UNIT 3

Crop Production

TARGETS AND ACHIEVEMENTS IN FOODGRAIN PRODUCTION IN INDIA SINCE INDEPENDENCE

Since India gained independence in 1947, there has been a significant growth in foodgrain production. India's foodgrain production has increased from 50.8 million tonnes in 1950-51 to 296.65 million tonnes in 2019-20. In the early years after independence, the government focused on increasing the production of foodgrains, particularly wheat and rice, through the introduction of high-yielding varieties (HYVs), better irrigation facilities, and increased fertilizer usage. The Green Revolution in the 1960s and 70s played a crucial role in increasing food production, particularly in wheat and rice.

The following are some of the key targets and achievements in foodgrain production in India:

- The first Green Revolution in the 1960s and 70s helped increase the production of wheat and rice in India. As a result, the country became self-sufficient in food production and even started exporting foodgrains.
- The government launched the National Food Security Mission (NFSM) in 2007 with the aim of increasing foodgrain production by 10 million tonnes annually. The mission focused on rice, wheat, and pulses and provided farmers with improved seeds, fertilizers, and other inputs.
- The government launched the Pradhan Mantri Fasal Bima Yojana (PMFBY) in 2016 to provide insurance coverage to farmers against crop loss due to natural calamities, pests, and diseases. This scheme helped in stabilizing the income of farmers and increasing foodgrain production.
- The government introduced the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) in 2015 to promote irrigation facilities and improve water-use efficiency. The scheme aimed to provide water to every farm and improve the productivity of crops.
- The government launched the Soil Health Card Scheme in 2015 to assess the nutrient status of soil and provide recommendations for appropriate fertilizer use. This scheme helped in improving soil health and increasing crop yields.

SUSTAINABLE CROP PRODUCTION

Sustainable crop production is the practice of producing food in a way that preserves the environment, conserves natural resources, and ensures the long-term viability of agriculture. Sustainable crop production focuses on improving soil health, conserving water, reducing the use of pesticides and fertilizers, and minimizing greenhouse gas emissions.

The following are some of the practices that promote sustainable crop production:

- Crop rotation: The practice of growing different crops in a specific sequence on the same land is known as crop rotation. It helps in improving soil health, reducing pests and diseases, and improving crop yields.
- Integrated Pest Management (IPM): IPM is an approach that combines different pest management strategies to minimize the use of pesticides. This approach includes the use of natural enemies of pests, crop rotation, and the use of resistant varieties.
- Conservation agriculture: Conservation agriculture is a farming system that involves minimal soil disturbance, crop residue retention, and crop rotation. This practice helps in improving soil health, conserving water, and reducing greenhouse gas emissions.
- Organic farming: Organic farming is a farming system that relies on natural inputs such as compost, crop rotation, and natural pest control methods. It helps in improving soil health, reducing the use of synthetic inputs, and producing healthier food.

COMMERCIALIZATION OF AGRICULTURE AND ITS SCOPE IN INDIA

Commercialization of agriculture refers to the shift from subsistence farming to a more commercial approach to farming. In this approach, farmers focus on producing crops and livestock for sale in the market rather than just for their own consumption. Commercialization of agriculture has the potential to increase farmers' income, improve rural livelihoods, and promote economic growth.

The following are some of the factors that have contributed to the commercialization of agriculture and its scope in India:

1. Government Policies: The government has implemented policies and schemes to promote commercialization of agriculture, such as setting up of agricultural marketing infrastructure, price support systems, and credit facilities for farmers. These policies have encouraged farmers to invest in modern inputs and technology, leading to higher yields and better quality crops.
2. Technological Advancements: The development of high-yielding crop varieties, mechanization, precision farming, and adoption of modern irrigation techniques have increased productivity and efficiency in agriculture. This has led to the production of surplus crops, which can be sold in the market.
3. Access to Finance: Access to finance has been made easier for farmers, enabling them to invest in agriculture on a commercial scale. Banks, financial institutions, and government schemes provide credit and loans for farmers to invest in agriculture.
4. Market Integration: Integration of agricultural markets across the country through the introduction of electronic trading platforms and the removal of inter-state trade barriers has led to better price discovery and market access for farmers. This has also enabled them to participate in national and global value chains.
5. Private Sector Participation: Private sector participation in agriculture has increased, leading to the growth of contract farming, supply chain management, and value addition. This has provided farmers with access to better inputs, technology, and markets, leading to higher profits.

The commercialization of agriculture in India has immense scope, and it is important to sustain it through appropriate policies and investments. Commercialization can lead to increased productivity, better quality produce, and higher incomes for farmers, thus contributing to the overall growth of the agricultural sector and the economy.

CLASSIFICATION OF FIELD CROPS BASED ON THEIR UTILITY-CEREALS, PULSES, OILS SEEDS, FIBRE, SUGAR AND FORAGE CROPS

Classification of field crops based on their utility is an important aspect of agriculture. Here are some important details about each category:

Cereals: Cereals are one of the major categories of field crops and are primarily grown for their edible grains, which are rich in carbohydrates and provide a major source of energy to humans and livestock. Here are some important details about cereals:

- Rice: Rice is a staple food crop in India and is grown in almost all parts of the country. It is a major source of carbohydrates and provides a significant amount of protein as well. India is one of the largest producers of rice in the world.
- Wheat: Wheat is another important cereal crop grown in India, primarily in the northern and northwestern parts of the country. It is a rich source of protein and carbohydrates and is used to make a variety of food products, such as bread, pasta, and baked goods.
- Maize: Maize, also known as corn, is a widely grown cereal crop in India and is used for both human consumption and animal feed. It is a rich source of carbohydrates and provides a significant amount of protein as well.
- Sorghum: Sorghum is a hardy cereal crop that can be grown in dry and arid regions. It is primarily used as animal feed but can also be used for human consumption, such as in the production of sorghum flour.
- Millets: Millets are a group of small-seeded cereal crops that are grown in various parts of India. They are hardy and can be grown in dry and arid regions. Millets are a rich source of carbohydrates and provide a significant amount of protein as well.

Cereals are an important category of field crops in India and provide a major source of energy to humans and livestock. The various cereal crops grown in India have different characteristics and are suited to different agro-climatic conditions.

Pulses: Pulses are leguminous crops. They are an important category of field crops that are grown primarily for their seeds. They are rich in protein, fiber, and other essential nutrients and are an important source of nutrition for humans and livestock. Some of the important pulse crops grown in India include chickpea, pigeon pea, lentil, and mung bean. Here are some important details about pulses:

- Types of pulses: Pulses can be broadly classified into three types based on their size - large-seeded pulses (e.g. chickpea and kidney bean), medium-seeded pulses (e.g. pigeon pea and lentil), and small-seeded pulses (e.g. mung bean and urad bean).
- Nutritional value: Pulses are rich in protein, fiber, and other essential nutrients such as iron, potassium, and magnesium. They are also low in fat and cholesterol and are a good source of complex carbohydrates.
- Soil requirements: Pulses are adapted to a wide range of soil types but prefer well-drained soils that are rich in organic matter. They also have the ability to fix atmospheric nitrogen through symbiotic association with nitrogen-fixing bacteria.
- Climate requirements: Pulses require a warm and humid climate for optimal growth and yield. They are typically grown in the post-monsoon season or winter season in India.
- Cultivation practices: Pulses are generally sown in rows using seed drills or broadcasting methods. They require regular weeding and pest control measures, and irrigation may be necessary during dry spells.
- Yield and production: The average yield of pulses in India is around 800-900 kg per hectare. India is one of the largest producers of pulses in the world, accounting for around 25% of the global production.

Oilseeds: Oilseeds are a category of field crops that are grown primarily for the production of edible oils. India is one of the largest producers and consumers of edible oils in the world, and therefore, oilseeds are an important crop in the country's agricultural sector. Here are some important details about oilseeds:

- Some of the major oilseed crops grown in India include groundnut, sesame, mustard, soybean, and sunflower.
- The oil content in oilseeds varies widely, with some crops like sesame having a high oil content of around 50%, while others like soybean having a lower oil content of around 20%.
- Edible oils derived from oilseeds are used for cooking, as well as in the manufacture of various food products, such as margarine, mayonnaise, and salad dressings.
- Oilseeds are also used in the production of non-food products, such as soap, cosmetics, and biofuels.
- In addition to their use in the food and non-food industries, oilseeds are also important in crop rotation systems, as they help to improve soil fertility and reduce pest and disease pressure.
- However, the production of oilseeds in India has been hampered by a number of challenges, including low yields, poor quality seeds, and limited access to credit and market information.
- To address these challenges, the Indian government has implemented a number of initiatives, such as providing subsidies for inputs like fertilizers and seeds, as well as promoting contract farming and public-private partnerships in the sector.

Fibre crops: Fibre crops are those plants that are grown for their fibrous tissues, which are used in the production of textiles, paper, and other materials. Some of the important fibre crops grown in India include cotton, jute, hemp, and flax.

- Cotton: Cotton is one of the most important fibre crops grown in India and is primarily used for the production of textiles. It is grown in almost all parts of the country, with the major cotton-growing states being Gujarat, Maharashtra, and Andhra Pradesh. The fibre of the cotton plant is used in the production of a variety of textiles, including clothing, bed sheets, and towels.
- Jute: Jute is another important fibre crop grown in India and is primarily used in the production of jute bags, ropes, and carpets. It is grown mainly in the eastern states of West Bengal, Bihar, and Assam. Jute is known for its strong and durable fibres, which make it ideal for use in heavy-duty applications.
- Hemp: Hemp is a versatile fibre crop that can be used in the production of a variety of products, including clothing, paper, and building materials. It is grown in several states in India, including Uttarakhand, Uttar Pradesh, and Madhya Pradesh. Hemp fibres are known for their strength and durability, making them ideal for use in products that require high tensile strength.
- Flax: Flax is a fibre crop that is primarily grown for the production of linen, which is used in the production of clothing and household textiles. It is grown in several states in India, including Punjab, Haryana, and Uttar Pradesh. Flax fibres are known for their smooth texture and high absorbency, making them ideal for use in products that require good moisture management.

Fibre crops play an important role in the Indian economy and are used in the production of a variety of products. Cotton, jute, hemp, and flax are some of the important fibre crops grown in India, and each of these crops has its own unique characteristics and uses.

Sugar crops: Sugar crops are those crops that are primarily grown for their sweet sap or juice, which is then processed into sugar. Some important details about sugar crops include:

- Sugarcane: Sugarcane is the most important sugar crop grown in India. It is a tall perennial grass that can grow up to 5-6 meters in height. The stem of the sugarcane plant is rich in sucrose, which is the main component of table sugar. Sugarcane is mainly grown in the states of Maharashtra, Uttar Pradesh, and Karnataka.
- Sugar beet: Sugar beet is another important sugar crop, which is primarily grown in the temperate regions of the world. The roots of the sugar beet plant are rich in sucrose, which is extracted and processed into sugar. In India, sugar beet is not a major crop, and its cultivation is limited to a few experimental farms.
- Palmyra palm: Palmyra palm is a tropical palm tree that is primarily grown for its sweet sap, which is used to make jaggery and other traditional sweeteners. Palmyra palm is mainly grown in the southern states of India, such as Tamil Nadu and Kerala.
- Date palm: Date palm is another important sugar crop, which is primarily grown in the arid regions of the world. The fruits of the date palm are rich in sucrose, which is extracted and processed into sugar. In India, date palm is mainly grown in the desert regions of Rajasthan.

Overall, sugar crops play an important role in the economy of India, as they provide a major source of income to farmers and support the sugar industry, which is one of the largest agro-based industries in the country.

Forage crops: Forage crops are crops grown to feed livestock, mainly cattle, sheep, and goats. These crops are important for providing high-quality feed to animals and ensuring their productivity. Here are some important details about forage crops:

- Types of forage crops: Forage crops can be classified into two categories - annual and perennial. Annual forage crops are grown for one season and include crops such as maize, sorghum, and oats. Perennial forage crops, on the other hand, can be grown for several years and include crops such as alfalfa, clover, and grasses like Bermuda grass and Rhodes grass.
- Importance of forage crops: Forage crops are an essential part of livestock farming, as they provide the necessary nutrients required for animal growth and productivity. These crops are also important for soil conservation, as they help prevent soil erosion, improve soil fertility, and reduce soil compaction.
- Characteristics of forage crops: Forage crops are typically high in protein, fiber, and other nutrients required for animal growth and production. They are also adapted to a wide range of soil and climatic conditions, making them suitable for cultivation in many regions.
- Cultivation of forage crops: The cultivation of forage crops involves selecting the right crop for the specific soil and climate conditions, preparing the soil, sowing the seeds, and providing adequate irrigation and fertilizer. Proper management practices such as weed control and pest management are also crucial for successful cultivation of forage crops.
- Examples of forage crops in India: Some of the important forage crops grown in India include alfalfa, sorghum, maize, oats, and legumes such as cowpea and pigeon pea.

Forage crops play a vital role in livestock farming and soil conservation. The cultivation of these crops requires proper selection, preparation, and management practices to ensure their success and provide high-quality feed to livestock.

Each of these categories of crops has its own unique characteristics, cultivation practices, and economic significance. The classification of crops based on their utility helps in better understanding their importance and in developing appropriate strategies for their cultivation and marketing.

SOIL, SOIL FERTILITY, FERTILIZERS AND MANURES

SOIL

Soil is a complex and ever-changing natural body that develops as a result of various processes, including weathering of rocks, and the activities of plants and other organisms. In simple terms, soil is the uppermost layer of the earth's crust that is loose and rich in nutrients and minerals, which support the growth of plants.

According to Joffe (1949), soil is a natural body consisting of both organic and inorganic materials that are differentiated into layers or horizons, each with distinct physical, chemical, and biological characteristics. These horizons differ from the underlying material in terms of their composition, morphology, and physical makeup.

Overall, soil is a dynamic and essential resource that supports a wide range of ecosystem services, including food production, water filtration, carbon sequestration, and biodiversity. Understanding soil and managing it in a sustainable way is crucial for ensuring its continued health and ability to support life on Earth.

SOIL pH

Soil pH is a measure of the concentration of hydrogen ions (H^+) in the soil and determines whether it is acidic or alkaline.

An acidic soil has a higher concentration of H^+ ions, while an alkaline soil has more hydroxyl (OH^-) ions. A neutral pH occurs when the concentrations of H^+ and OH^- ions are equal.

Slightly acidic soils with a pH ranging from 6.5 to 7 are generally considered best for plant growth as they provide the maximum availability of nutrients. Soil pH can be measured using a pH meter, pH paper method, or pH scale, which ranges from 0 to 14. A pH of 7 is neutral, while lower values indicate higher H^+ ion concentration and more acidic soil. Higher values indicate an alkaline reaction with more OH^- ions.

The effects of soil pH on plant growth are significant, including:

- An optimum soil pH of 6.5 to 7.5 provides maximum availability of nutrients for plant growth.
- Low pH levels (<6.0) can lead to an increase in aluminum content in the soil, which may become toxic to plants.
- Acidic soils generally have higher levels of toxic metals that can negatively impact soil microorganisms' activity, affecting plant growth.

Monitoring and managing soil pH is essential for ensuring optimal plant growth and productivity. Regular soil testing and appropriate corrective actions, such as liming or acidifying, can help maintain a healthy soil pH and maximize plant nutrient uptake.

SOIL TEXTURE

Soil texture refers to the physical composition of soil particles, which includes sand, silt, and clay. Understanding soil texture is important because it affects various soil properties such as water-holding capacity, nutrient availability, and soil structure, which in turn affects plant growth and productivity.

Sand particles are the largest and are generally between 0.05 and 2.0 mm in diameter. They are relatively coarse and feel gritty to the touch. Sandy soils have large pore spaces between particles, which allow for good drainage but can also lead to rapid leaching of nutrients. Because sandy soils do not hold water well, they are often low in fertility and require frequent irrigation and fertilization.

Silt particles are smaller than sand particles and range in size from 0.002 to 0.05 mm in diameter. Silt feels smooth to the touch, and soils with high silt content tend to be more fertile than sandy soils. Silt particles have intermediate pore space, which allows for good water and air movement through the soil. Soils with high silt content are often well-structured and can be easily tilled.

Clay particles are the smallest, with diameters of less than 0.002 mm. They are very fine and feel sticky and smooth to the touch. Clay soils have very small pore spaces between particles, which can cause poor drainage and waterlogging. However, they have a high capacity to hold water and nutrients, making them highly fertile. Clay soils are often prone to compaction, which can reduce plant growth and yield.

Soil texture is determined by the relative proportion of sand, silt, and clay particles in the soil. The proportion of each particle type determines the soil's texture class. The USDA soil texture triangle is a widely used tool that helps to determine soil texture based on the proportion of sand, silt, and clay in a soil sample.

In addition to sand, silt, and clay, organic matter also plays an important role in soil texture. Organic matter can help to improve soil structure and water-holding capacity, as well as provide nutrients for plant growth.

SOIL STRUCTURE

Soil structure refers to the arrangement of soil particles into aggregates, which can vary in size, shape, and stability. Soil structure is an important characteristic because it affects various soil properties, such as water infiltration, soil aeration, nutrient availability, and plant root development.

Soil aggregates can be classified into different types based on their size, shape, and stability. These include:

1. Macroaggregates: These are larger aggregates that range in size from 0.25 to 10 mm in diameter. Macroaggregates are stable and are held together by organic matter, roots, and fungal hyphae. They provide large pore spaces that allow for good water infiltration and soil aeration.
2. Microaggregates: These are smaller aggregates that range in size from 0.002 to 0.25 mm in diameter. Microaggregates are less stable than macroaggregates and are held together by clay particles and organic matter. They provide small pore spaces that can hold onto water and nutrients.
3. Single particles: These are individual soil particles that are not aggregated. Single particles can be sand, silt, or clay, and they determine soil texture.

Soil structure can be improved through various management practices, including:

1. Organic matter addition: Organic matter can act as a cementing agent, holding soil particles together and forming stable aggregates. Adding organic matter to soil can improve soil structure, increase water-holding capacity, and promote nutrient availability.
2. Reduced tillage: Excessive tillage can break down soil aggregates, leading to soil compaction and reduced soil structure. Reduced tillage practices, such as no-till or minimum tillage, can help to maintain soil structure and promote soil health.

3. Crop rotation: Growing a diverse range of crops can improve soil structure by promoting different types of root systems and organic matter inputs. Crop rotation can also help to reduce soil-borne diseases and pest pressure.
4. Cover crops: Growing cover crops can help to protect soil from erosion, improve soil structure, and add organic matter to the soil.

Soil structure is an essential factor in the health and productivity of soils. Farmers and soil scientists need to understand the different types of soil structure and their impacts to manage soil properly. Maintaining healthy soil structure ensures that soil can support plant growth, filter water, and store carbon.

SOIL ORGANISMS

Soil organisms are living organisms that inhibit the soil and play important roles in soil fertility, nutrient cycling, and plant growth. These organisms include microorganisms, such as bacteria, fungi, and protozoa, as well as larger organisms, such as earthworms, nematodes, and arthropods.

Microorganisms are the most numerous and diverse group of soil organisms. They are involved in various processes in the soil, such as decomposition of organic matter, nutrient cycling, and plant-microbe interactions. Bacteria and fungi are the most abundant and play crucial roles in these processes. Bacteria are important in the cycling of nutrients, such as nitrogen and phosphorus, while fungi are important in the decomposition of complex organic matter, such as lignin.

Protozoa are single-celled organisms that play important roles in nutrient cycling and plant-microbe interactions. They are predators of bacteria and other microorganisms, and their grazing can affect microbial populations and nutrient availability in the soil.

Larger soil organisms, such as earthworms, nematodes, and arthropods, also play important roles in soil health. Earthworms help to improve soil structure and nutrient cycling by burrowing through the soil and creating channels for water and air movement. Nematodes are important in the decomposition of organic matter and nutrient cycling, while some species are also plant pathogens. Arthropods, such as insects and mites, can be both beneficial and harmful to soil health, depending on the species and their interactions with other soil organisms.

Soil organisms can be affected by various environmental factors, such as temperature, moisture, and pH. Changes in these factors can affect the abundance and diversity of soil organisms, which in turn can affect soil health and plant growth. For example, high temperatures can reduce microbial activity and nutrient cycling, while low moisture levels can limit the growth of soil organisms.

Soil management practices can also affect soil organisms. Practices such as tillage, fertilization, and pesticide use can have both positive and negative effects on soil organisms. For example, tillage can disrupt soil structure and reduce microbial activity, while organic matter addition can promote microbial growth and nutrient cycling.

Soil organisms play important roles in soil health and plant growth. Understanding the diversity and functions of soil organisms can help farmers and gardeners make informed decisions about soil management practices that promote soil health and sustainable agriculture.

SOIL TILTH

Soil tilth refers to the physical condition of soil, particularly its ability to support plant growth. It is determined by various factors, such as soil structure, soil texture, soil organic matter content, and soil moisture.

Good soil tilth is important for plant growth because it affects various soil properties, such as water infiltration, soil aeration, nutrient availability, and root development. Soil with good tilth has a crumbly, well-aggregated structure that allows for good water infiltration and soil aeration, while also providing enough pore space to hold onto water and nutrients. Good soil tilth also promotes the growth of beneficial soil organisms, such as bacteria, fungi, and earthworms, which help to maintain soil fertility and nutrient cycling.

Factors that can affect soil tilth include:

1. Soil texture: Soil texture refers to the relative proportions of sand, silt, and clay in soil. Soil with a balanced texture, such as loam, tends to have good tilth because it provides a good balance of pore space and water-holding capacity.
2. Soil organic matter: Soil organic matter is an important component of soil that helps to maintain good tilth. Organic matter acts as a cementing agent, holding soil particles together and forming stable soil aggregates. It also provides a source of nutrients for plants and beneficial soil organisms.
3. Soil compaction: Soil compaction can reduce soil tilth by reducing pore space and limiting water infiltration and soil aeration. Compaction can be caused by heavy machinery, foot traffic, or other factors that compress soil particles.
4. Soil erosion: Soil erosion can also reduce soil tilth by removing topsoil and exposing subsoil, which may have a different texture or structure. Erosion can be caused by water, wind, or other factors that remove soil particles.

Improving soil tilth can be achieved through various management practices, including:

1. Organic matter addition: Adding organic matter to soil can help to improve soil structure and promote good tilth. Organic matter can be added through practices such as cover cropping, composting, and manure application.
2. Reduced tillage: Reduced tillage practices, such as no-till or minimum tillage, can help to maintain good soil structure and reduce soil compaction, which in turn promotes good tilth.
3. Crop rotation: Crop rotation can help to maintain soil fertility and promote good tilth by promoting diverse root systems and adding organic matter to the soil.
4. Mulching: Mulching can help to improve soil tilth by protecting soil from erosion, maintaining soil moisture, and adding organic matter to the soil.

Soil tilth is an important characteristic of healthy soil that affects various soil properties that are important for plant growth and productivity. Improving soil tilth through management practices such as organic matter addition, reduced tillage, crop rotation, and mulching can help to maintain soil health and promote sustainable agriculture.

SOIL FERTILITY

Soil fertility refers to the ability of soil to support plant growth and productivity. It is influenced by various factors, such as soil structure, soil texture, soil organic matter content, soil nutrients, and soil pH.

Soil nutrients are essential for plant growth, and their availability is a critical factor in determining soil fertility. There are 17 essential plant nutrients, including macronutrients such as nitrogen, phosphorus, and potassium, and micronutrients such as iron, zinc, and manganese. Plants absorb these nutrients from the soil through their roots, and deficiencies or imbalances of these nutrients can limit plant growth and productivity.

Soil organic matter is also an important factor in soil fertility. Organic matter is composed of decomposing plant and animal material and can influence soil fertility through its effect on soil structure, water-holding capacity, nutrient availability, and soil microorganisms. Organic matter can also provide a source of nutrients for plants as it decomposes.

Soil pH is another important factor in soil fertility. Soil pH is a measure of the acidity or alkalinity of the soil and can affect plant nutrient availability. Most plants grow best in slightly acidic soil with a pH range between 6.0 and 7.5.

Soil management practices can also affect soil fertility. Practices such as tillage, fertilization, irrigation, and crop rotation can all affect soil fertility. Overuse of fertilizers can lead to nutrient imbalances and environmental problems, while underuse of fertilizers can lead to nutrient deficiencies and reduced plant growth. Irrigation can affect soil fertility by affecting soil moisture levels and nutrient availability. Crop rotation can help to maintain soil fertility by promoting diverse root systems and adding organic matter to the soil.

In addition to these factors, soil fertility can also be influenced by external factors, such as climate and weather patterns, topography, and land use.

SOIL HEALTH

Soil health is a term used to describe the overall quality and function of soil as a living ecosystem. It refers to the ability of soil to support plant growth, maintain environmental quality, and provide other benefits such as biodiversity, carbon sequestration, and water filtration. Soil health is influenced by a complex interplay of physical, chemical, and biological factors, and is an important consideration for sustainable agriculture and environmental management.

Physical factors that affect soil health include soil structure, texture, and water-holding capacity. Soil structure refers to the arrangement of soil particles into aggregates, which can affect water infiltration, root penetration, and nutrient availability. Soil texture refers to the relative proportions of sand, silt, and clay particles in the soil, which can affect soil water-holding capacity, nutrient retention, and aeration. Water-holding capacity is another important factor in soil health, as it affects plant growth and can impact soil erosion and runoff.

Chemical factors that affect soil health include soil pH, nutrient availability, and the presence of contaminants. Soil pH is a measure of the acidity or alkalinity of the soil, and can impact the availability of plant nutrients and the activity of soil microorganisms. Nutrient availability is influenced by factors such as soil organic matter content, nutrient cycling, and the use of fertilizers and other amendments. The presence of contaminants such as heavy metals or pesticides can also impact soil health and environmental quality.

Biological factors that affect soil health include microbial activity, plant roots, and the presence of soil fauna such as earthworms and insects. Microbial activity is a key component of soil health, as it supports nutrient cycling, improves soil structure, and can protect plants from diseases and pests. Plant roots play a role in nutrient uptake and can improve soil structure through their growth and decay. Soil fauna such as earthworms and insects can also contribute to nutrient cycling and soil structure.

Improving soil health involves a range of management practices that aim to support soil structure, nutrient cycling, and microbial activity. Practices such as cover cropping, reduced tillage, composting, and crop rotation can help to increase soil organic matter content, reduce soil compaction, and support beneficial soil microorganisms. Integrated pest management and the use of natural fertilizers such as compost can also help to maintain soil health and reduce the use of synthetic chemicals.

Assessing soil health involves monitoring key indicators such as soil structure, texture, organic matter content, pH, nutrient availability, microbial activity, and water-holding capacity. Soil tests can be used to measure these indicators and guide soil management decisions. Regular soil testing and monitoring can help farmers and gardeners maintain healthy soil ecosystems that support sustainable agriculture and other ecosystem services.

ESSENTIAL PLANT NUTRIENTS, THEIR FUNCTIONS AND DEFICIENCY SYMPTOMS

Arnon and Stout (1939) established criteria for determining the essentiality of elements in plant growth, and based on these criteria, a total of 17 elements have been identified as essential for higher green plants. These essential plant nutrients can be classified into two groups based on the relative amounts required by plants: macronutrients and micronutrients.

Macronutrients are required by plants in large amounts, and include carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). These nutrients are required for the synthesis of organic compounds such as carbohydrates, proteins, and nucleic acids, which are essential for plant growth and development.

Micronutrients, also known as trace elements, are required by plants in smaller amounts, and include iron (Fe), chlorine (Cl), manganese (Mn), boron (B), zinc (Zn), copper (Cu), nickel (Ni), and molybdenum (Mo). These nutrients are essential components of enzymes and co-factors involved in various metabolic processes.

Deficiency of any of these essential plant nutrients can lead to stunted growth, reduced yield, and ultimately death of the plant. Deficiency symptoms vary depending on the nutrient, but common symptoms include yellowing of leaves (chlorosis), necrosis, and abnormal growth patterns.

Some examples of the functions of essential plant nutrients and their associated deficiency symptoms include:

- Nitrogen (N): Required for the synthesis of proteins and nucleic acids. Deficiency symptoms include yellowing of leaves and stunted growth.
- Phosphorus (P): Required for energy transfer, nucleic acid synthesis, and root development. Deficiency symptoms include stunted growth and purplish leaves.
- Potassium (K): Required for water balance, enzyme activation, and protein synthesis. Deficiency symptoms include yellowing and scorching of leaf margins.
- Calcium (Ca): Required for cell wall development, enzyme activation, and ion balance. Deficiency symptoms include leaf necrosis and deformation.
- Iron (Fe): Required for chlorophyll synthesis and electron transfer in photosynthesis. Deficiency symptoms include chlorosis of young leaves.

In addition to these essential plant nutrients, there are other elements that may have beneficial effects on plant growth, but are not considered essential. These elements are referred to as beneficial elements or plant growth-promoting elements, and include silicon (Si), sodium (Na), cobalt (Co), and selenium (Se), among others.

Classification of Plant Nutrients based on Quantity

Classification of plant nutrients based on quantity is a common way to categorize different types of nutrients essential for plant growth and development. The following are the various categories of plant nutrients based on quantity:

1. Framework Nutrients/Structural Nutrients: These are plant nutrients that participate in structural development and are essential for the formation of plant tissues. Examples of framework nutrients include carbon, oxygen, and hydrogen.
2. Macro Nutrient: Macro nutrients are essential plant nutrients that are required in relatively large amounts. They must be present in plant tissue in concentrations greater than 1 mg per gram of dry weight. Macro nutrients can be further divided into two categories:
   (i) Primary Nutrients: The three primary nutrients are nitrogen (N), phosphorus (P), and potassium (K). These nutrients are required in large quantities by plants and are crucial for successful crop growth.
   (ii) Secondary Nutrients: The secondary nutrients include calcium (Ca), magnesium (Mg), and sulfur (S). They are required in smaller quantities than primary nutrients but are still important for plant growth and development.
3. Micro Nutrients/Trace Nutrients: These are plant nutrients that are present in plant tissue in concentrations of ≤ 1 mg/gram. They are also known as trace elements or micronutrients. Examples of micro nutrients include iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), boron (B), and chlorine (Cl).
4. Ultra-Micro Nutrients: These are plant nutrients that are present in plant tissue in concentrations of < 1 ppb. They are also known as ultra-trace elements or ultra-micronutrients. Examples of ultra-micronutrients include molybdenum (Mo) and cobalt (Co).

5. Beneficial Plant Nutrients: These are plant nutrients that are not required by all plants but can promote plant growth and development. They may be essential for several plant species. Examples of beneficial plant nutrients include sodium (Na), vanadium (V), silicon (Si), and cobalt (Co).
6. Quasi-Essential Elements: Quasi-essential elements are plant nutrients that are not considered essential in the traditional sense. However, their deficiency can cause various abnormalities with respect to plant growth and development. Silicon (Si) is considered a quasi-essential element for plants. Its deficiency can affect the structural integrity of plants, especially those with high silica demands such as grasses.

Classification on the basis of Mobility of Nutrient in the Soil

Plant nutrients can also be classified based on their mobility within the plant. This classification is important because it helps to understand how nutrients are transported and distributed within different parts of the plant.

1. Highly mobile nutrients: These nutrients are easily translocated within the plant and can move from older to younger tissues. Examples of highly mobile nutrients include nitrogen (N), phosphorus (P), and potassium (K). Deficiencies of these nutrients typically show up first in older leaves.
2. Moderately mobile nutrients: These nutrients can be translocated within the plant, but the rate of movement is slower than highly mobile nutrients. Zinc (Zn) is an example of a moderately mobile nutrient. Deficiencies of these nutrients usually show up first in the middle leaves.
3. Less mobile nutrients: These nutrients are not easily translocated within the plant and do not move from older to younger tissues. Examples of less mobile nutrients include sulfur (S), iron (Fe), manganese (Mn), chlorine (Cl), molybdenum (Mo), and copper (Cu). Deficiencies of these nutrients typically show up first in the younger leaves.
4. Immobile nutrients: These nutrients remain fixed in one location and cannot be translocated within the plant. Calcium (Ca) and boron (B) are examples of immobile nutrients. Deficiencies of these nutrients show up first in the growing points of the plant.

Understanding the mobility of nutrients within the plant is important for identifying and addressing nutrient deficiencies. Foliar application of nutrients is often used for less mobile nutrients since they cannot be easily translocated within the plant. In contrast, highly mobile nutrients can be addressed by applying fertilizers to the soil.

Nutrient Deficiency Symptoms in Plants

Nutrient deficiency symptoms in plants can be observed in different parts of the plant. Here are the common deficiency symptoms and the parts of the plant where they can be observed:

Old Leaves:

- Nitrogen (N) deficiency: Yellowing of lower leaves, starting from tips and spreading to the base of the leaves.
- Phosphorus (P) deficiency: Purple or reddish color on the underside of leaves, reduced growth and smaller leaves.
- Potassium (K) deficiency: Yellowing of the edges and between veins of leaves, curling of leaves and necrosis.
- Magnesium (Mg) deficiency: Yellowing of older leaves starting from the edges and spreading towards the base of the leaves, have a reddish-brown color on the edges.

New Leaves:

- Iron (Fe) deficiency: Yellowing between veins of new leaves, leaves turn pale and the veins remain green.
- Copper (Cu) deficiency: Leaves become twisted and wilted, reddish-brown spots appear on leaves.
- Chlorine (Cl) deficiency: Yellowing of leaves, chlorosis in veins, necrosis of leaves.
- Sulfur (S) deficiency: Leaves turn yellow and small, reduced growth.

Old and New Leaves:

- Zinc (Zn) deficiency: Chlorosis between veins of new leaves, reduced growth and smaller leaves, leaves may have brown spots.

Apical Bud:

- Calcium (Ca) deficiency: Young leaves and growing points become twisted and distorted, dead tips and buds.
- Boron (B) deficiency: Bud dieback, stem and root tips die, growth slows down.

Essential plant nutrients

There are many essential plant nutrients that are required for optimal growth and development of plants. These nutrients can be grouped into two categories based on their availability to plants - macronutrients and micronutrients.

Macronutrients

- Nitrogen (N): Nitrogen is an essential component of amino acids, nucleic acids, and chlorophyll. It is required for the development of plant leaves, stems, and roots. Nitrogen is also involved in many important plant processes, including photosynthesis, respiration, and the uptake of other nutrients.
- Phosphorus (P): Phosphorus is essential for energy transfer within the plant, as well as for the formation of DNA and cell membranes. It is particularly important for root growth and flower and seed formation. Phosphorus also plays a role in the regulation of many plant processes, including photosynthesis, respiration, and the uptake of other nutrients.
- Potassium (K): Potassium is involved in the regulation of water movement in plant cells and is essential for the proper functioning of enzymes. It is also important for overall plant growth and development, as well as for the regulation of many plant processes such as photosynthesis, respiration, and the uptake of other nutrients.
- Calcium (Ca): Calcium is essential for the formation of cell walls and for the regulation of cell division and growth. It is also involved in the movement of other nutrients within the plant, and plays a role in the regulation of plant processes such as photosynthesis, respiration, and the uptake of other nutrients.
- Magnesium (Mg): Magnesium is a central component of chlorophyll and is therefore essential for photosynthesis. It is also involved in the activation of many enzymes and plays a role in the regulation of plant processes such as photosynthesis, respiration, and the uptake of other nutrients.
- Sulfur (S): Sulfur is a component of many important plant compounds, including amino acids, proteins, and vitamins. It is also involved in the production of chlorophyll and plays a role in the regulation of plant processes such as photosynthesis, respiration, and the uptake of other nutrients.

Micronutrients

- Boron (B): Boron is involved in the formation of cell walls and in the regulation of many important plant processes, including the uptake of other nutrients. It also plays a role in the production of nucleic acids and in the regulation of hormone levels in plants.
- Copper (Cu): Copper is involved in the formation of lignin, which is a component of cell walls. It is also important for the production of enzymes that are involved in photosynthesis and respiration. Copper also plays a role in the regulation of plant processes such as the uptake of other nutrients.
- Iron (Fe): Iron is essential for the formation of chlorophyll and is involved in many other plant processes, including respiration and photosynthesis. It is also important for the regulation of plant processes such as the uptake of other nutrients.
- Manganese (Mn): Manganese is involved in the formation of chloroplasts and in the production of enzymes that are important for photosynthesis. It also plays a role in the regulation of plant processes such as the uptake of other nutrients.
- Zinc (Zn): Zinc is involved in the production of auxins, which are plant hormones that regulate growth and development. It is also involved in the formation of chlorophyll and in the regulation of carbohydrate metabolism. Zinc also plays a role in the regulation of plant processes such as the uptake of other nutrients.
- Molybdenum (Mo): Molybdenum is involved in the production of enzymes that are important for nitrogen fixation and for the conversion of inorganic phosphorus to organic forms.
- Chlorine (Cl): Chlorine is involved in the regulation of water movement within plant cells and plays a role in photosynthesis by helping to maintain the balance of positive and negative charges within the plant. Chlorine deficiency can lead to wilting, stunted growth, and leaf damage.
- Cobalt (Co): Cobalt is involved in the production of vitamin B12, which is important for many plant processes, including the formation of nucleic acids.
- Nickel (Ni): Nickel is involved in the production of enzymes that are important for nitrogen metabolism.
- Vanadium (V): Vanadium is involved in the regulation of many plant processes, including the uptake and transport of other nutrients.
- Sodium (Na): Sodium is involved in the regulation of water movement within plant cells and plays a role in the maintenance of cell turgor.
- Silicon (Si): Silicon is involved in the formation of cell walls, and it can also help to increase plant resistance to pests and diseases.

All of these essential plant nutrients play crucial roles in the growth, development, and survival of plants. Deficiencies in any one of these nutrients can lead to a range of problems, including stunted growth, poor flowering or fruiting, and susceptibility to pests and diseases. It is important for farmers and gardeners to ensure that their plants are receiving the right balance of essential nutrients to support their growth and development.

SOIL TYPES OF INDIA AND THEIR CHARACTERISTICS

Classification of Soils

India has varied relief features, landforms, climatic realms and vegetation types. These have contributed in the development of various types of soils in India. In ancient times, soils used to be classified into two main groups – Urvara and Usara, which were fertile and sterile, respectively. In the 16th centrury A.D., soils were classified on the basis of their inherent characteristics and external features such as texture, colour, slope of land and moisture content in the soil. Based on texture, main soil types were identified as sandy, clayey, silty and loam, etc. On the basis of colour, they were red, yellow, black, etc. Since Independence, scientific surveys of soils have been conducted by various agencies. Soil Survey of India, established in 1956, made comprehensive studies of soils in selected areas like in the Damodar Valley.

The National Bureau of Soil Survey and the Land Use Planning an Institute under the control of the Indian Council of Agricultural Research (ICAR) did a lot of studies on Indian soils. In their effort to study soil and to make it comparable at the international level, the ICAR has classified the Indian soils on the basis of their nature and character as per the United States Department of Agriculture (USDA) Soil Taxonomy.

On the basis of genesis, colour, composition and location, the soils of India have been classified into:

(i) Alluvial soils
(ii) Black soils
(iii) Red and Yellow soils
(iv) Laterite soils
(v) Arid soils
(vi) Saline soils
(vii) Peaty soils
(viii) Forest soils

Alluvial Soils

Alluvial soils are widespread in the northern plains and the river valleys. These soils cover about 40 per cent of the total area of the country. They are depositional soils, transported and deposited by rivers and streams. Through a narrow corridor in Rajasthan, they extend into the plains of Gujarat. In the Peninsular region, they are found in deltas of the east coast and in the river valleys. The alluvial soils vary in nature from sandy loam to clay. They are generally rich in potash but poor in phosphorous. In the Upper and Middle Ganga plain, two different types of alluvial soils have developed, viz. Khadar and Bhangar.

Khadar is the new alluvium and is deposited by floods annually, which enriches the soil by depositing fine silts. Bhangar represents a system of older alluvium, deposited away from the flood plains. Both the Khadar and Bhangar soils contain calcareous concretions (Kankars). These soils are more loamy and clayey in the lower and middle Ganga plain and the Brahamaputra valley. The sand content decreases from the west to east. The colour of the alluvial soils varies from the light grey to ash grey. Its shades depend on the depth of the deposition, the texture of the materials, and the time taken for attaining maturity. Alluvial soils are intensively cultivated.

Black Soil

Black soil covers most of the Deccan Plateau which includes parts of Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh and some parts of Tamil Nadu. In the upper reaches of the Godavari and the Krishna, and the northwestern part of the Deccan Plateau, the black soil is very deep. These soils are also known as the 'Regur Soil' or the 'Black Cotton Soil'.

The black soils are generally clayey, deep and impermeable. They swell and become sticky when wet and shrink when dried. So, during the dry season, these soil develop wide cracks. Thus, there occurs a kind of 'self ploughing'. Because of this character of slow absorption and loss of moisture, the black soil retains the moisture for a very long time, which helps the crops, especially, the rain fed ones, to sustain even during the dry season. Chemically, the black soils are rich in lime, iron, magnesia and alumina. They also contain potash. But they lack in phosphorous, nitrogen and organic matter. The colour of the soil ranges from deep black to grey.

Red and Yellow Soil

Red soil develops on crystalline igneous rocks in areas of low rainfall in the eastern and southern part of the Deccan Plateau. Along the piedmont zone of the Western Ghat, long stretch of area is occupied by red loamy soil. Yellow and red soils are also found in parts of Odisha and Chattisgarh and in the southern parts of the middle Ganga plain. The soil develops a reddish colour due to a wide diffusion of iron in crystalline and metamorphic rocks. It looks yellow when it occurs in a hydrated form. The fine-grained red and yellow soils are normally fertile, whereas coarse-grained soils found in dry upland areas are poor in fertility. They are generally poor in nitrogen, phosphorous and humus.

Laterite Soil

Laterite has been derived from the Latin word 'Later' which means brick. The laterite soils develop in areas with high temperature and high rainfall. These are the result of intense leaching due to tropical rains. With rain, lime and silica are leached away, and soils rich in iron oxide and aluminium compound are left behind.

Humus content of the soil is removed fast by bacteria that thrives well in high temperature. These soils are poor in organic matter, nitrogen, phosphate and calcium, while iron oxide and potash are in excess. Hence, laterites are not suitable for cultivation; however, application of manures and fertilisers are required for making the soils fertile for cultivation. Red laterite soils in Tamil Nadu, Andhra Pradesh and Kerala are more suitable for tree crops like cashewnut. Laterite soils are widely cut as bricks for use in house construction. These soils have mainly developed in the higher areas of the Peninsular plateau. The laterite soils are commonly found in Karnataka, Kerala, Tamil Nadu, Madhya Pradesh and the hilly areas of Odisha and Assam.

Arid Soils

Arid soils range from red to brown in colour. They are generally sandy in structure and saline in nature. In some areas, the salt content is so high that common salt is obtained by evaporating the saline water. Due to the dry climate, high temperature and accelerated evaporation, they lack moisture and humus. Nitrogen is insufficient and the phosphate content is normal. Lower horizons of the soil are occupied by 'kankar' layers because of the increasing calcium content downwards.

The 'Kankar' layer formation in the bottom horizons restricts the infiltration of water, and as such when irrigation is made available, the soil moisture is readily available for a sustainable plant growth. Arid soils are characteristically developed in western Rajasthan, which exhibit characteristic arid topography. These soils are poor and contain little humus and organic matter.

Saline Soils

They are also known as Usara soils. Saline soils contain a larger proportion of sodium, potassium and magnesium, and thus, they are infertile, and do not support any vegetative growth. They have more salts, largely because of dry climate and poor drainage. They occur in arid and semi-arid regions, and in waterlogged and swampy areas. Their structure ranges from sandy to loamy.

They lack in nitrogen and calcium. Saline soils are more widespread in western Gujarat, deltas of the eastern coast and in Sunderban areas of West Bengal. In the Rann of Kuchchh, the Southwest Monsoon brings salt particles and deposits there as a crust. Seawater intrusions in the deltas promote the occurrence of saline soils. In the areas of intensive cultivation with excessive use of irrigation, especially in areas of green revolution, the fertile alluvial soils are becoming saline.

Excessive irrigation with dry climatic conditions promotes capillary action, which results in the deposition of salt on the top layer of the soil. In such areas, especially in Punjab and Haryana, farmers are advised to add gypsum to solve the problem of salinity in the soil.

Peaty Soils

They are found in the areas of heavy rainfall and high humidity, where there is a good growth of vegetation. Thus, large quantity of dead organic matter accumulates in these areas, and this gives a rich humus and organic content to the soil. Organic matter in these soils may go even up to 40-50 per cent. These soils are normally heavy and black in colour. At many places, they are alkaline also. It occurs widely in the northern part of Bihar, southern part of Uttaranchal and the coastal areas of West Bengal, Odisha and Tamil Nadu.

Forest Soils

As the name suggests, forest soils are formed in the forest areas where sufficient rainfall is available. The soils vary in structure and texture depending on the mountain environment where they are formed. They are loamy and silty on valley sides and coarse-grained in the upper slopes. In the snow-bound areas of the Himalayas, they experience denudation, and are acidic with low humus content. The soils found in the lower valleys are fertile. It is evident from the foregoing discussions that soils, their texture, quality and nature are vital for the germination and growth of plant and vegetation including crops. Soils are living systems. Like any other organism, they too develop and decay, get degraded, respond to proper treatment if administered in time. These have serious repercussions on other components of the system of which they themselves are important parts.

Types of Cropping Systems

Different types of cropping systems are adopted on farms depending on the climate, soil, and available resources.

Monoculture: Monoculture is a cropping system in which a single crop is cultivated on a particular piece of land over an extended period. In this system, the same crop is grown repeatedly on the same land, often for several years in a row.

1. Advantages of Monoculture: One of the main advantages of monoculture is that it allows for the efficient use of resources such as water, fertilizers, and pesticides. Farmers can optimize their production by using the same techniques for each crop and minimizing input costs. Monoculture can also simplify the management of crops and improve harvest efficiency.
2. Disadvantages of Monoculture: One of the main disadvantages of monoculture is that it can lead to soil degradation and reduced soil fertility. Repeated planting of the same crop can deplete the soil of

specific nutrients and encourage pest infestations, leading to lower crop yields over time. Monoculture can also reduce biodiversity and create favorable conditions for pests and diseases to spread, which can increase the risk of crop failure.

3. Strategies to mitigate the disadvantages of monoculture: Farmers can adopt several strategies to mitigate the disadvantages of monoculture. Crop rotation involves alternating the crops grown on a particular piece of land to reduce soil depletion and pest infestations. Inter-cropping involves growing multiple crops simultaneously on the same land to reduce pest infestations and improve nutrient cycling. Cover crops can also be used to protect the soil from erosion and maintain soil fertility.
4. Examples of monoculture: Monoculture is commonly used in agriculture to grow crops such as wheat, rice, and corn. Large-scale agricultural operations often rely on monoculture to maximize production and reduce costs. However, small-scale farmers may also use monoculture to produce cash crops that have a high demand in the market.

Monoculture is a common cropping system used in agriculture that has both advantages and disadvantages. While it allows for efficient use of resources, it can also lead to soil degradation and reduced crop yields over time. Farmers can adopt strategies such as crop rotation, inter-cropping, and cover cropping to mitigate the disadvantages of monoculture and maintain soil fertility.

Multiple cropping: Multiple cropping is a cropping system in which two or more crops are grown on the same piece of land in a single growing season. This system allows farmers to maximize the use of available resources and increase crop yields.

1. Advantages of Multiple cropping: Multiple cropping allows farmers to make efficient use of available resources such as water, sunlight, and nutrients. It can increase crop yields by optimizing the use of resources and reducing the risk of crop failure due to adverse weather conditions. Multiple cropping can also improve soil fertility by reducing nutrient depletion and increasing nutrient cycling.
2. Types of Multiple cropping: There are several types of multiple cropping, including mixed cropping, intercropping, and sequential cropping. In mixed cropping, two or more crops are grown simultaneously on the same piece of land. In intercropping, two or more crops are grown in alternate rows or in the same row. Sequential cropping involves growing two or more crops in sequence on the same piece of land.
3. Factors that influence Multiple cropping: The success of multiple cropping depends on several factors, including the availability of resources such as water, sunlight, and nutrients. Soil fertility is also an essential factor, as multiple cropping can deplete the soil of specific nutrients. Climate and weather conditions can also influence the success of multiple cropping.
4. Challenges of Multiple cropping: Multiple cropping can present some challenges for farmers. Managing multiple crops can be labor-intensive, and coordinating the timing of planting, harvesting, and other activities can be difficult. Pest and disease management can also be challenging, as some crops may be more susceptible to specific pests or diseases.
5. Examples of Multiple cropping: Multiple cropping is common in many parts of the world, particularly in areas with limited resources. Examples of multiple cropping include growing wheat and legumes together, or growing maize and beans in alternate rows.

Multiple cropping is a cropping system that can help farmers maximize the use of available resources and increase crop yields. There are several types of multiple cropping, including mixed cropping, intercropping, and sequential cropping. While multiple cropping can present some challenges, it is a valuable tool for farmers looking to optimize their production and maintain soil fertility.

Intercropping is a cropping system in which two or more crops are grown simultaneously on the same piece of land. In this system, crops are planted in alternate rows or in the same row, and each crop benefits from the presence of the other

1. Advantages of Intercropping: Intercropping has several advantages, including better use of resources such as water, sunlight, and nutrients. By growing different crops together, intercropping can improve soil fertility, reduce pest and disease pressure, and increase crop yields. Intercropping can also help farmers diversify their production and reduce their dependence on a single crop.
2. Types of Intercropping: There are several types of intercropping, including mixed intercropping, row intercropping, and relay intercropping. In mixed intercropping, different crops are grown together in the same field. In row intercropping, different crops are grown in alternate rows. Relay intercropping involves planting a second crop after the first crop has reached maturity.
3. Factors that influence Intercropping: The success of intercropping depends on several factors, including the crop combination, the spacing between plants, and the management practices used. Crop combinations must be carefully chosen to ensure that the crops benefit from each other and do not compete

for resources. Spacing between plants must also be carefully managed to avoid overcrowding and ensure adequate light and nutrients for each crop.

4. Challenges of Intercropping: Intercropping can present some challenges for farmers. Managing multiple crops can be labor-intensive, and coordinating the timing of planting, harvesting, and other activities can be difficult. Pest and disease management can also be challenging, as some crops may be more susceptible to specific pests or diseases.
5. Examples of Intercropping: Intercropping is common in many parts of the world, particularly in areas with limited resources. Examples of intercropping include growing beans and maize together, or growing legumes with cereals.

Intercropping is a valuable cropping system that can help farmers maximize the use of available resources, increase crop yields, and maintain soil fertility. There are several types of intercropping, and each type presents its own unique advantages and challenges. By carefully managing crop combinations, spacing, and management practices, farmers can successfully implement intercropping and improve their production.

Mixed cropping: Mixed cropping is a type of multiple cropping system where two or more crops are grown simultaneously on the same piece of land in the same row, without any distinct pattern or arrangement. The crops are selected based on their complementary growth habits and requirements, and they help to maximize the use of resources such as sunlight, water, and nutrients.

1. Advantages of Mixed cropping: Mixed cropping has several advantages, including better utilization of available resources and a reduced risk of crop failure. By growing different crops together, mixed cropping can improve soil fertility, reduce pest and disease pressure, and increase crop yields. It can also help farmers diversify their production and reduce their dependence on a single crop.
2. Types of Mixed cropping: There are several types of mixed cropping, including pure or simple mixed cropping, mixed intercropping, and crop rotation. In pure mixed cropping, two or more crops are grown together without any distinct pattern or arrangement. In mixed intercropping, different crops are grown together in the same field, but in alternate rows or specific patterns. In crop rotation, different crops are grown in the same field in a specific sequence to maintain soil fertility.
3. Factors that influence Mixed cropping: The success of mixed cropping depends on several factors, including the crop combination, the spacing between plants, and the management practices used. Crop combinations must be carefully chosen to ensure that the crops benefit from each other and do not compete for resources. Spacing between plants must also be carefully managed to avoid overcrowding and ensure adequate light and nutrients for each crop.
4. Challenges of Mixed cropping: Mixed cropping can present some challenges for farmers. Managing multiple crops can be labor-intensive, and coordinating the timing of planting, harvesting, and other activities can be difficult. Pest and disease management can also be challenging, as some crops may be more susceptible to specific pests or diseases.
5. Examples of Mixed cropping: Mixed cropping is common in many parts of the world, particularly in areas with limited resources. Examples of mixed cropping include growing beans and maize together, or growing legumes with cereals.

Mixed cropping is a valuable cropping system that can help farmers maximize the use of available resources, increase crop yields, and maintain soil fertility. By carefully managing crop combinations, spacing, and management practices, farmers can successfully implement mixed cropping and improve their production.

Strip cropping: Strip cropping is a type of cropping system in which two or more crops are grown in alternating strips across a field. The strips are arranged in a way that maximizes the use of resources such as water, sunlight, and nutrients, and can help to reduce soil erosion and improve soil fertility.

1. Advantages of Strip cropping: Strip cropping has several advantages, including reduced soil erosion, increased soil fertility, and improved water management. By planting crops in alternating strips, the soil is better able to absorb water, reducing runoff and erosion. Strip cropping can also help to maintain soil fertility by reducing nutrient depletion, and can provide habitats for beneficial insects and wildlife.
2. Types of Strip cropping: There are several types of strip cropping, including contour strip cropping, crop rotation strip cropping, and alley cropping. Contour strip cropping involves planting crops in strips that follow the contour of the land, while crop rotation strip cropping involves alternating strips of different crops in a specific rotation. Alley cropping involves planting crops in strips between rows of trees or shrubs.
3. Factors that influence Strip cropping: The success of strip cropping depends on several factors, including the slope of the land, the types of crops used, and the management practices employed. Sloping land is particularly suited to contour strip cropping, as it can help to reduce erosion and runoff. The types of crops used must be carefully selected to ensure that they complement each other and do not compete for resources.

4. Challenges of Strip cropping: Strip cropping can present some challenges for farmers. Managing multiple crops can be labor-intensive, and coordinating the timing of planting, harvesting, and other activities can be difficult. Pest and disease management can also be challenging, as some crops may be more susceptible to specific pests or diseases.
5. Examples of Strip cropping: Strip cropping is used in many parts of the world, particularly in areas with steep slopes or other conditions that make traditional row cropping difficult. Examples of strip cropping include planting alternating strips of corn and soybeans, or alternating strips of wheat and clover.

Strip cropping is a valuable cropping system that can help farmers maximize the use of available resources, reduce soil erosion, and improve soil fertility. By carefully managing crop combinations, spacing, and management practices, farmers can successfully implement strip cropping and improve their production.

Sequence cropping: Sequence cropping is a farming practice where a sequence of different crops is grown in the same field over time. Each crop is planted and harvested in a specific order, with the goal of maximizing yields and reducing the risk of crop failure.

1. Advantages of Sequence cropping: Sequence cropping has several advantages, including reduced risk of crop failure, increased soil fertility, and improved weed and pest control. By rotating crops, the soil is less likely to become depleted of nutrients and less likely to develop pest and disease problems. This can result in higher yields and better crop quality over time.
2. Types of Sequence cropping: There are several types of sequence cropping, including simple crop rotation, double cropping, and triple cropping. Simple crop rotation involves planting two or more different crops in a specific sequence over time. Double cropping involves planting two different crops in the same field during the same growing season, while triple cropping involves planting three different crops in the same field in a single year.
3. Factors that influence Sequence cropping: The success of sequence cropping depends on several factors, including soil type, climate, crop types, and available resources. Some crops are better suited to specific soil types or climates, and the timing of planting and harvesting must be carefully managed to ensure that each crop has the optimal growing conditions.
4. Challenges of Sequence cropping: Sequence cropping can present some challenges for farmers, including managing multiple crops, coordinating planting and harvesting schedules, and controlling pests and diseases. Additionally, different crops may have different soil and nutrient requirements, which must be carefully managed to ensure that each crop receives the appropriate level of resources.
5. Examples of Sequence cropping: Sequence cropping is commonly used in many parts of the world, particularly in areas where small farms are common. Examples of sequence cropping include rotating corn and soybeans, rotating wheat and legumes, and planting different crops in the same field over time.

Sequence cropping is a valuable farming practice that can help to maximize yields, reduce the risk of crop failure, and improve soil fertility. By carefully managing crop types, planting and harvesting schedules, and soil and nutrient requirements, farmers can successfully implement sequence cropping and improve their production.

Relay cropping: Relay cropping is a farming practice in which a second crop is planted before the first crop is harvested. This practice can help to increase yields, reduce the risk of crop failure, and improve soil health.

1. Advantages of Relay cropping: Relay cropping can offer several advantages, including improved soil health, increased yields, and reduced risk of crop failure. By planting a second crop before the first is harvested, farmers can help to reduce soil erosion, improve soil fertility, and maintain a healthy soil ecosystem.
2. Types of Relay cropping: There are several types of relay cropping, including intercropping, double cropping, and multi-cropping. Intercropping involves planting two or more crops in the same field at the same time, while double cropping involves planting two crops in the same field during the same growing season. Multi-cropping involves planting three or more crops in the same field during a single growing season.
3. Factors that influence Relay cropping: The success of relay cropping depends on several factors, including soil type, climate, crop types, and available resources. Some crops are better suited to specific soil types or climates, and the timing of planting and harvesting must be carefully managed to ensure that each crop has the optimal growing conditions.
4. Challenges of Relay cropping: Relay cropping can present some challenges for farmers, including coordinating planting and harvesting schedules, controlling pests and diseases, and managing soil and nutrient requirements. Additionally, different crops may have different soil and nutrient requirements, which must be carefully managed to ensure that each crop receives the appropriate level of resources.

5. Examples of Relay cropping: Relay cropping is commonly used in many parts of the world, particularly in areas where small farms are common. Examples of relay cropping include planting wheat before soybeans are harvested, planting beans before corn is harvested, and planting a cover crop before the main crop is harvested.

Relay cropping is a valuable farming practice that can help to improve soil health, increase yields, and reduce the risk of crop failure. By carefully managing crop types, planting and harvesting schedules, and soil and nutrient requirements, farmers can successfully implement relay cropping and improve their production.

Multistoried cropping: Multistoried cropping is a farming practice in which crops of different heights are grown in the same field, often on different levels or stories. This practice can help to increase yields, maximize land use, and improve soil health.

1. Advantages of Multistoried cropping: Multistoried cropping can offer several advantages, including increased yields, improved soil health, and reduced water use. By planting crops at different levels, farmers can maximize land use and improve the efficiency of water and nutrient use. Additionally, the diverse crop types can help to maintain a healthy soil ecosystem and reduce the risk of pests and diseases.
2. Types of Multistoried cropping: There are several types of multistoried cropping, including agroforestry, alley cropping, and vertical farming. Agroforestry involves planting trees and crops together in the same field, while alley cropping involves planting crops in the spaces between rows of trees. Vertical farming involves growing crops on multiple levels, often in a controlled environment.
3. Factors that influence Multistoried cropping: The success of multistoried cropping depends on several factors, including climate, soil type, crop types, and available resources. Some crops are better suited to specific soil types or climates, and the timing of planting and harvesting must be carefully managed to ensure that each crop has the optimal growing conditions.
4. Challenges of Multistoried cropping: Multistoried cropping can present some challenges for farmers, including managing the different crop heights and spacing, coordinating planting and harvesting schedules, and managing soil and nutrient requirements. Additionally, different crops may have different water and nutrient requirements, which must be carefully managed to ensure that each crop receives the appropriate level of resources.
5. Examples of Multistoried cropping: Multistoried cropping is becoming increasingly popular in many parts of the world, particularly in urban areas where space is limited. Examples of multistoried cropping include planting tomatoes on trellises, growing mushrooms in stacked trays, and growing herbs and lettuce in a vertical garden.

Multistoried cropping is a valuable farming practice that can help to maximize land use, improve yields, and promote a healthy soil ecosystem. By carefully managing crop types, planting and harvesting schedules, and soil and nutrient requirements, farmers can successfully implement multistoried cropping and improve their production.

Catch cropping: Catch cropping, also known as intercropping or relay cropping, is a farming practice in which a quick-growing crop is grown in the same field after the main crop has been harvested.

1. Advantages of Catch cropping: Catch cropping can offer several advantages, including improved soil health, reduced erosion, and increased yields. By planting a quick-growing crop after the main crop has been harvested, farmers can help to maintain soil structure and nutrient levels, prevent soil erosion, and improve the efficiency of water and nutrient use. Additionally, catch crops can provide additional yields and income for farmers.
2. Types of Catch cropping: There are several types of catch cropping, including cover crops, green manure crops, and forage crops. Cover crops are planted primarily to protect the soil, while green manure crops are grown primarily to add organic matter to the soil. Forage crops are grown to provide feed for livestock.
3. Factors that influence Catch cropping: The success of catch cropping depends on several factors, including climate, soil type, crop types, and available resources. Some crops are better suited to specific soil types or climates, and the timing of planting and harvesting must be carefully managed to ensure that each crop has the optimal growing conditions.
4. Challenges of Catch cropping: Catch cropping can present some challenges for farmers, including managing the different crop types and spacing, coordinating planting and harvesting schedules, and managing soil and nutrient requirements. Additionally, different crops may have different water and nutrient requirements, which must be carefully managed to ensure that each crop receives the appropriate level of resources.
5. Examples of Catch cropping: Catch cropping is a popular farming practice in many parts of the world, particularly in areas where the growing season is short

or the soil is prone to erosion. Examples of catch cropping include planting a cover crop of clover or rye after harvesting wheat or corn, or planting a forage crop of oats or barley after harvesting soybeans.

Farmers adopt different types of cropping systems based on their resources, climate, and soil conditions. Each system has its own advantages and disadvantages, and farmers must choose the right system to maximize their crop yield and maintain soil fertility.

ORGANIC MANURE

Organic manure refers to the natural substances that are added to the soil to improve its fertility and texture. These are usually derived from plants and animal waste, and are an important aspect of sustainable agriculture. Here are some important details about organic manure:

- Types of organic manure: Organic manure can be broadly classified into two types - plant-based and animal-based. Plant-based manure includes green manure, compost, and crop residues. Animal-based manure includes dung, urine, and other animal waste.
- Benefits of organic manure: Organic manure has several benefits for the soil and crops. It improves soil structure and texture, enhances water retention, and increases soil organic matter content. It also improves nutrient availability, promotes healthy microbial activity, and reduces soil erosion. Organic manure can also improve crop yield, quality, and disease resistance.
- Methods of application: Organic manure can be applied to the soil in various ways, such as broadcast application, furrow application, and band application. The method of application depends on the type of crop, soil texture, and nutrient requirements.
- Precautions while using organic manure: While organic manure is beneficial for the soil and crops, it is important to use it judiciously. Over-application of manure can lead to nutrient imbalances and soil pollution. Also, manure from diseased animals or plants should not be used as it can spread the disease to healthy plants.
- Sources of organic manure: Organic manure can be obtained from various sources, such as farmyard manure, compost pits, vermicomposting, and green manure crops. It is important to choose the right source of manure based on the nutrient requirements of the crops and the availability of resources.

Organic manure is an important aspect of sustainable agriculture and plays a crucial role in maintaining soil fertility and improving crop yield and quality.

COMMON FERTILIZERS INCLUDING STRAIGHT, COMPLEX, FERTILIZER MIXTURES AND BIOFERTILIZERS

Fertilizers are an essential component of modern agricultural practices as they provide the necessary nutrients for plant growth and development. There are several types of fertilizers available in the market, including straight fertilizers, complex fertilizers, fertilizer mixtures, and biofertilizers.

1. Straight Fertilizers: These are fertilizers that contain only one primary nutrient. For example, urea is a straight fertilizer that provides only nitrogen to plants.
2. Complex Fertilizers: These are fertilizers that contain two or more primary nutrients. For example, NPK (Nitrogen, Phosphorus, and Potassium) fertilizers are complex fertilizers that provide a balanced ratio of these essential nutrients to plants.
3. Fertilizer Mixtures: These are combinations of straight and complex fertilizers. They provide a balanced combination of essential nutrients to plants.
4. Biofertilizers: These are natural fertilizers that contain living organisms, such as bacteria, fungi, and algae, which help in nutrient fixation and improve soil health.

In addition to these fertilizers, micronutrient fertilizers are also used to provide essential trace elements such as iron, zinc, copper, and manganese, which are required in small quantities for plant growth and development.

It is essential to use fertilizers in the right amounts and at the right time to avoid overuse, which can lead to soil and water pollution. Proper soil testing and analysis can help determine the right type and amount of fertilizer required for a specific crop and soil type.

The use of fertilizers is crucial for ensuring sustainable and efficient agricultural practices that can help meet the growing demand for food in a world with a rapidly growing population.

INTEGRATED NUTRIENT MANAGEMENT SYSTEM

Integrated Nutrient Management (INM) is a comprehensive approach that aims to optimize nutrient use efficiency and promote sustainable agriculture. It involves the integration of various sources of plant nutrients, including chemical fertilizers, organic manures, biofertilizers, and other soil amendments, in a balanced and optimal manner to meet the crop's nutrient requirements.

INM includes the following components:

1. Soil Testing: Soil testing is the first step in INM, which involves determining the soil's nutrient status and pH. Based on the results of the soil test, nutrient

deficiencies can be identified, and a suitable fertilizer and manure application plan can be developed.

2. Balanced Fertilizer Application: INM aims to apply the right amount of fertilizers based on the crop's needs. It involves the use of both chemical and organic fertilizers, which are applied in a balanced manner to provide optimal nutrition to the plants.
3. Organic Manure Application: Organic manure is a vital component of INM, and its use is encouraged to improve soil fertility and promote sustainable agriculture. It includes the use of farmyard manure, compost, green manure, and other organic materials.
4. Biofertilizer Application: INM also promotes the use of biofertilizers, which are microbial inoculants that help fix atmospheric nitrogen and solubilize soil nutrients, making them more available to the plants.
5. Crop Rotation: Crop rotation is an essential component of INM, which involves growing different crops in a sequence. It helps in maintaining soil health and fertility, reducing pest and disease incidence, and improving the overall productivity of the farm.
6. Conservation Agriculture: Conservation agriculture practices, such as minimum tillage, residue retention, and crop diversification, are promoted under INM. These practices help in conserving soil moisture, improving soil health, and reducing the use of synthetic fertilizers and pesticides.

Benefits of INM:

1. Improved Soil Fertility: INM helps in maintaining and improving soil fertility by providing a balanced supply of plant nutrients.
2. Increased Crop Productivity: INM promotes the efficient use of nutrients, resulting in increased crop productivity.
3. Reduced Environmental Pollution: INM reduces the environmental pollution caused by excess use of synthetic fertilizers and pesticides.
4. Sustainable Agriculture: INM promotes sustainable agriculture practices by reducing the dependence on chemical fertilizers and promoting the use of organic and biofertilizers.

INM is an effective approach to optimize nutrient use efficiency and promote sustainable agriculture.

IRRIGATION AND DRAINAGE

SOURCES OF IRRIGATION

Sources of irrigation refer to the different methods or means of supplying water to crops in agricultural fields. Here are some important details about the various sources of irrigation:

1. Rain: Rainfall is a natural source of irrigation that is dependent on the season and location of the agricultural field. It is the most common source of irrigation in regions that receive adequate rainfall throughout the year.
2. Canals: Canals are man-made channels that carry water from rivers or other sources to agricultural fields. They are used for irrigation in areas that do not receive enough rainfall and require additional water to support crop growth.
3. Tanks: Tanks or reservoirs are artificial water storage structures that are used to store rainwater and surface water. They are often used in areas that experience frequent droughts or do not have access to other sources of irrigation.
4. Rivers: Rivers are a natural source of water that can be used for irrigation. They are often used in areas that are situated near a river and have the infrastructure to channel water from the river to agricultural fields.
5. Wells: Wells are man-made structures that are dug into the ground to extract groundwater. They are often used in areas that do not have access to other sources of irrigation.
6. Tubewells: Tubewells are a type of well that uses a motorized pump to extract groundwater. They are often used in areas that have high water tables and are situated near aquifers.

The choice of irrigation source depends on the location and the availability of water resources. Each source of irrigation has its advantages and disadvantages, and the selection of the appropriate source of irrigation is essential for sustainable crop production.

SCHEDULING OF IRRIGATION

Scheduling of irrigation is an important aspect of agriculture, as it helps to optimize water usage and increase crop productivity. Here are some important details about the scheduling of irrigation:

1. Critical stages of growth: Different crops have different critical stages of growth, during which they require more water. For example, during the vegetative stage, plants require more water to support their growth, while during the reproductive stage, they require more water for flowering and fruit development.
2. Time interval: The time interval between two irrigations depends on various factors, such as the crop type, soil type, weather conditions, and water availability. For example, some crops may require irrigation every 3-4 days, while others may require irrigation once a week.

3. Soil moisture content: Soil moisture content is an important parameter for scheduling irrigation. The moisture content of the soil should be maintained at an optimal level to ensure proper plant growth and development. Soil moisture can be measured using various techniques, such as tensiometers, gypsum blocks, and neutron probes.
4. Weather parameters: Weather conditions such as temperature, humidity, and wind speed can affect the water requirement of crops. For example, on hot and dry days, crops may require more water than on cool and humid days.
5. Irrigation methods: The scheduling of irrigation also depends on the irrigation method used. For example, in drip irrigation, water is supplied directly to the roots of the plants, which reduces water loss due to evaporation and increases water use efficiency.

Overall, scheduling of irrigation based on critical stages of growth, time interval, soil moisture content, and weather parameters can help to ensure optimal water usage and increase crop productivity.

WATERSHED MANAGEMENT

Watershed management is an important aspect of agricultural and environmental management. It involves the planning, development, and management of land and water resources within a specific watershed to ensure sustainable use and conservation of natural resources. Here are some important details about watershed management:

1. Definition: Watershed management refers to the process of managing land and water resources within a specific watershed to optimize the use of resources and minimize the impact of human activities on the environment.
2. Importance: Watershed management is important for several reasons, including the conservation of water resources, prevention of soil erosion, enhancement of agricultural productivity, protection of natural habitats, and mitigation of the impacts of climate change.
3. Components: The key components of watershed management include land-use planning, soil conservation, water conservation, water quality management, and biodiversity conservation.
4. Techniques: Several techniques are used in watershed management, including the construction of check dams, contour bunds, and contour trenches to prevent soil erosion and retain moisture; the use of crop rotation, mulching, and intercropping to enhance soil fertility and productivity; and the establishment of water harvesting systems, such as ponds, lakes, and wells, to conserve water resources.
5. Challenges: Some of the major challenges in watershed management include inadequate funding, lack of awareness and participation of local communities, inappropriate land-use practices, and conflicting interests of stakeholders.
6. Benefits: Effective watershed management can lead to several benefits, including increased agricultural productivity, improved water quality, enhanced biodiversity, and better management of natural resources.

Objectives of Watershed Management

- To control damaging run off and degradation and thereby conservation of soil and water.
- To promote sustainable farming and stabilize crop yield by adopting suitable cropping and crop management system.
- To check soil erosion and increase water infiltration rate.
- To cover non-arable area effectively through afforestation and pasture land.
- To restore ecological balance.
- To enhance the income of the individuals by adopting alternate enterprises.
- To minimize the risk of flood, drought and land slide.
- Supply and securing of clean and sufficient drinking water.

Watershed management is an important approach to sustainable agricultural and environmental management. It involves the planning and management of land and water resources within a specific watershed to optimize their use and minimize their impact on the environment.

WEED CONTROL

Weeds are unwanted plants that grow in crops and compete with them for nutrients, water, and light. They can also serve as hosts for pests and diseases. Therefore, weed control is an essential part of crop management. Here are some important details about the principles and methods of weed control:

PRINCIPLES OF WEED CONTROL

1. Prevention: One of the most effective ways to control weeds is to prevent their establishment. This can be done by using certified seeds, proper land preparation, and timely planting.
2. Early detection: Weeds should be detected early so that they can be removed before they become established.
3. Integrated weed management: This involves the use of a combination of control methods to manage weeds. This can include cultural, mechanical, chemical, and biological control methods.

4. Selectivity: Weed control methods should be selective, so they do not harm the crop.

METHODS OF WEED CONTROL

1. Cultural control: This involves the use of practices that prevent or suppress weed growth. These practices include crop rotation, intercropping, cover cropping, and timely planting.
2. Mechanical control: This involves the use of equipment to physically remove weeds. These methods include hand weeding, hoeing, and cultivation.
3. Chemical control: This involves the use of herbicides to kill or suppress weeds. Herbicides can be applied pre-emergence or post-emergence of weeds.
4. Biological control: This involves the use of natural enemies of weeds, such as insects or diseases, to suppress weed growth.
5. Integrated weed management: This involves the use of a combination of the above control methods to manage weeds. Integrated weed management is the most effective way to control weeds because it reduces the dependence on any single control method.

Weed control is an important aspect of crop management. Farmers should use a combination of control methods to manage weeds effectively. The choice of control method will depend on the type of weed, the crop, and the environment.

CROPS

SEED BED PREPARATION

Seed bed preparation is the process of creating a suitable environment for the germination and growth of seeds. Some important details about seed bed preparation in agriculture:

- Purpose: The main purpose of seed bed preparation is to create an optimal environment for seed germination and growth. This involves preparing the soil by breaking up clumps, removing weeds, and improving soil fertility.
- Soil preparation: Soil preparation is the first step in seed bed preparation. The soil should be plowed or tilled to a depth of 15-20 cm to break up any clumps or compacted soil. This also helps to incorporate organic matter into the soil, which improves soil fertility.
- Levelling: After plowing or tilling, the soil should be levelled to ensure uniform seed distribution and seedling emergence. This can be done using a harrow or a drag.
- Weed control: Weeds can compete with crops for nutrients, sunlight, and water, and can reduce crop yield. It is important to remove weeds before planting. This can be done mechanically, chemically, or by hand.
- Fertilization: Fertilizers are added to the soil to improve soil fertility and provide essential nutrients for plant growth. The type and amount of fertilizer used depends on the type of crop and soil conditions.
- Irrigation: Adequate moisture is essential for seed germination and plant growth. Irrigation should be done after seed bed preparation to ensure that the soil is moist but not waterlogged.
- Timing: Seed bed preparation should be done at the right time to ensure that the soil is at the right temperature and moisture level for seed germination. The timing varies depending on the crop and local weather conditions.

Seed bed preparation is an important step in agriculture that involves preparing the soil for seed germination and growth. This involves plowing or tilling the soil, levelling, weed control, fertilization, irrigation, and timing. Proper seed bed preparation can improve crop yields and ensure a successful harvest.

SEED TREATMENT

Seed treatment is a process of treating seeds with various chemicals or biological agents to protect them from pests, diseases, and other environmental stresses. Here are some important details about seed treatment:

1. Purpose: The primary purpose of seed treatment is to improve seed quality, germination rate, and crop yield by protecting the seeds from pests, diseases, and other environmental stresses.
2. Chemicals used: The chemicals used for seed treatment include fungicides, insecticides, nematicides, and herbicides. These chemicals can be applied to seeds using various methods such as seed coating, seed soaking, and seed dressing.
3. Biological agents: In addition to chemicals, biological agents such as biofungicides, bioinsecticides, and biofertilizers can also be used for seed treatment. These agents are derived from natural sources such as bacteria, fungi, and algae and are considered eco-friendly and safe for the environment.
4. Methods of application: Seed treatment can be done using various methods such as dusting, soaking, and coating. In the dusting method, the seeds are coated with a powder containing the required chemical or biological agent. In the soaking method, the seeds are soaked in a solution containing the required agent. In the coating method, the seeds are coated with a layer of material containing the required agent.

5. Benefits: Seed treatment has several benefits such as improving seed quality, enhancing germination rate, protecting the seeds from pests and diseases, and reducing environmental pollution by reducing the amount of chemicals required for crop protection.
6. Precautions: Seed treatment should be done with caution as some chemicals used for seed treatment can be toxic to humans and animals. It is important to follow the instructions on the product label and use appropriate protective gear when handling chemicals.

Seed treatment is an important practice in modern agriculture that helps improve seed quality, protect crops from pests and diseases, and increase crop yield.

TIME AND METHOD OF SOWING/ PLANTING

Time and method of sowing/planting are critical factors in crop production as they determine the crop's yield potential and performance. Some important details about time and method of sowing/planting:

1. Time of sowing/planting: The time of sowing/planting varies depending on the crop and the region where it is grown. Generally, crops are sown/planted during the optimal season for growth and development. For example, wheat is sown in the winter season, while rice is sown in the rainy season.
2. Method of sowing/planting: The method of sowing/planting also varies depending on the crop and the farming system. Some of the commonly used methods are:
   - Broadcasting: This involves spreading the seeds uniformly over the entire field without any specific arrangement. This method is commonly used for crops like wheat, barley, and mustard.
   - Dibbling: This involves making holes in the soil with a pointed stick or dibber and placing the seed in the hole. This method is commonly used for crops like maize and sorghum.
   - Transplanting: This involves raising seedlings in a nursery and then transplanting them in the field. This method is commonly used for crops like rice and vegetables.
   - Drilling: This involves sowing the seeds in rows at a predetermined depth using a drill machine. This method is commonly used for crops like wheat, maize, and soybean.
3. Planting density: The planting density refers to the number of plants per unit area of land. The optimal planting density varies depending on the crop and the farming system. In general, a higher planting density results in a higher yield but may also increase the risk of pest and disease outbreaks.
4. Seed rate: The seed rate refers to the amount of seed required to sow a unit area of land. The optimal seed rate varies depending on the crop and the farming system. In general, a higher seed rate results in a higher yield but also increases the cost of production.
5. Seed treatment: Seed treatment is the process of treating seeds with fungicides, insecticides, or other chemicals to protect them from pests and diseases. This is often done before sowing/planting to ensure better germination and establishment of the crop.

The time and method of sowing/planting, planting density, seed rate, and seed treatment are important factors that farmers need to consider when planning crop production.

SEED RATE

Seed rate refers to the amount of seed that is sown per unit area of land. The appropriate seed rate varies depending on the crop, variety, soil type, and other environmental factors. The goal of selecting the right seed rate is to achieve an optimum plant population that can provide the highest possible yield.

The seed rate is usually expressed as weight or number of seeds per unit area. For example, in wheat, the recommended seed rate is usually around 100-120 kg per hectare (ha), while for maize, it can be between 18-25 kg/ha. For vegetable crops, the seed rate is often given as the number of seeds per meter or row.

Factors that influence seed rate include seed size, seed viability, seed dormancy, germination percentage, and plant stand desired. Seed rate can be adjusted based on the fertility of the soil, expected yield, and management practices.

Planting too much seed can result in overcrowding, which can lead to competition for nutrients, water, and light, resulting in reduced yields, increased pest and disease pressure, and lodging. On the other hand, planting too few seeds can result in low plant populations, reduced yields, and wastage of land and other resources.

Therefore, it is important for farmers to follow recommended seed rates, which are usually based on research and experience, to ensure optimal plant populations and maximum yields.

DOSE, METHOD, AND TIME OF FERTILIZER APPLICATION

Dose, method, and time of fertilizer application are important considerations for optimizing crop productivity and minimizing nutrient loss. Here are some details:

1. Dose: The dose of fertilizer needed varies depending on the crop, soil fertility, and cropping system. It is important to determine the appropriate dose for a specific crop in a given field to avoid under or over

application. Soil testing can provide information on the nutrient status of the soil and guide the appropriate dose of fertilizer.

2. Method: There are different methods of fertilizer application including broadcasting, band placement, and fertigation. Broadcasting involves spreading fertilizer uniformly over the entire field. Band placement involves placing fertilizer in a narrow band near the seed or plant. Fertigation involves applying fertilizer through the irrigation system.
3. Time: The timing of fertilizer application is critical for maximizing nutrient use efficiency and crop productivity. Generally, fertilizers can be applied in pre-planting, at planting, and during the crop growing period. Pre-planting application can be done several weeks before planting to allow sufficient time for the fertilizer to mix with the soil. At planting application involves placing the fertilizer in the soil near the seed. During crop growing period, the fertilizer can be applied as a top dressing.

In addition to these considerations, it is important to follow recommended application rates and timing, avoid nutrient imbalances, and use fertilizers that are appropriate for the soil and crop needs.

IRRIGATION

Irrigation is the process of artificially applying water to crops for their growth and development. It is essential in areas where rainfall is insufficient or unreliable, or during certain stages of crop growth. Here are some details on irrigation:

1. Types of Irrigation: There are different types of irrigation systems, including surface irrigation, sprinkler irrigation, and drip irrigation. The type of system used depends on factors such as soil type, crop type, topography, and water availability.
2. Water Requirements: The amount of water required for irrigation varies depending on the crop, soil type, and climate. The water requirement is usually expressed in terms of the crop water requirement (CWR), which is the amount of water required to meet the evapotranspiration (ET) needs of the crop.
3. Irrigation Scheduling: The timing of irrigation is crucial for efficient water use and crop growth. Over-irrigation can lead to waterlogging, leaching of nutrients, and soil erosion, while under-irrigation can result in reduced crop yields. Irrigation scheduling involves determining the frequency and amount of water required for irrigation based on the crop growth stage, soil type, weather conditions, and other factors.
4. Water Quality: The quality of water used for irrigation is also important. Poor quality water can contain high levels of salts, which can accumulate in the soil and damage the crop. Water with high salinity or sodium content should be avoided or treated before use.
5. Irrigation Management: Effective irrigation management involves ensuring that the irrigation system is functioning properly and efficiently, and that water is being applied evenly across the field. Monitoring soil moisture levels and adjusting irrigation schedules accordingly can help to improve water use efficiency and crop yields.

Overall, irrigation is a critical component of crop production, and proper irrigation management can help to improve crop yields and reduce water use.

INTERCULTURE

Interculture is the process of managing the growth of crops between rows and within the crop itself. The objective of interculture is to control weeds, loosen the soil, and provide appropriate soil aeration and water-holding capacity. This practice is also known as cultivation or tillage.

Interculture activities vary depending on the type of crop, the stage of crop growth, and the specific needs of the soil. Some common interculture practices include:

1. Weed control: Weeds compete with crops for nutrients, water, and sunlight. Regular weeding helps to keep the weed population under control, reducing the competition with the crop.
2. Soil aeration: Regular interculture helps to loosen the soil, increasing its porosity, and allowing air and water to penetrate more easily. This can improve root development and increase water holding capacity.
3. Fertilizer application: Fertilizer can be applied during interculture by broadcasting, top-dressing, or banding. The timing and method of application depend on the type of fertilizer and the crop.
4. Pest control: Interculture can also help to control pests that may be damaging the crop. By breaking up soil clods and removing debris, interculture can disrupt the habitat of pests, reducing their population.
5. Mulching: Mulching involves covering the soil around the plants with organic material such as straw or leaves. This helps to suppress weed growth, retain moisture, and improve soil structure.

Interculture practices should be carefully timed to avoid damage to the crop. For example, interculture should not be performed during sensitive stages of crop growth, such as when the crop is flowering or fruiting.

WEED CONTROL

Weed control is an important aspect of crop management as weeds compete with crops for nutrients, sunlight, and water. Effective weed control can increase crop yield and quality. There are several methods of weed control including:

1. Mechanical methods: This involves the physical removal of weeds through hand weeding, hoeing, or plowing. These methods are effective but can be time-consuming and labor-intensive.
2. Chemical methods: The use of herbicides is a common method of weed control. Herbicides can be selective or non-selective, with selective herbicides targeting specific weed species and non-selective herbicides killing all vegetation. Herbicides should be applied according to the label instructions to ensure safety and effectiveness.
3. Cultural methods: Crop rotation, intercropping, and proper irrigation and fertilization can reduce weed growth and competition with crops.
4. Biological methods: The use of natural enemies such as insects, mites, or pathogens to control weeds can be effective, but requires careful management to prevent negative impacts on non-target organisms.

The timing of weed control is also important. Weeds should be controlled as early as possible before they compete with crops for resources. Herbicides should be applied when weeds are actively growing and at the correct stage of growth for maximum effectiveness. Regular monitoring and early detection of weeds is crucial for effective weed control.

COMMON PESTS, DISEASES AND THEIR CONTROL

Common pests and diseases in agriculture can cause significant damage to crops and result in yield loss if not properly controlled. Here are some important details about common pests and diseases and their control:

1. Bacterial diseases: Bacterial diseases in crops are caused by various bacteria that infect plants through wounds or natural openings. Some common bacterial diseases include bacterial blight, bacterial wilt, and bacterial spot. Control measures include the use of resistant varieties, crop rotation, sanitation, and copper-based bactericides.
2. Fungal diseases: Fungal diseases are caused by various types of fungi that infect plants and cause symptoms such as leaf spots, blights, and rots. Some common fungal diseases include powdery mildew, downy mildew, and rusts. Control measures include the use of resistant varieties, crop rotation, fungicides, and cultural practices such as pruning and removal of infected plant parts.
3. Viral diseases: Viral diseases in plants are caused by various viruses that are transmitted by insects or other vectors. Symptoms of viral diseases include stunting, yellowing, and mottling of leaves. Control measures include the use of virus-free seed or planting material, insecticides to control vectors, and removal of infected plants.
4. Nematode diseases: Nematodes are microscopic roundworms that live in soil and feed on plant roots. Symptoms of nematode damage include stunting, yellowing, and wilting of plants. Control measures include the use of resistant varieties, crop rotation, and soil fumigation with nematocides.

Integrated pest management (IPM) is an approach that combines different control measures to manage pests and diseases in a sustainable manner. It includes cultural practices such as crop rotation, sanitation, and use of resistant varieties, as well as biological control methods such as the use of natural enemies and biopesticides. Chemical control measures such as the use of pesticides are also used in IPM, but only as a last resort and with proper application techniques to minimize environmental impact.

STORAGE, PROCESSING AND MARKETING OF MAJOR FIELD CROPS

Storage, processing, and marketing of major field crops are essential components of agriculture. Proper storage and processing ensure the quality of the crops, while effective marketing helps in earning a better price for the farmers. Here are the important details regarding storage, processing, and marketing of some major field crops in India:

1. RICE

Rice (Oryza sativa) is a crucial staple food for over 3 billion people globally. It is cultivated in more than 100 countries across 154 million hectares, producing approximately 600 million tonnes with an average productivity of 3.9 tonnes per hectare. Among the rice-growing nations, India holds the largest area under cultivation. However, in terms of production, India ranks second with 131.2 million tonnes of coarse rice.

In India, rice is grown on an area of 44.6 million hectares, producing 132 tonnes with an average productivity of 2.97 tonnes per hectare. Rice is cultivated in almost all states in India, with Uttar Pradesh, West Bengal, and Punjab being the leading states in terms of area, production, and productivity, respectively. Punjab has the highest rice productivity among all states.

Around 90% of the world's rice is grown in Asia, and it provides approximately 29.4% of the total calories per capita per day in Asian countries. Milled rice generally contains 6-7% protein, with low fat content (2.0-2.5%), and most of the fat is lost during the milling process.

Climatic and Soil Requirements

Rice cultivation extends from sea level to as high as 3000 m above mean sea level (amsl) in India. High temperature, high humidity and high rainfall have considerable effect on growth and development of rice plant. Rice crop is grown during Kharif season in north-western plains zone, but in south and north-eastern parts of the country, it is grown in all the three seasons, as these areas do not have very cold weather during winter. Rice crop needs a hot and humid climate. It is essentially a C3 plant.

The wide range of agro-climatic conditions suggests an equally wide variety of soils. As regards texture, rice is grown on loamy sands in Punjab to heavy clay loams or clays in Andhra Pradesh and some other states. Soils having good water holding capacity with good amount of clay and organic matter are ideal for puddled rice.

Rice Eco-systems in India

Rice farming is practiced in several agro-ecological zones in India. No other country in the world has such diversity in rice ecosystems than India. Rice cultivation in India is done in four distinct types of ecosystems:

- Irrigated rice eco-system
- Rainfed upland rice eco-system
- Rainfed lowland rice eco-system
- Flood prone rice eco-system

Rice cropping pattern in India vary widely from region to region and to a lesser extent from one year to another year depending on a wide range of soil and climatic conditions. Some of the rice based cropping patterns being followed in the country are: Rice-wheat, rice-wheat-mungbean, rice-toria-wheat, rice-toria/chickpea, rice-wheat/barley/potato, rice-potato-blackgram, rice -pea-greengram and rice-rice-rice

Recommended Varieties

A good number of rice varieties/hybrids having resistance to various biotic and abiotic stresses and grain quality have been developed in India.

Some of the improved cultivars of rice are described as under:

Important Rice Cultivars Recommended for Different States

Cultivar type	Rice cultivars
Hybrids	APHR 1, DRRH-3, PA 6201, Pusa RH 10, HRI 120, Sahyadri-2, UPRH 27, Rajalaxmi, Pant Sankar Dhan 1, Pant Sugandh Dhan-17, PHB 71
Basmati/ scented varieties	Basmati 370, Pusa Basmati 1, Taraori Basmati (Karnal local), Pusa Sugandh 3, Pusa Sugandh 4, Pusa Sugandh 6, PRH 10, Pant Dhan 15, Punjab Basmati-1, Pusa Basmati 1121, Pusa Basmati 6, Pusa Basmati 1509
Other improved varieties	Mahamaya, GK 5003, Pusa 33, Pusa 169, Mehsuri, JKRH-401, Gurjari, GR-6, Dandi, HKR-127, Bhrigu Dhan, Himalaya 2216, SKAU 23, SKAU 27, GK 5003, Gauri, Sweta, Ratnagiri 24, Rajeshwari, PR 108, PR 109, PMK 2, Pant Dhan 10, Pant Dhan 11, VL Dhan 221, IR 20, Jayanthi

Methods of Cultivation

Rice is generally grown under dry or wet cultivation methods, which are briefly described below:

(a) Dry Cultivation

1. Direct seeded rice: Rice is sown directly in dry soil (dry seeding) or wet soil (wet seeding), and irrigation is given to keep the soil sufficiently moist for good plant growth, but the soil is never flooded. Dry system of rice cultivation is followed in uplands. Sowing of rice is usually done in May-June in the case of the crop dependent on south-west monsoon and in September for the crop dependent on north-east monsoon.

   Three methods are commonly followed in sowing dry and semi-dry crop. These are broadcasting, drilling or sowing in furrows behind country plough, and dibbling in general, a seed rate of 30-50 kg ha^{-1} is required for drilling, while 60-100 kg ha^{-1} is required for broadcasting. A row spacing of 15-20 cm is optimum for upland rice. There are mainly two methods of direct seeding.

   - Dry seeding: In dry seeding, seed is directly sown in dry soil either by seed drill or broadcasting of un-sprouted seed in well prepared and leveled dry soil.
   - Wet seeding: In wet seeding, seed is directly sown in puddled soil either by drum seeder or broadcasting of sprouted seed in wet soil.

2. Aerobic rice: It is a high-yielding rice, grown in non-puddled, aerobic soils under irrigation and high external inputs. Irrigation is applied when the soil becomes dry, and the quantity of applied water is sufficient to bring the soil to field capacity. The realization of water savings combined with high yields depends on good water management. Dry seeding of rice can be done by drilling the seed into a fine seedbed at a depth of 2–3 cm. Weed management is a critical factor in aerobic rice. Timely application of herbicides and two or three hand-weeding may provide effective control. Seeding under dry situations is done in three different ways viz. drilling, dibbling, and broadcasting.

(b) Wet Cultivation

Conventional rice cultivation: The conventional rice cultivation is a wet system of cultivation and rice is grown under wet season right from the start. In this system, the field is brought to a soil puddle by repeated ploughing with 5-7 cm standing water. After getting the requisite puddle, rice seedlings are transplanted or sprouted seeds are direct seeded. The seedlings of rice are grown in nursery before transplanting.

Transplanting Operation

Time of planting is the most important factor influencing the yield of the crop. In general, timely transplanting of 20-25 days old seedlings in wet season is ideal. In general, 20 cm × 10 cm, 20 cm × 15 cm or 15 cm × 15 cm spacing is ideal in transplanted rice. For realizing the yield potential of high yielding varieties of rice, 2-3 seedlings per hill is generally recommended. In rice hybrids where the tillering is more profuse, 1-2 seedlings per hill is sufficient. Depth of transplanting rice seedlings is 2-4 cm.

System of Rice Intensification (SRI)

SRI is an unusual innovation that can raise productivity of land, labour, water, and capital invested in irrigated and rainfed rice production. SRI has evoked considerable interest among Agronomists over last decade and posed interesting research issues.

SRI may prove as a boon to enhance productivity while using less seed and irrigation water than conventional rice farming. The SRI essentially comprises the following methodological components:

- Shallow (1–2 cm) transplanting of young seedlings at the two-leaf stage into a moist seedbed.
- Transplanting of single rice seedling at 25 cm × 25 cm spacing.
- A minimum of three hand weedings at 10–12, 22–25 and 40–42 days after transplanting.
- Farmers may use mechanical weeding tool called weeder to remove weeds and aerate soil surface.
- Alternation of wetting and drying of the field for soil aeration during vegetative growth.
- Addition of organic manures to supply adequate nutrients and to improve soil structure. If necessary, chemical fertilizers may be used as a supplement.

Nutrient Management

Adequate supply of all the essential plant nutrients is a must for getting good yield of rice. A dose 100-150 kg N/ha is generally recommended for high yielding varieties of rice. A dose of 45-60 kg P_2O_5/ha and 40 kg K_2O/ ha is generally recommended for rice. Zn deficiency in rice-growing areas of India is widespread. Zinc sulphate @ 20-25 kg / ha is generally recommended in zinc-deficient soils.

Water Management

Rice is the largest consumer of water; about 3000-5000 litres water is required to produce 1 kg rice. The principal water loss processes from paddy fields are via run- off, percolation, seepage and evapotranspiration or consumptive water use. The submergence (2-5 cm) throughout the crop growth period is conducive to higher yields. Under water scarcity, the practice of intermittent submergence during the critical stages (tillering, flowering) and maintenance of saturation or field capacity in rest of the growth stages is recommended.

Weed Management

Hand weeding is most widely used method for controlling weeds in rice. Normally two weedings are done. Time of weeding slightly varies in different regions but weedings are generally done within 15 to 45 days after sowing. Weeding with some implements such as hand hoes, weeders and bullock drawn desi plough can be done to control weeds in rice. Use of herbicides is gradually increasing in rice culture. Herbicides are expensive to small farmers but not to the large farmers who face the problem of labour shortage.

Chemical Weed Management in Rice

Rice	Herbicides	Dose (kg a.i./ha)	Application time and remarks
Rice nursery	Butachlor	1.0-1.5	Pre-emergence at 5-6 days after sowing (DAS); If moisture is less in soil, irrigation should be done immediately.
	Pendimethalin	1.0-1.5	Pre-emergence at 5-6 DAS; If moisture is less in soil, irrigation should be done immediately.
	Pretilachlor (S)	0.3-0.4	Pre-emergence at 3-5 DAS.
Direct-seeded upland rice	Butachlor	1.0-1.5	To be applied before emergence of crop; One hand weeding at 30-35 DAS will supplement herbicide treatment.
	Pendimethalin	1.0-1.5	To be applied before emergence of crop; One hand weeding at 30-35 DAS will supplement herbicide treatment.

	Pretilachlor (S)	0.3-0.4	Pre-emergence at 3-5 DAS.
	Metsulfuron-methyl	0.010-0.015	Post-emergence at 30-35 DAS; basically a broad-leaved weed killer and recommended as a substitute of 2,4-D.
Direct-seeded puddled and transplanted rice	Butachlor	1.0-1.5	Pre-emergence at 3-5 days after transplanting (DAT) on saturated soil; No irrigation or standing water impounded for at least 3 days after treatment.
	Pendimethalin	1.0-1.5	Pre-emergence at 3-5 DAT on saturated soil; No irrigation or standing water impounded for at least 3 days after treatment.
	Pretilachlor (S)	0.3-0.4	Pre-emergence at 3-5 DAT.
	Metsulfuron-methyl	0.010-0.015	Post-emergence at 30-35 DAS; basically a broad-leaved weed killer and recommended as a substitute of 2,4-D.

Disease Management

To overcome the diseases, the seed should be disease free. For fungal and bacterial diseases, seed should be treated with bavistin @ 2g kg $^{-1}$ seed. Fungicides can be sprayed to control a diseases

Symptoms and Management of Important Diseases of Rice in India

Disease and its causal organism	Symptoms	Management
Leaf and neck blast	Initial symptoms on the leaves are white to grayish green circular lesions/spots with dark green borders, which may enlarge and coalesce to kill the entire leaves. Lesions on the neck cause the girdling of the neck and the panicle to fall over.	• Early sowing of seeds and balanced use of fertilizers. • Planting resistant varieties against the rice blast is the most practical and economical way. • Systemic fungicides are effective against the disease.
Bacterial leaf blight	Water-soaked to yellowish stripes on leaf blades or starting at leaf tips. Severely infected leaves tend to dry quickly.	• Field sanitation such as removing weed hosts, rice straws, ratoons, and volunteer seedlings. • Use of resistant varieties. • Seed treatment with bleaching powder (100 μg/ml) and zinc sulfate (2%) reduce bacterial blight.

Pest Management

Most of the rice pests are distributed throughout India, however, only a few pests are economically important in different regions. Agronomic practices and use of resistant cultivars should be given preference for pest management. The use of selective pesticides should also be stressed for efficient pest management.

Important Insect Pest, Nature of Damage and Pest Management in Rice

Insect-pest	Nature of damage	Management
Stem borer (yellow)	Symptoms of stem borer damage are deadhearts and whiteheads. Whiteheads are discolored panicles with empty or partially filled grains. Larvae feed on the tissues around the node.	• Adopt seedling root dip treatment in 0.05% chlorpyriphos emulsion forone minute before transplanting in endemic areas. • Apply carbofuran 3G @ 20 kg ha^{-1} or phorate 10 G @ 12.5 kg ha^{-1} or fenitrothion 50EC @ 0.1%.

Harvesting, Threshing and Yield

The plant should be cut close to the ground at ripening and left for drying. Threshing can be accomplished by manual methods, pedal threshers or power driven stationary threshers. Combine machines can be employed for combined harvesting and threshing. The produce should be properly sun-dried. The optimum moisture content for storage of rice grains is 12%. A well managed crop of mid-late duration (135-150 days) varieties and hybrids yield about 6–7 t/ha, whereas short duration cultivars yield about 4.5–5.5 t/ha.

2. WHEAT

Wheat (Triticum aestivum) is one of the most important cereal crops in the world, cultivated on a large scale for its edible seeds, which are used to make flour and a wide range of food products. It is a member of the grass family and belongs to the genus Triticum, which also includes other cereal crops such as barley and rye.

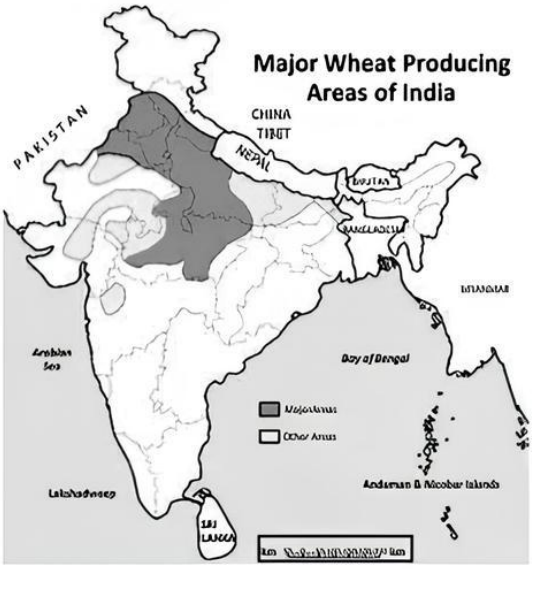
Wheat is widely grown in temperate regions, and it is the second most produced cereal crop after corn. It is a staple food for a large portion of the world's population, particularly in Europe, North America, and Asia. Wheat is a rich source of carbohydrates, protein, and essential nutrients, making it an important component of a healthy and balanced diet.

Climatic and Soil Requirements

Wheat is grown over a wide range of latitudes ranging between 60°N and 60°S and altitudes ranging from sea level to 3500 m amsl in the tropics and subtropics. Normally, the most ideal conditions for wheat cultivation are cool and moist weather during the vegetative growth period and warm and dry weather during grain formation. The optimum temperature for the germination of wheat is between 20-22°C, though wheat grain can also germinate at 4°C. The optimum temperature for vegetative growth ranges from 16 to 22°C. During the grain development, wheat requires a mean maximum temperature of about 25°C for at least four to five weeks. Wheat grows well in those areas where annual rainfall ranges between 250 and 1800 mm. Wheat crop also cannot withstand extended periods of soil moisture stress. Rainfed wheat requires a minimum evenly distributed winter rainfall of 15 to 20 cm. Wheat is grown on a wide variety of soils.

Major Cultivated Species of Wheat

- Common wheat or bread wheat (T. aestivum): A hexaploid species that is the most widely cultivated in the world.



- Durum wheat (T. durum): The tetraploid form of wheat and the second most widely cultivated wheat today.

Seed and Sowing

Under irrigated timely sown condition, wheat sowing may be done in the first fortnight of November in north India and the middle of November in north-east and central India. Under late sown conditions, the wheat is sown in first fortnight of December. Rainfed wheat is generally sown from second fortnight of October to early-November to get maximum benefit from residual soil moisture. Seeds can be sown through broadcasting or in lines in rows 20 cm apart. Under normal conditions, a seed rate of 100 kg/ha is sufficient. Under late sown conditions, seed rate should be increased by 25 per cent. Irrigated wheat is spaced 22.5 cm between rows and 8-10 cm between plants. Rainfed wheat is spaced 25-30 cm between rows and 5-6 cm between plants. Seed depth should be around 5 cm.

Nutrient Management

The general $N + P_2O_5 + K_2O$ recommendations for irrigated and rainfed wheat are 120 + 60 + 30 kg/ha and 80 + 40 + 20 kg/ha, respectively. Full dose of phosphorus and potassium and half of nitrogen should be applied at the time of sowing, while remaining half dose should be top dressed in two equal splits one at first irrigation and other at flowering stage. Farmyard manure (FYM) or organic manures @ 10 t/ha at the time of sowing is beneficial for long-term fertility maintenance.

Water Management

Wheat requires about 300-400 cm of irrigation water (4-6 irrigations), depending upon climatic factors, soil characteristics and the duration of the variety. If irrigation water is a constraint, then apply irrigation at critical stages.

Number of irrigations based on the availability of water

No of Irrigations	Critical stages for irrigation
1	CRI
2	CRI + LJ
3	CRI + B + M
4	CRI + LT + F + M
5	CRI + LT + LJ + F + M
6	CRI + LT + LJ + F + M + D

CRI – Crown root initiation (21 DAS), LT – Late tillering (42 DAS), LJ – Late jointing (60 DAS), F – Flowering (80 DAS), M – Milk (95 DAS), D – Dough (115 DAS).

Weed Management

The critical period of weed competition in wheat is 30-45 days after sowing (DAS). Hand weeding with a khurpi or hand hoe after 20-25 DAS is used as conventional practice. A pre-emergence application of pendimethalin (Stomp 30 EC) @ 1 kg a.i./ha in 500- 750 L/ha of water within 3 DAS provides a broad spectrum control of weeds in wheat. However, post-emergence application (25-30 DAS) of herbicides like sulfosulfuron @ 25 g/ha or fenaxaprop-p ethyl @ 100-120 g/ha is necessary for effective weed control.

Disease Management

Rusts: Wheat is infected by brown, yellow and black rusts. Brown or leaf rust is caused by a fungus known as Puccinia recondite tritici. Yellow or stripe rust is caused by the fungus, Puccinia striiformis. Black or stem rust of wheat is caused by the fungus Puccinia graminis tritici. For controlling rusts, treat the seed with Trichoderma viride @ 4 g/kg seed. Late sown crop is more susceptible to rust. Hence avoid late sowing of wheat. High nitrogen dose favours rust infection, whereas high potash dose reduces rust infection. Hence there is need for balanced fertilization. Spray the crop with propiconazole (Tilt 25 EC) @ 0.1% at yellow rust initiation. This spray will also help in the control of powdery mildew and Karnal bunt diseases. Second and third spray may be repeated with an interval of 10-15 days.

Loose smut: Loose smut is caused by fungus Ustilago nuda tritici. Terminal symptom of loose smut is the production of black powder in place of wheat grains in the ears. As the ear formation starts, fungus accumulates in the floral parts, which are completely destroyed due to formation of the black powder. Loose smut can be controlled by growing loose smut resistant varieties. Seed treatment should be done with carboxin (Vitavax 75 WP) @ 1.25 g/kg seed. Uproot the infected plants, bury them underground or burn to avoid further field infection.

Karnal bunt: Karnal bunt or partial bunt is caused by fungus Neovossia indica. A portion of infected grain along its groove is converted into a black powdery mass. The black powder gives a foul smell due to presence of trimethylamine. Do not grow highly susceptible wheat varieties. One spray of propiconazole (25 EC) @ 0.1% at ear head emergence stage can be given to attain near complete control.

Pest Management

Termites: The damaged plants dry up completely and can be easily pulled out. Infestation is heavy under unirrigated conditions and in the fields where undecomposed FYM is applied before sowing. Termites can be controlled by seed treatment with fipronil (Regent 5FS @ 0.3 g a.i./kg seed).

Harvesting, Threshing and Yield

The most suitable stage for harvesting wheat is when plants are completly dry and the grains becomes hard and contain 20-25% moisture. Wheat crop harvested manually or by reapers, is dried for 3-4 days on the threshing floor and then threshing is done by threshers. A well managed crop may yield about 3.5 to 4.5 t grains/ha.

3. MAIZE

Maize (Zea mays L.) is a highly versatile crop that can adapt to various agro-climatic conditions. It is the only grain crop with multiple types and is grown for diverse purposes such as normal yellow/white grain, sweet corn, baby corn, popcorn, quality protein maize (QPM), waxy corn, high amylase corn, high oil corn, fodder maize, etc. Globally, maize is known as the "queen of cereals" due to its high genetic yield potential among cereals.

In India, maize is the third most important food crop after rice and wheat.

It is cultivated in 8.78 m ha mainly during Kharif season which covers 80% area. Predominant maize growing states collectively contributing to more than 80% of total national maize production are Andhra Pradesh (20.9%), Karnataka (16.5%), Rajasthan (9.9%), Maharashtra (9.1%), Bihar (8.9%), Uttar Pradesh (6.1%), Madhya Pradesh (5.7%) and Himachal Pradesh (4.4%).

Climatic and Soil Requirement

Maize is grown globally from 50°N to 40°S, and from sea level up to 4000 m altitude. Maize crop requires good amount of moisture and can be grown in areas receiving well distributed rainfall of 500 to 1000 mm. It uses water more efficiently and relatively drought resistant from establishment to tasseling stage of the crop where it can stands with less moisture. Maize is relatively well adapted to a wide range of soils with pH 5.0 to 8.0. Maize can be grown successfully in a variety of soils, ranging from loamy-sand to clay-loam. Being a sensitive crop to excess soil moisture; it is desirable to have provision of proper drainage in maize.

Maize Based Cropping Systems in India

Maize-wheat is the 3rd most important cropping systems after rice-wheat and rice-rice that contributes about 3% in the national food basket. The other major maize systems in India are maize-mustard, maize-chickpea, maize-maize, cotton-maize etc.

Time of Sowing

Maize can be grown in all seasons viz; Kharif (monsoon), post monsoon, Rabi (winter) and spring. The optimum time of sowing are given below:

Season	Optimum time of sowing
Kharif	Last week of June to first fortnight July
Rabi	Last week of October for inter cropping and up to 15th of November for sole crop
Spring	First week of February

Seed Rate and Plant Geometry

The seed rate depends on purpose, seed size, plant type, season, sowing methods etc. The following crop geometry and seed rate should be adopted.

S.No.	Purpose	Seed rate (kg/ha)	Plant geometry (plant × row in cm)
1	Normal grain maize	20	60 × 20
2	Quality protein maize (QPM)	20	60 × 20
3	Sweet corn	8	75 × 25
4	Pop corn	12	60 × 20
5	Green cob (normal maize)	20	60 × 20
6	Fodder maize	50	30 × 10

Tillage and Crop Establishment

Generally, the raised bed planting is considered as best planting method for maize during monsoon and winter seasons both under excess moisture as well as limited water availability/rainfed conditions. Maize can also be successfully grown without any primary tillage under no-till situation with less cost of cultivation, higher farm profitability and better resource use efficiency.

Nutrient Management

Application of 10-15 t FYM/ha alongwith NPK fertilizers @ 120-150 kg N, 60-80 kg P_2O_5, 60-70 kg K_2O and 25 kg $ZnSO_4$ /ha is recommended in general for getting higher yield of HYV/hybrid maize. Full dose of P & K and half of N should be applied at the time of sowing, while remaining half N dose should be top dressed in two equal splits one dose at around knee high stage and other dose at tasseling stage of the crop keeping in view moisture availability in the field.

Water Management

The irrigation water management depends on season as about 80% of maize is cultivated during monsoon season particularly under rainfed conditions. In general, the irrigation should be applied in furrows up to 2/3rd height of the ridges/beds. Young seedling, knee high stage, flowering and grain filling are the most sensitive stages for water stress and hence irrigation should ensured at these stages.

Weed Management

Weeds are serious problem in maize particularly during Kharif season and they cause upto 35% yield losses. Thus, timely weed management is must to achieve higher yields. Pre-emergence application of atrazine (Atratraf 50 WP) @ 1.0-1.5 kg a.i./ha in 600 L water or pendimethalin (Stomp 30 EC) @ 1-1.5 kg a.i./ in 500-750 L is effective way for weed control. One-to-two hoeing are recommended for aeration and uprooting of the remaining weeds, if any.

Disease Management

The major diseases of maize and their management practices are described below:

Turcicum leaf blight: The disease is prevalent in cooler conditions or with high humidity. Long, elliptical, grayish-green or tan lesions (2.5-15 cm) appear on lower leaves progressing upward. Resistant varieties alongwith need-based sprays of mancozeb @ 2.5 g/L (with adjuant @ 0.05%) at 8-10 days interval decreases its incidence.

Maydis leaf blight: It is a major disease in the areas having warm humid temperate to tropical climate. Lesions on the leaves elongated between the veins, tan with buff to brown or dark reddish brown borders. Growing of resistant varieties with need based sprays of mancozeb or zineb @ 2.5g/L of water are recommended to control this disease.

Pest Management

Stem Borer: Major pest of maize in India is stalk borer. Its attack occurs during monsoon season. It lays eggs 10-25 days after germination on lower side of the leaves. The larva of the Chilo enters in the whorl and cause damage in the leaves.

Termites: Termite is also an important pest in many areas especially zero-tilled maize. For control of termite, fipronil granules @ 20 kg/ha on termite appearance followed by light irrigation is the recommended practice. If the termite incidence is in patches, the spot application of fipronil @ 2-3 granules/plant should be done.

Harvesting, Threshing and Yield

The crop acquires physiological maturity when black layer starts forming on the tip of the grains. The crop must be harvested at less than 22 to 25% moisture in grains with husk colour turning pale brown. The harvesting of the cob is done manually. After de-cobbing and threshing, the maize grains must be dried upto 12% moisture level for safe storage. A well managed maize HYV's and hybrid maize may yield about 4-5 and 5-7 t grains/ha, respectively.

4. SORGHUM

Sorghum is a versatile cereal crop that has been cultivated for thousands of years around the world, especially in Africa, Asia, and the Americas. It is a major staple food for millions of people, particularly in the arid and semi-arid regions where other crops are difficult to grow due to water scarcity and high temperatures. Sorghum is also used for animal feed, fuel, and industrial purposes, such as making paper, syrup, and biofuels. In recent years, there has been renewed interest in sorghum as a sustainable crop that can help address food and energy security, climate change, and rural development challenges. Sorghum is known for its ability to tolerate drought and extreme temperatures, adapt to different soil types, and resist pests and diseases, making it a resilient and valuable crop for farmers and communities.

Climatic and Soil Requirements

- Sorghum is a versatile crop that can grow in a wide range of climates, from tropical to subtropical and temperate regions.
- The crop requires a temperature range of 20-35°C for optimum growth and yield.
- Sorghum is relatively drought-tolerant and can grow on soils with low fertility, but performs best on well-drained soils with a pH range of 6-7.

Seed Rate and Sowing Method

- The recommended seed rate for sorghum is 15-20 kg/ha.
- The crop can be sown either by broadcasting or drilling method.
- The optimal time of sowing is between May to June in India, depending on the rainfall pattern.

Cultivars

- There are many cultivars of sorghum available, each adapted to specific agro-climatic regions and intended use.
- Some of the popular cultivars in India are CSH 9, CSV 15, Maldandi, and SPV 462.

Nutrient Management

- Sorghum requires a moderate amount of nutrients for optimum growth and yield.
- The recommended dose of NPK (nitrogen, phosphorus, and potassium) for sorghum is 60-80:40:40 kg/ha.
- Organic manures like farmyard manure (FYM) and green manure can also be used to enhance soil fertility.

Water Management

- Sorghum is relatively drought-tolerant, but requires timely irrigation during the critical growth stages.
- The crop needs about 450-500 mm of water during the growing season.
- Irrigation should be applied at an interval of 10-15 days during the vegetative stage and 20-25 days during the reproductive stage.

Weed Management

- Sorghum is vulnerable to weed competition, especially during the early growth stages.
- Hand weeding and hoeing are the common methods of weed control in sorghum.
- Pre-emergence herbicides like atrazine, metribuzin, and pendimethalin can also be used to control weeds.

Harvesting and Yield

- Sorghum takes about 100-120 days to mature, depending on the variety and environmental conditions.
- The crop is harvested when the grain moisture content reaches 18-22%.
- The yield of sorghum ranges from 1-2 t/ha under rainfed conditions and can go up to 3-4 t/ha with proper nutrient and water management.

Sorghum is a versatile crop that can grow in a wide range of climates and soil types. The crop has a good potential to provide food, feed, and fuel in areas with limited water resources. With proper management practices, sorghum can be a profitable crop for farmers.

5. PEARL MILLET

Pearl Millet, also known as Bajra, is a warm-season crop that is grown primarily for its nutritious grain. It is one of the oldest cultivated grains in the world, with a history of domestication dating back more than 4000 years in Africa and Asia. Pearl Millet is a major staple food in many parts of India, Africa, and Asia, particularly in regions with low rainfall and poor soil fertility. It is a hardy crop that can tolerate drought, heat, and pests, making it an important food and income source for millions of smallholder farmers.

Besides its nutritional value, Pearl Millet has many other uses, including fodder for livestock, fuel, and thatching material. In recent years, there has been a growing interest in Pearl Millet as a climate-resilient and sustainable crop that can contribute to food security, poverty reduction, and rural development. With its high tolerance to environmental stresses and adaptability to different agro-climatic conditions, Pearl Millet has the potential to play a crucial role in meeting the growing demand for food and feed in a changing world.

Climatic and Soil Requirements

- Pearl millet is best adapted to warm and dry climates with average temperatures between 25-30°C.
- The crop can tolerate temperatures up to 42°C and can survive in areas with annual rainfall as low as 200 mm.
- Pearl millet can grow on a wide range of soils, from sandy to clay soils, but performs best on well-drained soils with a pH range of 6.5-7.5.

Seed Rate and Sowing Method

- The recommended seed rate for pearl millet is 5-7 kg/ha.
- The crop can be sown either by broadcasting or drilling method.
- The optimal time of sowing is between mid-May to mid-July in India, depending on the rainfall pattern.

Cultivars

- There are many cultivars of pearl millet available, each adapted to specific agro-climatic regions and intended use.
- Some of the popular cultivars in India are HHB 67, J 104, Pusa 704, Pusa 345, and ICTP 8203.

Nutrient Management

- Pearl millet requires a moderate amount of nutrients for optimum growth and yield.
- The recommended dose of NPK (nitrogen, phosphorus, and potassium) for pearl millet is 30-40:20:20 kg/ha.
- Organic manures like farmyard manure (FYM) and green manure can also be used to enhance soil fertility.

Water Management

- Pearl millet is a drought-tolerant crop, but requires timely irrigation during the critical growth stages.
- The crop needs about 350-450 mm of water during the growing season.
- Irrigation should be applied at an interval of 10-15 days during the vegetative stage and 20-25 days during the reproductive stage.

Weed Management

- Pearl millet is vulnerable to weed competition, especially during the early growth stages.
- Hand weeding and hoeing are the common methods of weed control in pearl millet.
- Pre-emergence herbicides like atrazine, metribuzin, and pendimethalin can also be used to control weeds.

Harvesting and Yield

- Pearl millet takes about 70-100 days to mature, depending on the variety and environmental conditions.
- The crop is harvested when the grain moisture content reaches 20-25%.
- The yield of pearl millet ranges from 1-2 t/ha under rainfed conditions and can go up to 3-4 t/ha with proper nutrient and water management.

Pearl millet is a hardy crop that can thrive in arid and semi-arid regions with proper management practices. The crop has a good potential to provide food and feed in areas with limited water resources.

6. GROUNDNUT

Groundnut, also known as peanut or mungfali (Arachis hypogaea L), is a legume that contains about 45% oil and 26% protein in its seed. It is a rich source of essential nutrients such as niacin, folate, fiber, magnesium, vitamin E, manganese, and phosphorus. Globally, India has the largest acreage and is the second largest producer of groundnuts. In India, groundnuts are grown on an area of 5.86 million hectares, with a production of 8.26 million tonnes and an average productivity of 1411 kg/ha. The major groundnut-growing states in India are Gujarat, Tamil Nadu, Andhra Pradesh, Maharashtra, Karnataka, and Rajasthan. Morphologically, groundnuts are classified into two groups: (i) erect or bunch type (Arachis hypogaea subspecies fastigiata), and (ii) trailing or spreading type (Arachis hypogaea subspecies procumbens).

Climatic and Soil Requirements

Groundnut is grown in the tropical and subtropical countries and up to an altitude of 1000 m. The crop can be grown successfully in places receiving a minimum rainfall of 500 mm and a maximum of 1250 mm. The rainfall should be well distributed during flowering and pegging stages. The groundnut cannot withstand long and severe drought or water stagnation. During ripening period, it requires about a month of warm and dry weather.

Most suitable soils for groundnut production are well-drained, light-textured, loose sandy-loam or sandy clay loam with good drainage. Soils should have reasonable high calcium, pH 5.5 to 7.0 and a moderate organic matter.

Cropping Systems

Groundnut is grown in rotation with wheat, lentil, chickpea, pea, barley, etc. It is grown as a mixed crop with pearl millet, maize, sorghum, castor and cotton. The most common cropping systems are: groundnut-wheat/barley/chickpea/field pea/lentil.

Varieties

Some promising varieties recommended for different states are ICGS 76, Tirupati 2, Girnar 1, ICGS 37, ALR 3, ICGS 11, HNG 10, Punjab Mungphali 1, Mukta, Chitra, Jyoti, RS-1, M-335, MH-4, BG-2, TG-1, and TMV-6.

Seed Rate and Sowing Method

A seed rate of 80-100 kg/ha is enough for bunch type and 60-80 kg/ha for spreading type groundnut cultivars. In bunch types, the row to row distance is kept 30-40 cm and in spreading types 45-60 cm. Plant to plant distance would be 15 and 20-22.5 cm for bunch and spreading types, respectively. Sowing can be done through tractor-mounted groundnut planter. The depth of sowing should be 5 cm. One ploughing with soil turning plough followed by two harrowings would be sufficient to achieve a good surface tilth up to 12-18 cm depth.

In India, groundnut is grown over four seasons. Sow the rainfed crop with the onset of monsoon in the last week of June to first week of July. In irrigated conditions, sow in last week of June. In rabi, groundnut is sown during November-December. Summer groundnut is sown during mid-February. For seed purposes, pods should be shelled by hand one week before sowing. Hand shelling ensures little damage to seeds. Treat the selected kernels with thiram or captan or ceresan @ 5 g/kg kernels to check seed and soil borne diseases.

Nutrient Requirement

Groundnut, being legume, needs more phosphorous, and being an oilseed requires more sulphur. Seed should be inoculated with efficient strains of Rhizobium culture. Well decomposed FYM or compost @ 5-10 t/ha should be applied about 15-20 days before sowing. Apply 15 kg N, 50 kg P_2O_5 and 25 kg K_2O /ha at the time of sowing. Use of gypsum @ 100-150 kg/ha during field preparation can add to the yield. Calcium too has pronounced effect on proper development of pods and kernels.

Water Management

Being a rainy season crop, groundnut does not require irrigation. The field should be well drained. Flowering and pegging are the most critical stages for irrigation.

Weed Management

Two weedings 20 and 45 DAS are recommended. Pre-emergence application of pendimethalin @ 1 kg a.i./ha in 800-1000 L water/ha along with 2 intercultures at 30 and 45 DAS have been recommended in irrigated conditions.

Disease Management

Tikka disease or leaf spot (ansal organisation): The spots on leaves are circular to irregular and are surrounded by a yellow halo. The spots on the upper surface look like reddish brown to black, whereas on lower surface these spots are smooth and light brown in colour. Spray the crop two to three times with dithane M- 45 or blitox-50 @ 1.5-2.0 kg/ha at 10-15 days interval starting from the first appearance of spot.

Pest Management

White grub: The young grubs are white and translucent. Fully grown larvae are larger than a thumb. The larvae feed on soil organic matter for a few weeks and then they eat roots. They also damage pods. The grubs cut and eat the plant roots, and consequently the plants wilts and dies. White-grub is a menace in the light soils, which can be controlled effectively by treating seed with chlorpyriphos 20 EC @ 15 ml/kg seed.

Harvesting, Threshing and Yield

Harvesting of groundnut should be done at blackening of inner shell and development of testa colour. Harvest the crop at 80% pod maturity. After harvesting, the pods are dried in sun to reduce moisture content to 20-25% for threshing. After threshing, kernels are dried to reduce the moisture content to 8-10%. Under normal conditions, groundnut yields about 15-25 q pods/ha with shelling percentage of 68-69.

7. MUSTARD

Mustard is a versatile and popular plant that has been cultivated for centuries for its edible leaves, seeds, and oil. It belongs to the Brassicaceae family and is closely related to other well-known crops such as broccoli, cauliflower, and cabbage. Mustard is grown in many parts of the world, including India, Canada, and Europe, and is used in various culinary traditions, including Indian, French, and American. Mustard plants require specific soil and climatic conditions, and the crop requires proper care and attention to ensure a good yield. In this context, it is important to have a good understanding of the plant's growth habits, propagation, planting distance and time, pruning, manures and fertilizers, irrigation, plant protection, diseases, physiological disorders, maturity, and harvesting.

Soil and Climatic Requirements

Mustard grows well in well-drained loamy soils with a pH range of 6.0 to 7.5. It requires a cool and moist climate with a temperature range of 10 to 25°C during the growing season. The crop can tolerate light frost but not heavy frost. Mustard can be grown in both tropical and temperate climates.

Varieties

There are many varieties of mustard, including black, brown, and white mustard. Some popular varieties include Pusa Bold, Pusa Agrani, Pusa Mahak, and Pusa Jaikisan.

Propagation

Mustard is propagated by seeds. Seeds are sown directly in the field or in a nursery for transplanting.

Planting Distance and Time

Mustard is usually sown in rows with a spacing of 30 to 45 cm between rows and a spacing of 10 to 20 cm between plants. The best time to plant mustard is in the autumn season (September to November) in temperate regions and in the winter season (November to February) in tropical regions.

Pruning

Mustard does not require pruning, but if the plant becomes too tall and leggy, it can be pruned to promote bushy growth.

Manures and Fertilizers

Mustard requires a moderate amount of nitrogen, phosphorus, and potassium. A dose of 50-60 kg/ha of nitrogen and 40-50 kg/ha of phosphorus should be applied before sowing. A top dressing of nitrogen can be applied 4 to 6 weeks after sowing.

Irrigation

Mustard requires regular irrigation during the growing season, especially during the flowering and pod formation stages. The frequency and amount of irrigation depend on the soil moisture level and climatic conditions.

Plant Protection

Mustard can be attacked by pests such as aphids, flea beetles, cutworms, and cabbage loopers. It can also be affected by diseases such as blackleg, white rust, and downy mildew. The use of pesticides and fungicides can help control these pests and diseases.

Diseases

Mustard can be affected by various diseases such as blackleg, white rust, and downy mildew. These diseases can be controlled by the use of resistant varieties and proper plant protection measures.

Physiological Disorders

Mustard can also be affected by physiological disorders such as lodging and bolting. Lodging occurs when the plant falls over due to its own weight or strong winds. Bolting is the premature formation of a flowering stem before the plant has produced enough leaves.

Maturity and Harvesting

Mustard is ready for harvest in about 90 to 120 days after sowing. The crop is harvested when the pods turn yellow and the seeds are mature. The crop is harvested by cutting the plants close to the ground and threshing the seeds. The seeds can be dried and stored for later use or sold in the market.

8. PIGEON PEA

Pigeon pea (Cajanus cajan L.) or Redgram is a popular pulse crop in India, occupying approximately 90% of global area and 85% of world production. Known as arhar or Tur in Hindi, it is the second most important pulse crop in India, following chickpea, in terms of area and production. Pigeon pea seeds, used as dal, are an excellent source of protein (21%), iron, and iodine. They are also rich in essential amino acids such as lycine, tyrocene, cystine, and arginine. Being a legume, pigeon pea possesses valuable properties as a restorer of nitrogen in soil. It is mainly a kharif crop, but the cultivation of pigeon pea in summer season is also gaining attention, especially in intercropping systems in north and northeast states, with the development of short duration varieties. India has the largest area (3.38 million ha) under pigeon pea. Pigeon pea's maturity duration varies from about 90 days for extra-early varieties to over 260 days for late maturing varieties that fit well in various niches and cropping systems.

Climate and Soil Requirements

Pigeon pea is a crop of arid and semi-arid climates grown between 30°N and 35°S latitudes and thrives well in areas with 500-1000 mm of rainfall. Its drought hardy nature due to deep tap root system makes it a crop of low rainfall situations. It is grown in the temperature ranges of 20-40°C and can withstand a minimum temperature of 10°C and maximum temperature of 40°C.

Sandy-loam to loam soil with sufficient organic matter content is ideal for cultivation of pigeon pea. The soil should be deep, well-drained and free from soluble salts. It can be grown on soils with a pH range of 5.5-8.0 successfully, but most favourable pH for its growth and development is 6.0-6.5.

Varieties

Based on time required for maturity, all the varieties have been classified into 3 groups viz.

(i) Short duration (120-150 days)
(ii) Medium duration (150-180 days)
(iii) Long duration (180-300 days)

Selection of varieties should be done carefully keeping in mind the climate, water retention capacity of the soil, water availability and irrigation conditions. In case of rain-fed conditions with low to no moisture availability beyond October and poor soils, early maturing varieties (120-150 days) should be preferred over medium and long duration. Some of improved pigeon pea cultivars are: Pusa 855, Pusa 991, Pusa 992, Pusa 2001, Pusa 2002, UPAS 120, Manak, AL-15, and AL 201. For arhar-wheat rotation, Pusa 991, Pusa 992, Pusa 2001 and Pusa 2002 are suitable cultivars.

Sowing Time

Redgram is grown during June to July. Ideal time for sowing is second week of June to second week of July. Under delayed monsoon conditions, it can be sown up to end of August. Treat the seeds with Trichoderma viride (8 g/kg of seed). Dry the seeds in shade. Then again treat the seeds with redgram Rhizobium and PSB biofertilizer (5 g/ kg seed) and dry the treated seeds in shade. Such treated seeds should be sown within 4-6 hour of treatment.

Seed Rate and Sowing

In general, a seed rate of 8-10 kg for long duration, 10-12 kg for medium and 12-15 kg/ ha for short duration varieties is sufficient in pigeon pea. Seeds are sown 4-6 cm deep, when the soil is wet. In short duration varieties, a row spacing of 40-60 cm and intra- row spacing of 10-15 cm is optimum. While long duration varieties require 60-120 cm inter-row and 10-20 cm intra-row spacing. Quantity of seed and spacing depending upon the variety and its crop duration are as follows:

Very early maturing:	Monocrop: 20 kg/ha, spacing 120 × 30 cm
Early maturing:	Monocrop: 20 kg/ha, spacing 120 × 30 cm
Medium duration:	Monocrop: 15 kg/ha, spacing 60 × 20 cm
	Intercrop: 5 kg/ha, spacing 30 × 20 cm
Long duration:	Monocrop: 12 – 15 kg/ha, spacing 60 × 20 cm
	Intercrop: 5 kg/ha, spacing 90 × 20 cm

Cultural Operations

Between 50 and 60 days of germination, the main shoot tip and the secondary branch tips are pruned. This promotes development of large number of tertiary shoots, which bear more number of pods, thus increasing the yield by 30-50%.

Nutrient Management

As redgram is a deep-rooted crop, it requires at least one deep tilling up 1 to 1.5 feet and one shallow tilling. Application of 5-10 t FYM mixed with 5 kg PSB during last tilling, when soil is wet is highly beneficial. Apply 20 kg nitrogen, 50 kg P_2O_5, 20-30 kg K_2O + 20 kg sulphur per ha as a basal dressing. Fertilizer should be broadcasted evenly and mixed thoroughly in the soil at the time of final preparation of land before sowing.

Water Management

Redgram requires 35-40 cm water during its entire growth period. Optimum moisture is necessary during budding, flowering and pod formation stages. Redgram grown in assured rainfall areas, usually it does not require any irrigation. If there is water stress, protective irrigation may be given in alternate rows at these three stages. Use harvested intercrops' biomass as mulch to preserve soil moisture and to maintain microbial activity.

Weed Management

Weed management is required only up to 60 days of crop growth, as this is the time when weeds compete with the crop for nutrients. First weeding is done at 20-25 DAS, while second hoeing is done at 50-60 DAS. Pre-emergence application of pendimethelin @ 1.0 kg a.i./ha is quite effective in controlling weeds.

Disease Management

During the growing phase, incidence of yellow mosaic can be seen. The affected plants show yellow mottled symptoms. These plants can be rouged out as and when they appear. White fly is known to spread this disease; hence after removal of the affected plants, an insecticide spray is important. Apart from this, redgram is also affected by root rot and wilt, where the affected areas are sprayed with 0.1% bavistin solution.

Pest Management

Pod borer: Pod borer survives on many host plants across different seasons, including cotton and legumes. Redgram is its preferred choice. Monocrotophos (0.04%) spray at pre and post-flowering stage is effective in controlling this pest.

Harvesting, Threshing and Yield

When most of the leaves are shed and 80% pods turn brown, is the best time for harvest. A grain yield of 15-20 q/ha as rainfed intercrop and 25-30 q/ha as irrigated monocrop can be obtained. Very early and early varieties yield 20-30% less. Dry clean seeds in sun to ensure moisture below 8%. Beetles affect redgram in storage. Mix crushed neem leaves with grain and store in gunny bags. Gunny bags can also be treated with 5% neem oil.

9. GRAM

Gram, also known as chickpea, is a popular pulse crop that is widely grown in many parts of the world, including India, Pakistan, and Australia. The crop is an excellent source of protein and other essential nutrients, making it an important part of many diets. Gram belongs to the Fabaceae family and is closely related to other leguminous crops such as lentils, beans, and peas. Gram requires specific soil and climatic conditions, and the crop requires proper care and attention to ensure a good yield. In this context, it is important to have a good understanding of the plant's growth habits, propagation, planting distance and time, pruning, manures and fertilizers, irrigation, plant protection, diseases, physiological disorders, maturity, and harvesting.

Soil and Climatic Requirements

Gram prefers well-drained loamy soils with a pH range of 6.0 to 7.5. It requires a warm and dry climate with a temperature range of 20 to 30°C during the growing season. The crop can tolerate moderate drought conditions but not waterlogged soils. Gram can be grown in both tropical and temperate climates.

Varieties

There are many varieties of gram, including desi and kabuli. Some popular desi varieties include KAK-2, H-208, and JAKI-9218, while popular kabuli varieties include Pusa 391 and BG 256.

Propagation

Gram is propagated by seeds. Seeds are sown directly in the field or in a nursery for transplanting.

Planting Distance and Time

Gram is usually sown in rows with a spacing of 30 to 45 cm between rows and a spacing of 10 to 20 cm between plants. The best time to plant gram is in the winter season (October to December) in tropical regions and in the spring season (February to March) in temperate regions.

Pruning

Gram does not require pruning, but if the plant becomes too tall and leggy, it can be pruned to promote bushy growth.

Manures and Fertilizers

Gram requires a moderate amount of nitrogen, phosphorus, and potassium. A dose of 20-25 kg/ha of nitrogen and 40-50 kg/ha of phosphorus should be applied before sowing. A top dressing of nitrogen can be applied 4 to 6 weeks after sowing.

IRRIGATION

Gram requires regular irrigation during the growing season, especially during the flowering and pod formation stages. The frequency and amount of irrigation depend on the soil moisture level and climatic conditions.

Plant Protection

Gram can be attacked by pests such as pod borers, aphids, and cutworms. It can also be affected by diseases such as wilt, blight, and rust. The use of pesticides and fungicides can help control these pests and diseases.

Diseases

Gram can be affected by various diseases such as wilt, blight, and rust. These diseases can be controlled by the use of resistant varieties and proper plant protection measures.

Physiological Disorders

Gram can also be affected by physiological disorders such as lodging and pod shattering. Lodging occurs when the plant falls over due to its own weight or strong winds. Pod shattering is the premature opening of pods before the crop is harvested.

Maturity and Harvesting

Gram is ready for harvest in about 90 to 120 days after sowing. The crop is harvested when the pods turn yellow and the seeds are mature. The crop is harvested by cutting the plants close to the ground and threshing the seeds. The seeds can be dried and stored for later use or sold in the market.

10. SUGARCANE

Sugarcane is a perennial plant belonging to the genus Saccharum, which encompasses five important species: Saccharum officinarum, S. sinense, S. barberi, S. robustum, and S. spontaneum . Of these, the first three are cultivated species, while the last two are wild. Among the cultivated species, S. officinarum is highly prized due to its high sucrose content. Sugarcane is a tall plant that can grow up to 5-6 meters, producing multiple stems. It is a C4 plant that efficiently stores solar energy and is the most effective converter of solar energy to sucrose. Brazil is the largest producer of sugarcane, followed by India.

Climatic and Soil Requirement

In the tropical region, sugarcane gets more or less ideal climatic conditions for its growth. The different critical stages are germination, tillering, early growth, active growth and elongation. Optimum temperature for sprouting (germination) of stem cuttings is 32° to 38°C. For ripening, however, relatively low temperatures in the range of 12° to 14°C are desirable. Sugar recovery is highest when the weather is dry with low humidity; bright sunshine hours, cooler nights with wide diurnal variations and very little rainfall during ripening period.

A well drained, deep, loamy soil with ample available water holding capacity is considered ideal for sugarcane cultivation. The optimum soil pH is about 6.5 but sugarcane can tolerate considerable degree of soil acidity and alkalinity. Hence, it is found growing in soils with pH in the range of 5 to 8.5.

Seed Rate and Sowing Method

Seed rate in sugarcane varies from region-to-region. In north India, seed rate generally varies from 35,000 three budded sets/ha while in south it ranges between 25,000 to 40,000 three budded sets/ha. The row spacing in subtropical part ranges from 60 to 120 cm whereas, it is 90-150 cm in tropical regions.

Sugarcane take generally one year to mature in subtropical states called "Eksali" however in some tropical states, it matures in 18 months called "Adsali". In India planting seasons of sugarcane in subtropical regions are September to October (Autumn) and February to March (spring). Whereas in tropical regions, it is June to August (Adsali) and January-to-February and October-to-November (Eksali). Sugarcane can be planted by improved method of planting like, deep furrow, trench methods, ring pit method and paired row method instead of furrow system.

Cultivars

Some of the promising sugarcane cultivars are: COS 687, COS 8436, COS 767, BO 106, BO 108, BO 90, CO 7508, CO 7704, CO 1108, COJ 83, CO 89003, CO 29, CO 997, CO 527, CO 775, CO 419, CO 775, CO 8021, CO 8011, CO 671, CO 8208, COG 93076.

Nutrient Management

The NPK recommendation for sugarcane crop varies from region-to-region. The recommendation of N is from 70-400 kg/ha, P_2O_5 is 27-74 kg/ha and K_2O is 25-141 kg/ha. Apply FYM or compost @ 10-15 t/ha. Recommended dose of bio-fertilizers for sugarcane crop is 10-12 kg/ha. Acetobacter, Azotobacter, Azospirillum and PSB are the major biofertilizers, which are being used in sugarcane crop.

Water Management

In tropical area, irrigations are to be given once in 7 days during germination phase, once in 10 days during tillering phase, again in 7 days during grand growth phase and once in 15 days during maturity phase, adjusting it to the rain fall pattern of the area. About 30 to 40 irrigations are needed. Whereas in subtropics, about 7-10 irrigations are being given to the sugarcane crop. Sugarcane is a high water requirement crop. About 250 tonnes of water is needed to produce one tonne of sugarcane. Methods like alternate furrow irrigation, drip irrigation and trash mulching could be of use to economize irrigation water during water scarcity periods.

Weed Management

In pure crop of sugarcane spray atrazine 2 kg or oxyflurofen 750 ml/ha mixed in 500 L water as pre-emergence herbicide on 3rd day of planting. Pre-mergence application of thiobencarb @ 1.25 kg a.i./ha under intercropping system in sugarcane with soybean, blackgram or groundnut gives effective weed control.

Plant Protection

Sugarcane is liable to be attacked by a number of insect-pests and diseases. Due to diversity in agro-ecological conditions, the importance of insect-pests and diseases varies and therefore, management strategy should be adopted accordingly. Top borer and stalk borer are found pre-dominantly in sub-tropical areas whereas early shoot borer and among diseases rust & eye spot are prevalent in tropical region.

Harvesting and Yield

Harvesting and collection of cane should either be mechanical or manual. In subtropical India, it has been shown that spring harvested crop would result in a better ratoon than that obtained by harvesting in the autumn. Sugarcane crop is harvested after attending maturity, generally it starts from the month of October and continue till the month of May in sub-tropical states whereas in Tropical states, it starts from the month of December and continues till the month of May. Cane tonnage at harvest with best management practices can vary between 120 and 150 t/ha, which depends on the length of the total growing period and whether it is a main or ratoon crop. The sugar recovery in sugarcane varies from state-to-state. Average sugar recovery in the country is 10.25%.

11. COTTON

Cotton, also known as "white gold", is a significant commercial crop in India. It is primarily grown for its fibers, but its seeds are also a source of oil, known as cottonseed oil. The Gossypium species, which belong to the Malvaceae family, include 52 species, of which four are commercially cultivated worldwide, namely Gossypium arboreum, Gossypium herbaceum, Gossypium hirsutum, and Gossypium barbadense . In India, G. hirsutum and G. arboreum are grown in all major cotton-growing states. India has the largest acreage of cotton in the world, with 11.99 million hectares, producing 6 million tons and an average yield of 512 kg/ha.

Climatic and Soil Requirements

Cotton is a warm season loving shrub, adapted to a wide range of climate. A frostless season of 180-240 days is required for successful cotton production. The cotton-picking period from mid-September to November must have bright sunny days to ensure a good quality of the produce. Abundant sunshine during the period of boll maturity and harvesting is essential to obtain a good quality produce.

It is raised mainly as a rainfed crop in the black cotton and medium soils and as an irrigated crop in the alluvial soils. Proper drainage of excess water during rains is essential. Soils with a pH >9.0 and <6.5 and $CaCO_3$ content >10% are not suitable for cotton cultivation.

Cropping Systems

Cotton–fallow, cotton–wheat/barley, cotton–sunflower, cotton–senji/barseem/oats, cotton–sunflower-paddy-wheat, cotton–raya.

Varieties

Zone	G. arboreum	G. herbaceum	G. hirsutum	G. barbadense
North Zone	Lohit, Shyamali, RG 1, LD 230, HD 11	Digvijay	Ganganagar Ageti, Pusa 31, Pusa 8-3, H 1117	—
Central Zone	Sanjay, G 22, AKH 4, AKA 1	F 46, V 797, Digvijay, CNH 36	Laxmi, Badnawar 1, Nimbakar 1, Deviraj	Suvin
South Zone	Nardium, Srisailam, Mahanandi	Jayadhar, Raichur 51, Ajanta	Laxmi, Mysore Vijay, Hampi, Krishna, Supriya	Suvin, Sujata, TNB 1

Hybrids

The currently cultivated hybrids include H6, H8, H10 in Gujarat; DCH 32, DHB 105 and DHH 11 in Karnataka; Savita, TCHB 213, Surya and Sruthi in Tamil Nadu, LAHH 4 and JKHy-1 and JKHy-2 in Madhya Pradesh.

Seed Rate and Sowing Method

The seed rate varies with species, growing zone and irrigation availability. The general seed rate for different species/ cultivars is as under:

Varieties/hybrids	Seed-rate (kg/acre)
American Cotton Bt Hybrids	0.750
Non Bt Hybrid: LHH 144	1.5
Varieties: LH 2108, LH 2076 and F 1861	3.5
Desi Cotton Hybrid	1.25
Varieties	3.0

Time of sowing is first April to 15th May. Sowing during this period ensures better yield and escapes the attack of insect pests and diseases. Sowing should be done in morning and evening hours. Sow in lines 67.5 cm apart with a cotton sowing drill. The plants within rows be kept 45-60 cm apart by thinning. However for hybrids (both Bt and non-Bt), the plant to plant distance should be kept at 75 cm. It may be done after first irrigation or heavy shower. For desi cotton hybrid, the plant to plant spacing should be kept at 60 cm. A fine seed-bed is essential for securing a good plant stand.

Weed Management

A deep summer ploughing is desirable once in 3 years to kill perennial weeds, pests and disease propagules hibernating in the soil. For this, hoeing should be done two or three times. The first hoeing should be done before first irrigation. For chemical weed control, apply pendimethalin @ 1.0 kg a.i./ha as pre-emergence spray.

Nutrient Management

Apply 75 kg N/ha, 30 kg P_2O_5/ha in HYVs and 150 kg N/ha, 60 kg P_2O_5/ha in Bt and non-Bt hybrids. Apply whole P & K as basal dose while half N is applied at thinning and the remaining half N at flowering. Apply 20 kg muriate of potash in soils medium in available potassium and 25 kg zinc sulphate heptahydrate (21%) per ha to cotton on light soils.

Water Management

Cotton requires four to six irrigations, depending upon the seasonal rainfall. The first irrigation should be given 4 to 6 weeks after sowing and the subsequent ones at interval of two or three weeks. Sowing of cotton on ridges and irrigation in furrows save considerable amount of water. In cotton, four critical stages of irrigation have been identified viz. commencement of sympodial branching (60-70 DAS), flowering (90-100 DAS), boll formation (125 DAS) and boll bursting (140 DAS). Drain out the stagnant water, if such a situation arises.

Disease Management

Root rot: The loss in yield occurs due to reduction in sudden death of plants. Due to this disease, healthy plants may wilt within 24 hr with leaves drooping without showing any discoloration. Soil should be drenched with 0.2% carbendazim.

Fusarium wilt: In young as well as old plants the initial symptoms are stunning followed by yellowing, wilting and dropping of most of the leaves. Soak 4 kg seed in 8 L water containing 8 g of bavistin for 6-8 hr and 2-3 hr in case of delinted cotton.

Pest Management

Pink boll worm: It is a notorious pest of cotton in all cotton growing areas. Bt cotton provides effective protection against all cotton bollworms.

Harvesting Threshing and Yield

Cotton is harvested in 3-4 pickings by hand as the bolls mature. By adopting improved technology, it is possible to harvest about 1.5-2 t/ha of seed cotton (kapas). However, much higher yields may be obtained from hybrid cottons. Cotton lint production is 33% of kapas production, while cotton to seed production is 66% of kapas production. Oil to seeds crushed is 14-18% and cake to seeds crushed is 82-86%.

12. BERSEEM

Berseem, scientifically known as Trifolium alexandrinum L., is a highly valued forage legume in India, primarily cultivated as a winter annual in tropical and subtropical regions. It serves as an excellent source of nutritious, succulent, and palatable forage for milch animals. Berseem forage is rich in crude protein, containing about 20% protein, and has high digestibility, up to 65%, making it a preferred choice among livestock farmers.

Climatic and Soil Requirements

Berseem is adapted to cool and moderately cold climate. Such conditions prevail during winter and spring seasons in north India, which is considered as favourable and productive zone for this crop. It can be grown successfully in areas which receive annual rainfall of 150-250 cm or even lower but the irrigation must be assured.

Berseem can be grown on all types of soils except very light sandy soils. Well-drained clay to clay-loam soils rich in humus, calcium and phosphorus are suitable for berseem.

Varieties

Some of the promising cultivars of fodder berseem are Pusa Giant, Mescavi, Berseem Ludhiana-1, Jawahar Berseem-1, Wardan, BL-10, BL-22, UPB-10, Bundel Berseem-2, Bundel Berseem-3, BL-180, Hisar Berseem-1 and JB-5.

Seed Rate and Sowing Method

The optimum seed rate is 25 kg/ha, which may be increased up to 35 kg in early or late sown conditions. For yield compensation in first cutting, 1.5 kg mustard should be sown alongwith berseem. Being a legume, berseem enriches the soil with biological nitrogen fixation. Therefore, berseem seed should be inoculated with Rhizobium trifollii. The seeds being very small, berseem requires a fine seedbed. After the arrest of rains, sowing of berseem can be done from last week of September to first week of December in north-west to eastern and central India.

Nutrient Management

Top dressing of 10 kg N/ha is done after each cut in addition to 30 kg N/ha basal dose to encourage good regeneration, quick growth and high yield. In general, the crop responds significantly upto 80-90 kg P_2O_5/ha. The potassium requirement of berseem has been found to be 30 to 40 kg K_2O/ha in low potassium soils.

Water Management

Berseem requires huge quantities of water for producing high succulent biomass. Normally, the crop should be irrigated after each cutting. About 12-15 irrigations will be needed during the entire crop season.

Weed Management

The major associated weed of berseem is chicory (Chicorium intybus). Chicory infestation can be minimized by seed cleaning in 10% solution of common salt, besides deep summer ploughing.

Cutting Management and Forage Yield

The first cutting should be taken at 50-55 days after sowing of crop. The subsequent cuttings should be taken at 25-30 days interval. The number of cuts depends upon rate of growth and temperature during the life cycle of the crop. The crop is capable of producing 100 to 120 t/ha of green forage and 15-20 tonnes/ha dry fodder under improved agronomic management practices and favorable weather conditions.

MULTIPLE CHOICE QUESTIONS

1. Match the following:

List-I (Herbicide)	List-II (Example)
(a) Selective herbicide	I. Diquat
(b) Foliage active herbicide	II. Glycophosate
(c) Contact herbicide	III. 4-D
(d) Translocated herbicide	IV. Isoproturon

Choose the correct answer from the options given below:

	(a)	(b)	(c)	(d)
A.	I	III	II	IV
B.	III	IV	I	II
C.	II	I	IV	III
D.	IV	II	III	I

2. Match List-I with List-II.

List-I (Weed)	List-II (Bio control agent)
(a) Prickly pear	I. Sameodes albiguttalis
(b) Water hyacinth	II. Chrosidosima lantana
(c) Lantana camara	III. Conchineal insect
(d) Carrot grass	IV. Zygograma bicholoreta

Choose the correct answer from the options given below:

	(a)	(b)	(c)	(d)
A.	I	II	III	IV
B.	III	I	II	IV
C.	II	III	IV	I
D.	IV	I	II	III

3. Atrazine is an example of:
A. herbicide B. insecticide
C. fungicide D. miticide

4. The chemical which is used to kill or control weed is called as:
A. Fungicide B. Insecticide
C. Herbicide D. Acaricide

5. _______ was the first person to use the word weed.
A. Jenny B. Jethro Tull
C. Marshal D. Philip Kotler

6. Which of the following is NOT a method of asexual reproduction in plants?
A. Fragmentation B. Budding
C. Grafting D. Apomixis

7. Which of the following can NOT be further hydrolyzed to simple sugars?
A. Disaccharides B. Trisaccharides
C. Monosaccharides D. Polysaccharides

8. _______ is called as anti-hemorrhagic vitamin.
A. Vitamin K B. Vitamin E
C. Vitamin D D. Vitamin A

9. Vitamin C is also known as _______.
A. Carotene B. Ascorbic acid
C. Folic acid D. Thiamine

10. Scurvy disease is caused by deficiency of:
A. Vitamin A B. Vitamin B
C. Vitamin C D. Vitamin D

11. ______ is caused due to the deficiency of vitamin A.
A. Skin disease B. Scurvy
C. Night blindness D. Rough skin

12. Koshland's theory of enzyme action is known as ____.
A. Lock and Key theory
B. Reduced fit theory
C. Induced fit theory
D. Enzyme co-enzyme theory

13. Enzyme that catalyzes the transfer of a group, other than hydrogen, belongs to the class:
A. Oxidoreductase B. Transferase
C. Hydrolase D. Ligase

14. All the carbon compounds that we get from living tissues can be called as ____.
A. Bioresource B. Bio-informatics
C. Biovar D. Biomolecules

15. A non-proteinaceous enzyme is:
A. Ribozyme B. Ligase
C. Deoxyribonuclease D. Lysozyme

16. Deficiency of ______ affects the clotting of blood in human beings.
A. Vitamin B12 B. Vitamin B2
C. Vitamin E D. Vitamin K

17. Gas which is produced during the processes of fermentation of dough, cheese making, and beverage production?
A. CO_2 B. H_2S
C. H_2O D. O_2

18. Which crop is commonly affected by tikka disease in India?
A. Paddy B. Groundnut
C. Gram D. Wheat

19. Which biological agent is commonly used as seed inoculant for symbiotic nitrogen fixation in groundnut crop?
A. Azotobacter B. Azolla
C. Rhizobium D. Acetobacter

20. Potato spindle tuber diseases is caused by which type of pathogen?
A. Virus B. Viroids
C. Prions D. Bacteria

21. Match List-I with List-II:

List-I (Crop name)	List-II (Botanical name)
(a) Soyabean	I. Zea mays
(b) Blackgram	II. Cicer arietinum
(c) Maize	III. Glycine max
(d) Chickpea	IV. Vigna mungo

Choose the correct answer from the options given below:

	(a)	(b)	(c)	(d)
A.	II	I	III	IV
B.	IV	II	I	III
C.	IV	III	II	I
D.	III	IV	I	II

22. Which of the following is an appropriate use of mulching?
A. Plant propagation
B. Watershed management
C. Livestock management
D. Soil management

23. Organic matter of soil plays a vital role in the plant productivity because of:
A. Presence of appropriate combination of plants protecting chemicals
B. Saving time and labour in its application
C. Contains two or three primary plant nutrients
D. Acts as a source of food for soil bacteria and fungi

24. Soil sampling and testing is essential to:
(a) identify fertility status
(b) identify seed viability
(c) identify fertilizer requirement
(d) identify physical properties
(e) control pest population

Choose the correct answer from the options given below:

A. (a), (b) and (d) only
B. (a), (c) and (d) only
C. (a), (b) and (e) only
D. (a), (b) and (c) only

25. _______ means the physical condition of soil resulting from tillage operations.

A. Threshing B. Soil tilth
C. Mulching D. Harvesting

26. Jowar seedlings of upto 8 weeks age contain _______.

A. Hydrocyanic acid
B. Carbonic acid
C. Oxalic acid
D. Malic acid

27. Botanical name of paddy is:

A. Oryza sativa B. Cicer arientinum
C. Tritim nestivum D. Aracitis irypogea

28. Which of the following is/are the diseases of groundnut:

(a) Tikka
(b) Root rot
(c) Stem borer
(d) Downey mildew
(e) Rust

Choose the correct answer from the options given below:

A. (c) & (d) only B. (c), (d), (e) only
C. (a) only D. (a) & (b) only

29. Which of the following is an important oilseed as well as pulse crop:

A. Soyabean B. Groundnut
C. Gram D. Redgram

30. The diseases of sugarcane are:

(a) Red rot
(b) Whip smut
(c) Black arm
(d) Grey mildew
(e) Grassy shoot disease

Choose the correct answer from the options given below:

A. (c) only B. (d) only
C. (c) & (d) only D. (a), (b), & (e) only

31. Match List-I with List-II:

List-I	List-II
(a) Paddy	I. Oryza Sativa
(b) Wheat	II. Triticum
(c) Gram	III. Cicer argenteum
(d) Groundnut	IV. Arachis hypogea

Choose the correct answer from the options given below:

	(a)	(b)	(c)	(d)
A.	IV	III	II	I
B.	III	IV	II	I
C.	I	II	III	IV
D.	II	III	IV	I

32. Glycine max is the botanical name of:

A. Soyabean B. Gram
C. Red gram D. Black gram

33. Emitters are the main components of which of the following irrigation system?

A. Sprinkler B. Surface
C. Subsurface D. Drip

34. Match List-I with List-II:

List-I (Crop)	List-II (Water requirement)
(a) Rice	I. 450 – 700 mm
(b) Cotton	II. 500 – 700 mm
(c) Soyabean	III. 700 – 1300 mm
(d) Potato	IV. 900 – 2500 mm

Choose the correct answer from the options given below:

	(a)	(b)	(c)	(d)
A.	I	II	III	IV
B.	IV	III	I	II
C.	IV	II	I	III
D.	IV	III	II	I

35. Milli watershed is which type of watershed?

A. Long watershed B. Short watershed
C. Broad watershed D. Milli watershed

36. _____ is the total depth of water required by a crop during the period of the crop.

A. Gamma B. Delta
C. Alpha D. Beta

37. Water harvesting is defined as the collection of runoff for its productive use.

A. Scheduling of Irrigation
B. Water storage
C. Flood irrigation
D. Water harvesting

38. Which irrigation system uses emitters as the main components?

A. Sprinkler B. Ring & basin
C. Drip D. Border strip

39. Soils with a pH above 7.5 is said to be:

A. Acidic B. Basic
C. Alkaline D. Organic

40. Which of the following is NOT an example of straight nitrogenous fertilizer?

A. Diammonium phosphate (DAP)
B. Ammonium sulphate
C. Ammonium chloride
D. Urea

41. The capacity of soil to provide essential nutrients in proper quantity and proportion for plant growth is called:
A. Soil profile B. Soil fertility
C. Soil age D. Soil erosion

42. Soil texture is a property of soil in terms of its:
A. Biochemical composition
B. Physical structure
C. Chemical composition
D. Biological activity

43. Muriate of potash is an example of which type of fertilizer?
A. Soil amendment B. Straight
C. Mixed D. Complex

44. Primary essential nutrients for plants are:
(a) Manganese
(b) Calcium
(c) Nitrogen
(d) Phosphorus
(e) Potassium

Choose the correct answer from the options given below:
A. (a) and (c) only
B. (b) and (d) only
C. (a), (b), and (c) only
D. (c), (d), and (e) only

45. _______ is a straight fertilizer.
A. Single super phosphate
B. 20 + 20:00
C. Diammonium phosphate (DAP)
D. Mono ammonium phosphate

46. _______ refers to the size of soil particles.
A. Soil structure B. Soil pH
C. Soil plasticity D. Soil texture

47. Nitrogen, Phosphorus, and Potassium are the plant nutrients:
A. Primary B. Secondary
C. Trace D. Minor

48. Which one of the following solutions is a buffer solution:
(a) HNO_2
(b) HCl
(c) HNO_3
(d) NaOH
(e) H_2SO_4

Choose the correct answer from the options given below:
A. (a) only B. (b) & (c) only
C. (d) & (e) only D. (e) only

49. Gypsum is a:
A. Soil amendment
B. Straight fertilizer
C. Complex fertilizer
D. Micronutrient

50. An example of a secondary nutrient is:
A. Nitrogen B. Phosphorus
C. Calcium D. Potash

51. Which of the following is a leguminous crop?
A. Wheat B. Maize
C. Paddy D. Gram

52. Which of the following is a root crop?
A. Sugarcane B. Cotton
C. Potato D. Tobacco

53. Which of the following crops is used for making paper?
A. Jute B. Sugarcane
C. Wheat D. Bamboo

54. Which crop is known as the 'King of cereals'?
A. Rice B. Wheat
C. Maize D. Barley

55. Which of the following is not a major oilseed crop in India?
A. Groundnut B. Mustard
C. Sunflower D. Wheat

56. What is the main cause of bacterial diseases in crops?
A. Fungal infection B. Viral infection
C. Bacterial infection D. Nematode infection

57. Which of the following is a fungal disease of wheat?
A. Bacterial blight B. Rust
C. Root knot D. Leaf curl

58. What is the most common method of controlling nematode infestation in crops?
A. Use of chemical pesticides
B. Use of biopesticides
C. Crop rotation
D. None of the above

59. What is the most common viral disease of tomato plants?
A. Bacterial wilt B. Mosaic virus
C. Anthracnose D. Fusarium wilt

60. Which of the following is a biopesticide used to control insect pests?
A. Malathion
B. Carbaryl
C. Bacillus thuringiensis
D. Glyphosate

61. What is the main goal of integrated pest management (IPM) in agriculture?
A. To completely eliminate all pests from the crops
B. To minimize the use of pesticides while maintaining pest control
C. To use only organic methods for pest control

D. To increase crop yield without considering pest control

62. Which of the following is NOT a step in the IPM process?
    A. Monitoring and identifying pests
    B. Applying pesticides at regular intervals
    C. Setting economic thresholds for pest control
    D. Implementing appropriate control measures

63. What is the purpose of threshing in agriculture?
    A. To remove weeds from the crop
    B. To separate the grain from the chaff
    C. To apply fertilizer to the crop
    D. To irrigate the crop

64. Which of the following post-harvest technologies is used to slow down the ripening of fruits and vegetables?
    A. Drying B. Canning
    C. Refrigeration D. Freezing

65. What is the main objective of crop harvesting in agriculture?
    A. To prepare the field for the next crop
    B. To collect the crops for storage and processing
    C. To remove pests and diseases from the field
    D. To apply fertilizer to the field

66. Which of the following is not a method of irrigation?
    A. Sprinkler irrigation
    B. Drip irrigation
    C. Solar irrigation
    D. Flood irrigation

67. Which of the following is a disadvantage of flood irrigation?
    A. High water use efficiency
    B. Uniform water distribution
    C. Low labor requirements
    D. Waterlogging and soil erosion

68. Which method of irrigation is most suitable for fruit crops?
    A. Sprinkler irrigation
    B. Drip irrigation
    C. Flood irrigation
    D. Furrow irrigation

69. Which of the following is not a method of drainage?
    A. Surface drainage
    B. Subsurface drainage
    C. Ditch drainage
    D. Furrow drainage

70. Which of the following is not a component of watershed management?
    A. Soil conservation
    B. Water conservation
    C. Forest conservation
    D. Monoculture crop production

ANSWERS

1	2	3	4	5	6	7	8	9	10
B	B	A	C	B	C	C	A	B	C
11	12	13	14	15	16	17	18	19	20
C	C	B	D	A	D	A	B	C	B
21	22	23	24	25	26	27	28	29	30
D	D	D	B	B	A	A	D	A	D
31	32	33	34	35	36	37	38	39	40
C	A	D	B	D	B	D	C	C	A
41	42	43	44	45	46	47	48	49	50
B	B	B	D	A	D	A	A	A	C
51	52	53	54	55	56	57	58	59	60
D	C	D	B	D	C	B	C	B	C
61	62	63	64	65	66	67	68	69	70
B	B	B	C	B	C	D	B	D	D