a uniform premium of two percent of the sum insured, to be paid by farmers for all Kharif crops, 1.5 percent of the sum insured for all Rabi crops, and five percent of sum insured for annual commercial and horticultural crops or actuarial rate, whichever is less, with no limit on government premium subsidy.
**Area-based Insurance Unit:** The PMFBY operates on an area approach. Thus, all farmers in a particular area must pay the same premium and have the same claim payments. The area approach reduces the risk of moral hazard and adverse selection.

**Coverage of Risks:** It aims to prevent sowing/planting risks, loss to standing crop, post-harvest losses and localised calamities. The sum insured is equal to the cost of cultivation per hectare, multiplied by the area of the notified crop proposed by the farmer for insurance.

**Innovative Technology Use:** It recommends the use of technology in agriculture. For example, using drones to reduce the use of crop cutting experiments (CCEs), which are traditionally used to estimate crop loss; and using mobile phones to reduce delays in claim settlements by uploading crop-cutting data on apps/online.

**Cluster Approach for Insurance Companies:** It encourages L1 bidding amongst insurance companies before being allocated to a district to ensure fair competition. A functional insurance office will be established at the local level for grievance redressal, in addition to a crop insurance portal for all online administration processes.

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### Comparison of crop insurance schemes in India

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<tbody>
<tr>
<td>Premium rate</td>
<td>Low</td>
<td>High (9–15%)</td>
<td>Low (Govt. to contribute five times that of farmer)</td>
</tr>
<tr>
<td>One season-one premium</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Insurance amount covered</td>
<td>Full</td>
<td>Capped</td>
<td>Full</td>
</tr>
<tr>
<td>On account payment</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Localised risk coverage</td>
<td>No</td>
<td>Hailstorm, landslide</td>
<td>Hailstorm, landslide, inundation</td>
</tr>
<tr>
<td>Post-harvest losses coverage</td>
<td>No</td>
<td>Coastal areas</td>
<td>All India</td>
</tr>
<tr>
<td>Prevented sowing coverage</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Use of technology</td>
<td>No</td>
<td>Intended</td>
<td>Mandatory</td>
</tr>
<tr>
<td>Awareness</td>
<td>No</td>
<td>No</td>
<td>Yes (target to double coverage to 50%)</td>
</tr>
<tr>
<td>Insurance companies</td>
<td>Only government</td>
<td>Govt and private companies</td>
<td>Govt and private companies</td>
</tr>
</tbody>
</table>

### Percentage change in indicators for Kharif season under PMFBY

<table>
<thead>
<tr>
<th></th>
<th>Kharif 2016</th>
<th>Kharif 2017</th>
<th>Percentage Change</th>
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<tr>
<td>Farmers insured</td>
<td>40,258,737</td>
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<td>Claims paid (crore)</td>
<td>10,496.3</td>
<td>17,209.9</td>
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<tr>
<td>States/UTs</td>
<td>2016-2017</td>
<td>2017-2018</td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------</td>
<td>-----------</td>
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<tr>
<td></td>
<td>Loanee</td>
<td>Non Loanee</td>
<td>Total</td>
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<td>Andaman and Nicobar Islands</td>
<td>324</td>
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<td>Andhra Pradesh</td>
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<td>5,09,37</td>
<td>6,99,327</td>
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<tr>
<td>Mizoram</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>Odisha</td>
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<td>326,16</td>
<td>1,82,826</td>
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<td>Puducherry</td>
<td>44</td>
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<td>85,37</td>
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<td>Rajasthan</td>
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<td>Sikkim</td>
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<tr>
<td>Tamil Nadu</td>
<td>3,26,98</td>
<td>1,12,343</td>
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<td>Telangana</td>
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<td>Tripura</td>
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<tr>
<td>Uttarakhand</td>
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<td>2,65,571</td>
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<td>India</td>
<td>43,69,666</td>
<td>1,13,80,98</td>
<td>57,48,7764</td>
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</tbody>
</table>

Source: Lak Sabha Unstarred Question No. 2915. dated on 13.03.2018.
Crop Forecasts

Current Status

1) Final estimates of crop production based on area through complete enumeration and yield rate through crop-cutter experiments become available much after the crop is harvested. However, the Government needs advance estimates of production for various decisions relating to pricing, distribution, export and import, etc. The Directorate of Economics & Statistics, Ministry of Agriculture (DESMOA) releases advance estimates of crop area and production through periodical forecasts in respect of principal food and non-food crops (food grains, oil seeds, sugarcane, fibres, etc.), which account for nearly 87 per cent of agricultural output. Four forecasts are issued, the first in the middle of September, the second in January, the third towards the end of March and the fourth by the end of May.

2) The first forecast relating to the kharif crops is mostly based on reports prepared by the States mainly guided by the visual observation of field officials. The second forecast covering both the kharif and rabi crops takes into account additional information obtained from various sources including agricultural inputs, incidence of pests and diseases, and weekly reports of State departments of agriculture regarding area coverage, conditions of standing crops, etc. Results of Remote Sensing data are also considered at this stage. In the third forecast, the earlier advance estimates of both the kharif and rabi seasons are firmed up, again taking into account information received from sources such as Market Intelligence Units, Meteorological Department and the Crop Weather Watch Group (CWWG). The fourth forecast is based on firm figures supplied by State Agricultural Statistics Authorities (SASAs) who are by then in a position to obtain fairly dependable estimates of yield rates through GCES. In addition to the four forecasts, the DESMOA issues the “Final Estimates” of crop area and production in December. As a few States continue to revise their data on delayed receipt of information, the all-India crop statistics are brought out as “Fully Revised” in the next crop year in the following December.

3) Recently, the Ministry of Agriculture has set up a National Crop Forecasting Centre (NCFC) with the object of examining the existing mechanism of building forecasts of principal crops and developing more objective techniques. The NCFC takes into account information on weather conditions, supply of agricultural inputs, pests, diseases and related aspects including the proceedings of CWWG in the formulation of scientific and objective forecasting methods to replace the present system. The work of the NCFC is still at a preliminary stage and it needs more statistical support to be able to develop appropriate models of forecasting.

Deficiencies

4) The present system of crop forecasts being based mostly on subjective appraisal at various levels does not reflect the ground situation correctly. This is specially the case with regard to the preliminary forecasts, which have to be fairly reliable for taking several policy decisions. There is need for more objective forecasting based on timely and detailed information on crop condition, meteorological parameters, water availability, crop damage, etc. The NCFC is still not in a position to develop a scientific procedure of forecasting using multi-dimensional models and assimilating

<table>
<thead>
<tr>
<th>Facebook Page</th>
<th>Facebook Group</th>
<th>Telegram Group</th>
<th>Telegram Channel</th>
</tr>
</thead>
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<td>Rabi 2016-17</td>
<td>1,296</td>
<td>6,027</td>
<td>5,681</td>
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<tr>
<td>Kharif 2017</td>
<td>3,039</td>
<td>19,768</td>
<td>17,210</td>
</tr>
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</table>
the information received from various sources. The DESMOA is handicapped due to non-receipt of timely information from the States and it often has to prepare such forecasts based on incomplete data.

5) Frequent changes in the production figures especially of food grains between one forecast and another, and the “final” and “fully revised” estimates cause confusion and doubt among the users. While releasing these figures, the DESMOA may indicate the reasons for the change.

Conclusions and Recommendations

6) The system of forecasting crop production in the country by the Ministry of Agriculture needs to be replaced as soon as possible by an objective method using appropriate statistical techniques. The recent establishment of the NCFC, which has been assigned the responsibility of streamlining and improving the quality of forecasting, should go a long way in accomplishing this objective. However, it needs additional professional support, comprising statisticians and multi-disciplinary team of experts to devise scientific techniques of crop forecasting.

7) Remote Sensing technology can also provide a satisfactory means of developing reliable estimates of crop area and condition of the crop at various stages of growth for forecast purposes. The Space Application Centre (SAC) is already at an advanced stage of experimenting with the approach of Remote Sensing to estimate the area under principal crops through the scheme known as “Forecasting Agricultural output using Space, Agro-meteorology and Land based observations” (FASAL). Incidentally, this will form an important input in the forecasting methodology to be developed by NCFC. The land-based observations should be used to measure quantitative changes in crop growth besides discriminating one crop from another.

8) The Commission, therefore, recommends that:

The Ministry of Agriculture and the National Crop Forecasting Centre (NCFC) should soon put in place an objective method of forecasting the production of crops.

The National Crop Forecasting Centre (NCFC) should be adequately strengthened with professional statisticians and experts in other related fields.

The programme of Forecasting Agricultural output using Space, Agro-meteorology and Land based observations (FASAL), which is experimenting the approach of Remote Sensing to estimate the area under principal crops should be actively pursued.

The States should be assisted by the Centre in adopting the objective techniques to be developed by the National Crop Forecasting Centre (NCFC).

Elementary entomology

Perhaps you imagine an entomologist as someone who likes exotic pets like tarantulas and scorpions. And, yes, some entomologists do study those creatures! But even if you don’t like tarantulas or scorpions, insects are way more important to life than you might imagine. Entomologists study bugs in a wide variety of contexts, and you can bet that many of them affect the world we live in.

Some entomologists work hard to study things that improve our health and safety. Some are interested in the food we eat. Some are interested in making sure we are comfortable at home and some are interested in the environment.
And, yes, some entomologists keep scorpions, tarantulas, and other exotic pets as a hobby. Let’s take a look at some important entomologists and what they do.

**Types of Entomologists**

**Med-vet, or medical/veterinary entomologists**, are interested in how insects affect human and animal health. A veterinary entomologist might, for example, study flies that bother cows and pigs. One inspiring story of creativity in veterinary entomology is the 'sterile insect technique', which successfully rid the US of screwworm flies by 1982. Screwworm flies are flies whose larvae (maggots) feed on wound tissue. They can kill a whole cow in a week or two, and they used to be a huge problem in the US. Edward Knipling, Raymond Bushland, and their team released thousands on thousands of sterile male screwworm flies, making it difficult for female screwworm flies to find a mate. Over time, the population crashed. Depending on where you live, if you’ve never seen a screwworm-infested wound, you may have Knipling and Bushland to thank.

**Agricultural entomologists** are interested in how to keep bugs from eating our crops. Agricultural entomologists cover a very broad ground. Geneticists may study the genes in bugs that make them pesticide resistant, or behaviorists may study ways to confuse bugs into avoiding laying eggs on crops. A shining example of clever agricultural entomology is the apple maggot trap. Apple maggot flies look for big, round, red things (like apples) to lay their eggs on. Some clever entomologist discovered that if you hang a trap that's bigger, redder, and rounder than the most beautiful apple, apple maggots go crazy! They will lay their eggs on the trap, and the apples will be protected.

**Entomologists** who are ecologists are interested in the interactions between insects, organisms and their environment. You can imagine that many agricultural entomologists are ecologists as well. But not all ecologists deal with pest insects. Some ecologists get to deal with charismatic, fun insects like butterflies. Some monarch butterflies, for example, migrate more than 2,500 miles to overwinter in a small region in Mexico. Ecologists are learning more about how they migrate and how they overwinter, so that we can better protect the beautiful monarch.

**Urban entomologists** deal with insects that infest our homes and businesses, like termites, cockroaches, and bedbugs. These insects may not be appealing to the average person, but their evolution, behavior, and relationships to humans make them endlessly fascinating to entomologists.

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