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Course No.: AGRO-121 (New)

Course Title: Introduction to Major Field Crops

- All the questions in this PDF file are based on the new 6th Dean Committee Syllabus.
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Lecture 1

AGRONOMY – DEFINITION, SCOPE AND IMPORTANCE, IT'S RELATIONSHIP WITH OTHER SCIENCES, HISTORICAL SKETCH OF AGRONOMY

Agronomy, its definition, Scope, Role of Agronomist and Relationship with other Sciences

Agriculture :- The term agriculture is derived from the Latin words **'*ager*'** or **'*agri*'** meaning **'Soil'** and **'*cultura*'** meaning **'Cultivation'**.

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

Agriculture is that sector of human activity in which there is greater interaction between environment and human culture which has grown in and from it. **Thus, agriculture is the science and art of farming including the work of cultivating the soil and producing the crops.** Agriculture is the most important enterprise in the world provides food, feed, fiber, fuel, furniture and raw material.

Factors governing crop production

Crop growth is depends on the environmental factors that consist of soil and above ground parameter that is weather and climate. Above ground parameter are difficult to control but soil is manipulated some extent for maximum crop production. There are many factors that are associated with crop growth and development that consists of soil physical environment (soil air, soil water and soil temperature etc.) soil solution pH, electrical conductivity, nutrient concentration are soil chemical parameters. The soil biological environment includes living organisms present in soil. The soil management part of agronomy deals with the manipulation of soil environment for better crop growth.

Agronomy is a study of plants in relation to soil and climate. As it deals with the principles and practices of crop production and field management, it needs the help of all applied sciences in increasing the crop production at least investment for getting maximum profit from the farm business.

The term Agronomy derived from Greek words ***agros*** meaning '**field'** and ***nomos*** meaning **'to manage'**

Definition of Agronomy

1. It is defined as an agricultural science which deals with principles and practices of crop production and field management.
2. Agronomy is branch of agricultural science, which deals with principles and practices of soil, water and crop management.
3. It is branch of agricultural science that deals with methods which provide favorable environment to the crop for higher productively.

In recent times, agronomy has achieved newer dimension and can be defined **as a branch of agricultural science that deals with methods which provide favorable environment for plant growth.**

Scope of Agronomy

Agronomy is a dynamic discipline. It has wide scope. Field of agronomy is very vast. It includes the art of soil management, crop production, and proper methods of tillage, suitable period for cultivation, right time of sowing, and proper methods of sowing i.e. crop management practices and maintaining farm implements and machineries in proper shape and managing the crops in efficient manner for obtaining maximum yield.

Besides this, agronomy is also concerned with the management of livestock including their feeding, management and disposal of farm animal products like milk and eggs as well as proper maintenance of farm accounts.

Agronomy also involves the scientific study of behavior of plant under different conditions like varying soils and climate, irrigation, fertilizers etc. by conducting the experiments in the field, pots and laboratories. It also involves the application of research outcome to develop suitable package of practices for particular crops under given set of soil and climatic conditions.

Agricultural practices are modified into new practices for higher productivity. For example there are number of agricultural inputs fertilizers, water, herbicides, seed and their utilization for higher productivity depends on their systematic use.

Fertilizer is a major input and their application necessary to crop that includes knowledge of method of application, time of application, quantity of application and form of application of fertilizer is very much essential.

Likewise, the herbicide use to control weeds which is harmful to crop. The correct use of herbicide depends on their knowledge. The knowledge of selectivity of herbicide is very important aspect in application methodology. Time of application and method of application of herbicides decides the crop yield and their effective use.

Water Management is one of the aspects of agronomy. Irrigation projects (dams) are advantageous for multiple cropping but because of excess use of irrigation water the other side effect like water logging and salinity create a problem for crop production. To overcome these problems appropriate water management practices are developed.

Population pressure increases but area under cultivation is static, therefore it is necessary to grow more number of crops on the same piece of land in a year. Multiple cropping/Intensive cropping concepts have come into existence. Similarly, no tillage practices have come in place of clean cultivation as a result of increase in cost of energy. New technology was developed to overcome the effect of moisture stress under dry land conditions. Under these conditions new varieties of crop with high yield potential become available. Package of practices has to be developed to exploit their full potential. Therefore there is more scope for soil, water and plant management to satisfy the need of food grain production.

Factor affecting/ restricting increased agriculture production

1. Low soil fertility
2. Crop varieties of low yield potential
3. Poor agronomic practices
4. Inadequate methods to control insect/diseases
5. Non-availability of improved production inputs.
6. Government economic policies about Agricultural Development programmes.

Restoration of soil fertility by soil management practices with nutrient management, preparation of good seed bed for better plant growth ,use of proper and good quality seed with

optimum seed rates, correct date of sowing and proper conservation and management of soil moisture are helpful for better and optimum utilization of natural resources i.e. land , water and air for maximum crop production .

Relationship of Agronomy with other Science

Agronomy is an applied science and is largely dependant on basic that is the fundamental science and other applied sciences. The knowledge of basic sciences is necessary to learn the basic facts which reveals or opens the facts and secrets of nature. The knowledge of basic science is used to solve problems in agriculture and other field. Agronomy is a dynamic discipline and synthesis of several disciplines like soil science, agricultural chemistry, crop physiology, plant ecology, entomology and plant pathology.

Traditional agricultural practices are modified into new practices for higher productivity. For higher crop production now a days more scientific cultivation methods are adopted by the farmer. The soil physical, chemical and biological properties have to be understood to create a favorable condition for good growth of crop plants. To supply the essential elements to crops there is need to understand the physiology of that crop to meet their requirements. Economic analysis of cost of production of crop indicates their profitability in terms of money. Breeder develops new verities that are suitable for cultivation in field condition. Entomology and plant pathology discipline suggests / develops suitable methods to control insects and pest that causes economic loss to crop.

Crop production depends on various inputs like seed, fertilizer, water, pesticides, herbicides and their utilization for higher productivity depends on their systematic use. Fertilizer is a major input and that supply essential nutrients to crop they are costliest, their precise use is necessary for maximum crop production. The knowledge of method of application, time of application (when to apply), quantity of application (Kg/ ha), form of fertilizer is essential. Likewise, the herbicide use to control weeds which are harmful to crop. The correct/precise use of herbicide depends on their knowledge. The selectivity of herbicide is very important aspect in application methodology. Time and method of application of herbicides decides the crop yield and their effective use.

There are various disciplines have directly related with crop production aspects. Agronomy is the integrated branch, it need the help of all applied sciences in increasing the crop

production. Therefore all applied sciences are closely related with each other for utilization of all recourses or inputs (seed, fertilizer, pesticide, nutrients and water) efficiently.

Role or Functions of Agronomist in agriculture

The person who is expert in the field of agronomy is known as **Agronomist.** In a large sense the Agronomist concerns with world food supplies. He is concerned with production of the food, fiber, fuel to meet the needs of growing population.

1. Agronomist is the key person and coordinator of different subject matter specialists.
2. He is scientist as he is studying the ways and means to increase the agriculture production through the research.
3. He is conducting the experiment on sowing time, seed rate, spacing, fertilizer requirement, irrigation requirement and weed management in different crops.
4. He is involved in the transfer of technology to the farmers for increasing per unit production.
5. He exploits the knowledge developed by basic and applied sciences for higher crop production.
6. He is testing the findings of other specialist by conducting field trials.
7. He is suggesting package of practices for a hybrid variety of crop developed by the breeder. Package of practices means optimum seed rate for sowing, manure or fertilizer dose, time and method of weed control, when to irrigate and how much to irrigate.
8. He assists the subject matter specialist like extension personnel for transfer of technology and motivating the cultivation to adopt new technology to increase the agricultural production.
9. Agronomist aims at obtaining maximum production at minimum cost.

Lecture 2

AGRO-CLIMATIC ZONES OF INDIA AND MAHARASHTRA STATE. NATIONAL AND INTERNATIONAL AGRICULTURAL RESEARCH ORGANIZATIONS IN INDIA

Agro-climatic zones

An agro-climatic zone is a land unit uniform in respect of climate and length of growing period (LGP) which is climatically suitable for a certain range of crops and cultivars (FAO, 1983).

Advantages of agro climatic zoning:-

- This enables in exploring agricultural potentiality of the region based on mainly soil and climatic resources.
- The map (with LGP) can be used for the crop planning e.g. a region with LGP 270 days. This enables in exploring agricultural potentiality of the region based on mainly soil and climatic resources.
- Agro climatic map has an important role in transferring technology/ knowledge/ experience from one region to another region
- Agro climatic maps prepared on the similar Agro climatic parameters with LGP makes possible to identify homo climates and enable to introduce a new crop in one region already tested in the another region.
- To identify the constraints and potentials in specific zone and to develop suitable, zone specific technology.
- To undertake the research with priority on zone specific problems

Classification by Planning Commission

- Planning Commission of India (1989) made an attempt to delineate the country into different agro climatic regions based on homogeneity in rainfall, temperature, topography, cropping and farming systems and water resources. India is divided into **15** agro-climatic regions.

1. Western Himalayan zone

This zone consists of three distinct sub-zones of Jammu and Kashmir, Himachal Pradesh meadow soils and hilly brown soils. Lands of the region have steep slopes in undulating terrain. Soils are generally silty loams and these are prone to erosion hazards.

2. ***Eastern Himalayan zone***

Sikkim and Darjeeling hills, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Tripura, Mizoram, Assam and Jalpaiguri and Coochibihar districts of West Bengal fall under this region, with high rainfall and high forest cover. Shifting cultivation is practiced in nearly one-third of the cultivated area and this has caused denudation and degradation of soils with the resultant heavy runoff, massive soil erosion and floods in lower reaches and basins.

3. ***Lower Gangetic Plains zone***

This zone consists of West Bengal-lower Gangetic plain region. The soils are mostly alluvial and are prone to floods.

4. ***Middle Gangetic Plains zone***

This zone consists of 12 districts of eastern Uttar Pradesh and 27 districts of Bihar plains. This zone has a geographical area of 16 million hectares and rainfall is high. About 39% of gross cropped area is irrigated and the cropping intensity is 142%.

5. ***Upper Gangetic Plains zone***

This zone consists of 32 districts of Uttar Pradesh. Irrigation is through canals and tube wells. A good potential for exploitation of ground water exists.

6. ***Trans-Gangetic Plains zone***

This zone consists of Punjab, Haryana, Union territories of Delhi and Chandigarh and Sriganganagar district of Rajasthan. The major characteristics of this

area are: highest net sown area, highest irrigated area, high cropping intensity and high groundwater utilization.

7. ***Eastern Plateau and Hills zone***

This zone consists of eastern part of Madhya Pradesh, southern part of West Bengal and most of inland Orissa. The soils are shallow and medium in depth and the topography is undulating with a slope of 1-10%. Irrigation is through tanks and tube wells.

8. ***Central Plateau and Hills zone***

This zone comprises of 46 district of Madhya Pradesh, part of Uttar Pradesh and Rajasthan. The topography is highly variable nearly 1/3rd of the land is not available for cultivation. Irrigation and cropping intensity are low. 75% of the area is rainfed grown with low value cereal crops. There is an intensive need for alternate high value crops including horticultural crops.

9. ***Western Plateau and Hills zone***

This zone comprises the major part of Maharastra, parts of Madhya Pradesh and one district of Rajasthan. The average rainfall of the zone is 904 mm. The net sown area is 65% and forests occupy 11%. The irrigated area is only 12.4% with canals being the main source.

10. ***Southern Plateau and Hills zone***

This zone comprises 35 districts of Andhra Pradesh, Karnataka and Tamil Nadu which are typically semi-arid zones. Dryland farming is adopted in 81% of the area and the cropping intensity is 111 percent.

11. ***East Coast Plains and Hills zone***

This zone comprises of east coast of Tamil Nadu, Andhra Pradesh and Orissa. Soils are mainly alluvial and coastal sands. Irrigation is through canals and tanks.

12. ***West Coast Plains and Ghats zone***

This zone comprises west coast of Tamil Nadu, Kerala, Karnataka, Maharashtra and Goa with a variety of crop patterns, rainfall and soil types.

Gujarat Plains and Hills zone

This zone consists of 19 districts of Gujarat. This zone is arid with low rainfall in most parts and only 32.5% of the area is irrigated largely through wells and tube wells.

14. ***Western Dry zone***

This zone comprises nine districts of Rajasthan and is characterized by hot sandy desert, erratic rainfall, high evaporation, scanty vegetation. The ground water is deep and often brackish. Famine and drought are common features of the region.

15. ***Islands zone***

This zone covers the island territories of Andaman and Nicobar and Lakshadeep which are typically equatorial with rainfall of 3000 mm spread over eight to nine months. It is largely a forest zone with undulated lands.

Agroclimatic zones of Maharashtra state

Zone no.	**Name of zone**	**Coverage zone**	**Climate and Annual Rainfall (RF),Rainy Days (RD)**	**Type of soil**	**Topography**	**Crops grown**
1	South Konkan Coastal Zone **Vengurla**	A narrow strip with 260 km length and 50 - 60 km width, The southern konkan coast consisting of Ratnagiri, South Raigad and Sindhudurg District. (Stn. Dapoli)	Warm humid RF=2500 mm RD=100	Lateritic Formed from basalt. Red, Reddish brown sandy	Hilly to undulating ,30-100cm depth soil	Paddy in plain, millets in high lands, Fruits crops also grown.

				loam, clay loam.		
2	North Konkan coastal zone **Karjat**	A strip of 260 km (north - south) andwidth140km in thane district and 50km in Raigad whole of Thane district and northern portion of Raigad.	Slightly warmer and humid than zone 1 RF=2600 mm RD=87	Non Lateritic soils from Deccan trap Coastal alluvial & coastal saline.	Hilly to undulating ,30-100 cm depth soil	Paddy ,Hill millets, Fruits crops-chiku, Mango.
3	Western Ghat zone **Igatpuri**	Hilly and high lying terrain of Amboli, Phonda, Amba in kolhapure, koyna ,mahabaleshwar, Lonawala, khandala, kalasubai hills,Igatpuri,Trimbak.	RF=3000 -6000 mm in terrain.	Shallow-light to dark brown on hill slope, red reddish to Brown lateritic on high level western parts.	Sahydri ranges with 1000 to 200altitude	Paddy , Hill millets.
4	Sub-montante zone **Kolhapur**	Eastern slope of the ghat falling in satara, sangali, Pune and Kolhapur district and Surgana, Peth, Nasik taluka of Nasik district. (Stn: Kolhapur)	Hot and humid well distributed RF=700 - 2500mm	Red brown to black with varying texture and depth.	slopes	Paddy, Groundnut, Jowar, Wheat, Grape

5	Western Maharashtra plaine zone **Pune**	Mid western portion of Dhule, Nasik, Ahamadnagar, Pune, Satara, Sangali and Northeast Kolhapur (Stn: Pune)	Well distributed RF=700 - 1250mm	Grayish black with varying texture and depth.	Plain	Groundnut, Jowar,Bajara, Pulses, Wheat, Gram. Fruits - Grapes
6	Western Maharastra Scarcity zone **Solapur**	Eastern portion of Dhule, Nasik, Ahmednagar, Pune, Satara, Sangali, west of Solapure,Western portion of Aurangabad, Beed, Osmanabad and Jalgaon (Stn:Rahuri , Dhule)	RF= 500-700mm RD=45 Bimodal rains	Black vertisols with varying texture and depth.	Plain	Groundnut, Jowar, Pulses, Sunflower, Safflower.
7	Central Maharastra Plateau zone **Aurangabad**	Entire Jalgaon and Lature district , Part of Dhule, Solapure,Beed,Parbhani,Nanded, Jalana,Aurangabad,Osmanabad ,Yavatmal, Akola and Amravati districts (Stn: Akola , Amaravati,Parbhani, Lature)	RF= 700-900mm RD=35-65 rainfall is assured	Derived from Deccan trap, black to red color vertisols.	Plain Altitude= 300-600m	Jowar, Cotton, Groundnut, Pulses,

8	Central vidarbha zone **Yavatmal**	Entire wardha district, part of Nagpur, Chandrpure, Parbhani, Jalana,Nanded,Yavatmal Districts (Stn:Nagpure,Warora)	RF=950 - 1250mm RD=59 Rainfall is well distributed.	Derived from basalt brownish black soil with varying depth And textures.	Plain Altitude= 300m	Jowar, Cotton, Groundnut, Pulse, Wheat.
9	Eastern vidarbha zone **Sindewahi**	Entire Bhandara and Gadchiroli district, umred, Tahasil of Nagpur, eastern part of chandrpure district.	RF=1200- 1700mm RD=60-70days.	Derived from mixed rocks, Yellowish brown to red	Plain Altitude= 150-300m	Paddy, Jowar, Gram, Linseed.

NATIONAL AND INTERNATIONAL AGRICULTURAL RESEARCH ORGANIZATIONS IN INDIA

Lecture 3

CLASSIFICATION OF CROPS. ORIGIN, GEOGRAPHIC DISTRIBUTION, ECONOMIC IMPORTANCE OF *KHARIF* CROPS

Classification Of Field Crops

It is well known that there are more than 600 cultivated plant species, from which there are about 100- 200 species play important role in the world trade. However, only fifteen plant species represent the most important economic crops. Therefore, these crop species must be classified or grouped in a convenient way to facilitate communication, dissemination and retrieval of scientific information as well as promotes the conservation, and improvement of certain plants. Generally, classification of these species is important for these reasons:

1. To get acquainted with crops.

2. To understand the requirement of soil & water different crops.

3. To know adaptability of crops.

4. To know the growing habit of crops.

5. To understand climatic requirement of different crops.

6. To know the economic produce of the crop plant & its use.

7. To know the growing season of the crop

8. Overall to know the actual condition required to the cultivation of plant.

The grown field crops are classified according to different stand points as follows:

1. Botanical classification.

2. Agronomic classification

3. Special- purpose classification.

4. Classification according to life span.

5. Classification according to root depth.

6. Classification according to growth habit.

7. Classification according to Co2 fixation.

8. Classification according to mode of pollinations.

1. Botanical Classification

Botanical classification is based upon similarity of plant parts and flower structure. This is the most important way of classification because it determines to what extent the plants are relatives. Field crops belong to the "spermatophyte", or seed plant, division of "plant kingdom", which includes plants reproduced by seeds. Within this division, the common crop plants belong to the subdivision of "Angiosperm", which are characterized by producing seeds with coats (covered seed). The "angiosperm", are then divided into two classes, namely, monocotyledons and the dicotyledons. All the grasses, which include the cereals and sugar cane are monocotyledons. The legumes and other plants except the grasses are classified as dicotyledons. Each of these two classes is still further divided into orders, familes, genera, species and varieties.

For example, maize crop (corn) which is monocotyledons belongs to the order "herbaceous"; family "Gramineae"; genus Zea; species mays; varieties; S.C. 10 as follows:

Plant Kingdom

Division–> Spermatophyte

Subdivision–> Angiosperms

Class–> monocotyledons

Order–> Herbaceous

Family–> Gramineae

Genus–> Zea

Species–> mays

Variety–> S.C. 10

1- Monocotyledons:

– Gramineae: includes the following crops: wheat, barley, rice, maize, oat, sugar cane, sorghum, rye grass, and sudan grass.

–Liliaceae: includes onion and garlic.

2- Dicotyledons:

– Leguminosae: includes: field bean, lupine, check pea, lentil, fenugreek, Egyptian clover, alfalfa, soybean, peanut, grass pea, caster bean, red clover and white clover.

– Malvaceae: includes: cotton.

– Linaceae: includes: flax.

– Solanceae: includes: potato, tomato, and tobacco.

– Pedaliaceae: includes: sesame.

– Composite: includes: sunflower, and safflower.

It is well known that the most important field crop families belong to two botanical families, the grass family (gramineae) and the legume family (Legumioseae). Therefore, we have to get an idea about the characteristics of both families.

Characteristics of grass family:

This family includes about three fourths of the cultivated forage crops and all the cereals. They have the following characters:

- They are winter annuals or perennials.
- They are almost herbaceous plants.
- Stems are usually hollow, cylindrical and made up of nodes and internodes.

- Leaves are alternative with parallel veins. The basal portions of the leaf sheath, encloses the stem, the sheath being open on the side opposite the blade. Where the blade of the leaf joins the sheath, there is usually found a peculiar appendage known as the “ligule”.
- The roots are fibrous and new roots are formed each year.
- The flowers are perfect and collected in inflorescence at the top of plant.
- The grain may be free (wheat) or enclosed (oats).

Characteristics of legume family:

- It ranks next in importance to grass family.
- Legumes may be annual, biennial, or perennial.
- The leaves are alternate compound, stipulate, with netted veins.
- The flowers are buttery- like.
- The fruit in a pod that contains one to several seeds. The seeds are usually without an endosperm, the two cotyledons being thick and full of stored food.
- Legumes have relatively large taproot. The roots bear enlargements called “nodules” caused by the activities of a bacterium Rhizobium, which has the ability to fix atmospheric nitrogen in their bodies and eventually in the plant residues.

2. Agronomic classification

Field crops can be classified according to their economic importance as follows:

1. **Cereal or grain crops**: Cereals are grasses grown for their edible seeds such as wheat, oats, barley, rye, rice, maize, and grain sorghum,
2. **Legumes** of seeds such as faba bean, pea nuts, fenugreek, lupine, cowpea, soybean, chick pea, and lentil.
3. **Sugar crops**: they include sugar beet and sugar cane.
4. **Oil crops**: they include: flax, soybean, peanut, sunflower, safflower, sesame, caster bean and rape.
5. **Fiber crops**: they include cotton. Flax, jute, sisal, and ramie.

6. **Fodder crops**: they include alfalfa, Egyptian clover, sorghum, Suddan grass, grass pea, lablab, Napier grass, millet, white clover, and red clover.
7. **Rubber crops:** including para rubber, Castilla rubber, and guayule.
8. **Tuber crops**: such as potatoes and Jerusalem artichoke.
9. **Root crops**: such as sweet potatoes and sugar beet.
10. **Medical plants**: such as caster bean and others.
11. **Stimulates** such as tobacco, tea and coffee.

3. Special- purpose classification

These classifications are used to refer to plants having special advantages to the farmer himself in relation to his farming practices, and include

1. **Catch or emergency crops**: These crops are used to substitute crops that have failed on account of unfavourable conditions. They are usually quick-growth crops, such as rye, millet and clover. In Egypt. Clover can be grown and one cut can be obtained before planting cotton crop.
2. **Cash crop**: any short maturing crop which is grown to generate income while the main crop is still in its vegetative stage of growth; any crop grown to generate cash rather than for subsistence. Some crops may be cash crops one year but not the next, or for one farmer but not another.
3. **Cover crops**: these crops are planted to provide a cover for the soil and to prevent erosion such as clover and rye.
4. **Green manure crops**: these crops are turned under while still green in order to improve the soil properties and increase organic matter content. Several field crops can be used such as Egyptian clover, lupine and cowpea.
5. **Companion crops**: in this case a crop can be intercropped with another one and each crop is harvested separately. For example, onion and garlic can be intercropped with cotton crop, or soybean with maize.
6. **Silage crops:** these crops are preserved in a succulent condition by partial fermentation in a tight receptacle. They include corn, sorghum, forage grasses and legumes.

Classification according to life span.

All field crops can be divided into three categories according to the length of their life cycle as follows:

a. **Annual crops:** plants of this category complete their entire life cycle from seed to seed in a single growing season and then die. Most field crops are considered annual crops such as wheat, barely, rice, maize, sorghum, faba bean, lentil, check pea, lupine, flax, soybean, sesame, sunflower, safflower, and others.
b. **Biennial crops**: these plants complete their life cycle in two seasons. Vegetative growth occurs during the first season resulting in a rosette form but plants don't start flowering (blooming). In the second season, the green plants give flowers and seeds. The crops of this category are onion, sweet clover, and sugar beet. If you expose sugar beet plants, grown in the first year to low temperature they can start blooming and flowering and behaved as annual crops.
c. **Perennial crops**: these crops are grown in the soil for more than two years (they can persist for more than two years). They may either produce seed or not every year. In other words, they have and indefinite life period. They do not die after reproduction but continue to grow indefinitely from year to year. Sugar cane, white clover, and alfalfa are examples of perennial crops.

5. Classification according to root depth

It is clear that the root system of field crops differ in structure, function and extent. Therefore, field crops can be classified according to the depth of their roots as follows:

1. **Hallow root crops**: the root system of these crops extends in the soil to a depth of one meter such as wheat, barley and rye.
2. **Intermediate crops**: the depth of the root system of these crops ranges from 1-1.5 meter in the case of faba bean and sugar beet.
3. **Deep root crops**: the root system of these plants extends in the soil to a depth more than 1.5 meter as in alfalafa.

6. Classification according to growth habit

Determining the best time of planting of any field crop is a very important task. That is because planting date must be in suitable time which ensure the best environmental conditions throughout the growing season of the crop. Crops need optimum levels of light, temperature, moisture and other environmental conditions to grow well and produce the highest productivity. Therefore, when field crops are classified according to growing season this means that the environmental requirements of such crop are prevail in such season. Accordingly, field crops can be classified as follows:

1. **The Kharif Season**: Crops are sown at the beginning of south-west monsoon and harvested at the end of the south-west monsoon.

Sowing Season: May to July.

Harvesting Season: September to October.

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

2. **The Rabi Season**: Crops need cool climate during growth period but warm climate during the germination of seed and maturation.

Sowing Season: October to December

Harvesting Season: February to April

Important Crops: Wheat, Barley, Gram, Linseed, Mustard, Masoor & Peas.

3. **The Zaid Season:** These Crops are raised throughout the year due to artificial irrigation.

1. Zaid Rabi Crops:

Sowing Season: August to September

Harvesting Season: December-January

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

2. Zaid Rabi Crops:

Sowing Season: February to March.

Harvesting Season: April-May.

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

Cereal Crops

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

Pulse Crops

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

Oil seed crops

Importance of oilseeds crop in Indian farming:-

• They can be grown on all kinds of soil.

• Important constituent of the crop rotation with millets and pulses.

• Valuable ash crops and bring ready cash to the farmers.

• They are a source of foreign exchange.

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

• Soaps, lubricating oils etc.

• They contribute vegetable oils and fats to Indian diet.

• The edible oil cakes provide concentrates for the cattle.

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

Cash, fiber and spice corps

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

7. Classification according to Co2 fixation

- C3 Plants
- C4 Plants
- Cam Plants

8. Classification according to mode of pollination

1. **Naturally self-pollinated crops**: – the predominant mode of pollination in these plants is selfpollination in which both pollen and embryo sac are produced in the same floral structure or in different flowers but within the same plant. Examples: rice, most pulses, okra, tobacco, tomato.

2. **Naturally cross-pollinated crops**: pollen transfer in these plants is from the anther of one flower to the stigma of another flower in a separate plant, although self-pollination may reach 5 percent or more. Examples: corn and many grasses, avocado, grape, mango, many plants with unisexual or imperfect flowers.

3. **Both self- and cross-pollinated crops**: these plants are largely self-pollinated but varying amounts of cross-pollination occur. Examples: cotton and sorghum.

Lecture 4

SELECTION OF SEED, DIFFERENT SOWING METHODS

As we all are aware of, there are multiple steps to be followed in the agricultural process. The first and the initial stage is the selection of the seeds. Seeds are the fundamental requirement in most of the agricultural process. Before beginning with the cultivation, selecting the best quality seeds is a challenging task for the farmers. Because only the good quality of seeds give an expected result or yield. Therefore, farmers have to choose suitable seeds from the variety of options available in the market.

Selection and sowing of seeds are two agricultural practices which demand extreme attention and care.

Selection of Seeds

Healthy and good quality seeds are the roots of a healthy crop. The seeds that are used to cultivate new crops have to be selected very carefully and of high quality. The good quality seeds can either be bought from different sources or farmers can produce by their own. The selection of seeds is used to improve the quality of yields. There are several diseases that are transmitted via the seeds. If the selected seeds are from the infected fields then the seed-borne diseases will cause severe problems in the agricultural process. Thus, always obtain seeds from healthy plants. Along with the diseases free and healthy seeds, farmers also need to check the germination period of the seeds, nutrients required and other benefits in terms of yield and finance. Overall, selecting good quality seeds are essential for growing strong and healthy crops.

The normal practice in smallholder agriculture is for seed from one year's harvest to be retained for planting the following season. With export horticulture this is usually not feasible for several reasons:

- use of pure certified seed is essential for obtaining the quality and uniformity of product which the market demands;
- many export crops are grown from hybrid seeds, which must be renewed each season;

- traceability of product can only be assured when the source of seed used is known and controlled by the company which purchases the farmers' crop.

It is therefore necessary that the company which contracts smallholders to grow a particular crop supplies them with certified seed ahead of the recommended planting date. Several issues require consideration:

- the variety of seed which is appropriate for smallholders;
- guarantee of seed quality;
- time and method of seed and seedling distribution;
- method of payment for seed.

Seed selection is very important step in cultivation, quality of seeds should always be good so that we may get better production of crops.

For sowing, seed selection depends upon the following factors:

1. We should select whole seeds and broken or crushed seeds should be avoided.
2. The sowing quality of seeds should be high.
3. They should have high germinating capacity.
4. Seeds should be free from infection.
5. The seeds should not be mixed with seeds of weeds or with other seeds.
6. Seeds should be disease-resistant.
7. The seeds should be purchased from good shops or should be supplied by good seed agency (certified seeds).

In India central seeds committee tests gives a certificate for good quality and purity of seeds. These seeds are known as certified seeds.

Factors Affecting Variety Selection

The selection of a locally adapted variety with good yield potential and acceptable grain characteristics is fundamental to successful crop production. There are several important variety related characteristics that should be considered when selecting seeds:

1. **Yield potential**: This is related to inherent natural vigor and other characteristics listed below.
2. **Time to maturity**: Varieties fall into three general maturity classes: early-, medium-and late-maturing (when grown under similar temperatures). Early varieties produce a crop more quickly, but yields may be about 10-15 percent lower compared with slower-maturing

types if both receive adequate moisture. However, early varieties are especially well suited to short rainy seasons or sequential cropping. Since temperature has a strong influence on a variety's actual length of growing period, some countries like the U.S. are now labeling maize varieties in terms of the growing degree days (total heat units) required for maturity rather than calendar days.

3. **Elevation adaption**: This has to do with a variety's time to maturity and growth ability at different elevations and temperatures. In regions with pronounced variations in elevation such as Central America, the Andean countries, and Ethiopia, maize and sorghum varieties are classified according to their elevation adaption (i.e., 01000, 10001500, etc.); a similar system may also be used for beans and other pulses.
4. **Heat or cold tolerance**: Varieties vary in their tolerance to excessive heat or cold.
5. **Drought tolerance**: Even varieties within a crop can vary considerably in this respect. In a 1978 International Maize and Wheat Improvement Center (CIMMYT) maize trial, a variety selected for drought tolerance outyielded the best fullirrigation variety by 64 percent under conditions of severe moisture shortage.
6. **Resistance (partial tolerance) to** insects, diseases, and nematodes, as well as to bird damage and soil problems such as excessive acidity and low phosphorus levels. Reference crop varieties can differ considerably in their tolerance to these problems, which are some of the major concerns of plant breeding work. Resistance to lodging also is an important consideration in selecting a maize variety.
7 **Growth habit and other plant characteristics**: For example, bean varieties can be bush, semi-vining or vining in their growth habit; millet varies in tillering ability and sorghum in its ratooning potential (see page 55). Plant height and the ratio of leaf and stalk also varies with variety.
8. **Daylength sensitivity (photosensitivity)** varies markedly among sorghum and millet varieties (see page 45).
9. **Seed color, shape, size, storability**, etc.

Traditional Versus Improved Varieties

In selecting a variety, it is important to understand the differences between traditional varieties, hybrids, synthetics, and other improved varieties.

1. Traditional (local) varieties: They tend to be relatively lowyielding but are usually hardy and have fair to good resistance to local insect and disease problems. However, most are adpated to low levels of soil fertility and management and often do not respond as well as improved types to fertilizer and other improved practices. Native varieties of maize, sorghum and millet tend to have an overly high ratio of stalk and leaves to grain, but this may be an advantage where livestock are important.

   Despite certain disadvantages, local varieties may be the best choice in some situations During the first years of the Puebla maize project in Mexico (see page 80), some of the local varieties consistently outyielded anything the plant breeders could come up with.

2. A hybrid is a type of improved variety produced by crossing two or more inbred lines of a crop. This is relatively easy to do with maize and sorghum, and a number of hybrids are available to these two crops. Hybrid development in peanuts, beans and the other pulses has proven more difficult, and they are not yet generally available. Millet research is still at too early a stage for hybrids to assume much importance.

   When grown under similar conditions, an adapted hybrid may out-yield the best adapted, normally-produced varieties by 15-35 percent, but not always. Despite these possible yield benefits hybrids have several disadvantages:

   Unlike naturally produced varieties, the seed harvested from a hybrid should not be replanted by the farmer. If reseeded, a hybrid begins to degenerate and revert back to the original (and usually less desirable) lines from which it was developed. Yields may drop as much as 15-25 percent each successive crop. Many small farmers lack the inclination or the money to buy new seed for each planting unless special arrangements and educational efforts are made.

   • Hybrid seed may be several times more expensive than that of other types.

   • Hybrids require good management or they may not yield much more than other types.

   • Hybrids show a narrower range of adaptation to different growing conditions than other varieties; this makes finding a suitable hybrid more difficult. It is estimated that 131 different hybrids had to be developed to suit varying maize growing conditions in the U.S.

3. Synthetics are improved varieties that have been developed from crosspollinating lines (naturally pollinated with no purposeful inbreeding as in hybrids). These lines are first

tested for their combining ability and then crossed in all combinations. Synthetic varieties often yield as well as hybrids under small farmer conditions and have several advantages over them:

- They have greater genetic variability than hybrids, which makes them more adaptable to different growing conditions.
- The seed costs less than that of hybrids.
- Unlike hybrids, seed harvested from a synthetic can be replanted without loss of vigor as long as farmers are willing to select it from the plants with the best characteristics.

4. Varieties improved through mass selection: This is the most elemental form of varietal improvement and consists of natural crossing between lines with no attempt made to test for combining ability (as with synthetics) and continually selecting seed from plants showing the best combination of desirable characteristics. While yields may not be as good as those from hybrids or synthetics, the seed is cheaper and also can be replanted.

Guidelines for Selecting Quality Seed

Seed quality can be influenced by the following factors:

1. Varietal purity: Farmers who use their own harvested seed for replanting can be reasonably assured of varietal purity, especially with crops that are naturally selfpollinated (millet, sorghum, peanutes, cowpeas, beans, and most other pulses). Since maize is cross-pollinated, there is opportunity for "contamination" from other nearby maize varieties. This can be minimized by selecting seed for replanting from the inner part of the field.

   Commercially available seed may or may not have good varietal purity, depending on its source and the country's commercial seed standards. In some areas, certified seed is available with guaranteed genetic purity and tested germination.

2. Germination and vigor depend largely on the seed's age and the conditions under which it has been stored. High temperature and humidity as well as insect damage (weevils, etc.) can drastically reduce both germination and vigor. Certified seed is usually labeled with a tested germination percentage, but post-tested storage conditions can make this a worthless guarantee. You should encourage farmers to run their own germination test (see page 121) before planting any seed, regardless of source.
3. Visual traits: Mold, insect damage, cracking, and shrunken or shriveled seed mean trouble.

IMPORTANT NOTE: Beans, soybeans and shelled peanuts are very susceptible to damage from rough handling of dry seeds in harvesting, processing, and shipping. Dropping a sack of beans on a cement floor is enough to harm them. Both the seedcoats and sects crack very easily; careless handling can also cause invisible damage. In both cases, these injuries can lead to stunted, malformed seedlings lacking in vigor.

4. Impurities such as weed seeds; These are more of a problem in crops with small seeds like millet and sorghum, where separation is more difficult.
5. Seed-borne diseases: Some diseases like anthracnose may show visible symptoms on contaminated seed, while many others do not. Certified seed, if grown under the proper procedures of inspection and roguing (elimination of diseased plants), is free from certain seed-borne diseases and is especially recommended for beans when available. Some common fungal diseases are carried mainly on the seed coat surface and can be controlled by dusting the seed with a fungicide; others (especially viruses) are internal and have no control.

How to Select home grown Seed

Most farmers not using hybrid will set aside some of their harvested seed for replanting future crops. This is fine as long as the variety is suitable, storage methods are adequate, and seed-borne diseases are not a problem. If the guidelines below are followed, the farmers actually may be able to improve the varieties they are using or at least prevent a decline in their performance:

1. Seed selection should start while the crop is still growing in the field: Most farmers wait until after harvest to select seed for replanting and go largely by seed or ear size. Selecting maize seed from the largest ears may have little, if any, value. This is because the ear's size may be due less to the plant's inherent genetic ability than to environmental or management factors like fertility, plant density, and available moisture.
2. When selecting plants as potential seed sources, keep in mind the important plant characteristics that favor good yields:
   - General: Resistance to disease, insects, drought and nematodes; general plant vigor, ratio of stalk and leaves to grain, and time to maturity.
   - Maize: Resistance to lodging, extent and tightness of husk covering (for insect, bird, and water resistance), and number of well-formed ears per plant.

When selecting maize plants, make selections from well within the field to avoid possible cross-pollination, so this is not a problem with them.

3. Mark the selected plants with cloth or stakes.
4. Additional guidelines for maize: When choosing among good ears after harvest, physical differences like the number of kernel rows, kernel size, and filling of the tips and butts of the cob are relatively useless as indicators of yield potential. However, the very small, misshapen seeds at the extreme ends of the cob should be discarded. Check also for uniformity of kernel color and for insect damage.

How to Conduct a Germination Test

Farmers should be encouraged to run a germination test on seed before planting, regardless of the source. The same holds true for extension workers receiving shipments of improved seed. Germination figures that appear on seed labels can be inaccurate even if the tests were conducted fairly recently. Warm, humid conditions in the tropics can rapidly lower the germination rate. To run the test:

- Count out 100 seeds and place them on top of several thicknesses of moist newspaper. Spread them out enough so you can distinguish which ones have germinated.
- Carefully roll up the moist newspaper so that the seeds remain separated from each other and stay pressed against the newspaper. Place in a plastic bag or periodically re-moisten the newspaper to keep it from drying out.
- Sprouting time will vary with temperature, but you should be able to get a good idea of germination within three to five days unless it is unusually,cold. Good seed should have a germination rate of at least 80-85 percent under these conditions. Up to a point, you can compensate for low germination by planting more seed, but below a rate of 50 percent or so seedling vigor may suffer also.

It is a good idea where possible to supplement this type of test with an actual field test, since soil conditions are not usually as ideal. Plant 50100 seeds, keep the soil moist enough, and then count the emerged plants. If germination is very much lower than with the newspaper method, do some troubleshooting to see if insects or seeds may have caused problems.

Sowing of Seed – Methods of Sowing

Methods of Sowing: The sowing method is determined by the crop to be sown. There are 6 sowing methods which differ in their merits, demerits and adoption. Those are:

1. Broad casting
2. Broad or Line sowing
3. Dibbling
4. Transplanting
5. Planting
6. Putting seeds behind the plough.

1. Broad casting: It is the scattering of seeds by hand all over the prepared field followed by covering with wooden plank or harrow for contact of seed with soil. Crops like wheat, paddy, Sesamum, methi, coriander, etc. are sown by this method.

Advantages:

1) Quickest & cheapest method
2) Skilled labour is not uniform.
3) Implement is not required,
4) Followed in moist condition.

Disadvantages:

1) Seed requirement is more,
2) Crop stand is not uniform.
3) Result in gappy germination & defective wherever the adequate moisture is not present in the soil.
4) Spacing is not maintained within rows & lines, hence interculturing is difficult.

2.Drilling or Line sowing: It is the dropping of seeds into the soil with the help of implement such as mogha, seed drill, seed-cum-ferti driller or mechanical seed drill and then the seeds are covered by wooden plank or harrow to have contact between seed & soil. Crops like Jowar, wheat Bajara, etc. are sown by this method.

Advantages:

1) Seeds are placed at proper & uniform depths,
2) Along the rows, interculturing can be done,
3) Uniform row to row spacing is maintained,
4) Seed requirement is less than 'broad casting'

5) Sowing is done at proper moisture level.

Disadvantages:

1) Require implement for sowing,

2) Wapsa condition is must.

3) Plant to plant (Intra row) spacing is not maintained,

4) Skilled person is required for sowing.

3. Dibbling: It is the placing or dibbling of seeds at cross marks (+) made in the field with the help of maker as per the requirement of the crop in both the directions. It is done manually by dibbler. This method is followed in crops like Groundnut, Castor, and Hy. Cotton, etc. which are having bold size and high value.

Advantages:

1) Spacing between rows & plants is maintained,

2) Seeds can be dibbled at desired depth in the moisture zone,

3) Optimum plant population can be maintained,

4) Seed requirement is less than other method,

5) Implement is not required for sowing,

6) An intercrop can be taken in wider spaced crops,

7) Cross wise Intercultivation is possible.

Disadvantages:

1) Laborious & time consuming method,

2) Require more labour, hence increase the cost of cultivation,

3) Only high value & bold seeds are sown,

4) Require strict supervision.

4. Transplanting: It is the raising of seedlings on nursery beds and transplanting of seedlings in the laid out field. For this, seedlings are allowed to grow on nursery beds for about 3-5 weeks. Beds are watered one day before the transplanting of nursery to prevent jerk to the roots. The field is irrigated before actual transplanting to get the seedlings established early & quickly which reduce the mortality. Besides the advantages & disadvantages of dibbling method, initial cost of cultivation of crop can be saved but requires due care in the nursery. This method is followed in crops like paddy, fruit, vegetable, crops, tobacco, etc.

5. Planting: It is the placing of vegetative part of crops which are vegetatively propagated in the laid out field. E.g.: Tubers of Potato, mother sets of ginger & turmeric, cuttings of sweet potato & grapes, sets of sugarcane.

6. Putting seeds behind the plough: It is dropping of seeds behind the plough in the furrow with the help of manual labour by hand. This method is followed for crops like wal or gram in some areas for better utilization of soil moisture. The seeds are covered by successive furrow opened by the plough. This method is not commonly followed for sowing of the crops.

Lecture 5

TILLAGE- OBJECTIVES, CLASSIFICATION AND FUNCTION OF TILLAGE

Tillage – Definition – objectives – types of tillage - modern concepts of tillage – main field preparation

Tillage

Tillage operations in various forms have been practiced from the very inception of growing plants. Primitive man used tools to disturb the soils for placing the seeds. The word tillage is derived from 'Anglo-Saxon' words Tilian and Teolian, meaning 'to plough and prepare soil for seed to sow, to cultivate and to raise crops'. Jethrotull, who is considered as father of tillage suggested that thorough ploughing is necessary so as to make the soil into fine particles.

Tillage is the mechanical manipulation of soil with tools and implements for obtaining conditions ideal for seed germination, seedling establishment and growth of crops.

Tilth is the physical condition of soil obtained out of tillage (or) it is the result of tillage. The tilth may be a coarse tilth, fine tilth or moderate tilth.

Objectives of tillage

The main objectives of tillage are,

- To prepare a good seed bed which helps the germination of seeds.
- To create conditions in the soil suited for better growth of crops.
- To control the weeds effectively.
- To make the soil capable for absorbing more rain water.
- To mix up the manure and fertilizers uniformly in the soil.
- To aerate the soil.
- To provide adequate seed-soil contact to permit water flow to seed and seedling roots.
- To remove the hard pan and to increase the soil depth.

To achieve these objectives, the soil is disturbed / opened up and turned over.

Types of tillage: Tillage operations may be grouped into

1. On season tillage 2. Off-season tillage

1. On-season tillage

Tillage operations that are done for raising crops in the same season or at the onset of the crop season are known as on-season tillage. They may be preparatory cultivation and after cultivation.

A. Preparatory tillage: This refers to tillage operations that are done to prepare the field for raising crops. It consists of deep opening and loosening of the soil to bring about a desirable tilth as well as to incorporate or uproot weeds and crop stubble when the soil is in a workable condition.

Types of preparatory tillage

a. Primary tillage

b. Secondary tillage

a. Primary tillage: The tillage operation that is done after the harvest of crop to bring the land under cultivation is known as primary tillage or ploughing. Ploughing is the opening of compact soil with the help of different ploughs. Country plough, mould board plough, bose plough, tractor and power tiller drawn implements are used for primary tillage.

b. Secondary tillage: The tillage operations that are performed on the soil after primary tillage to bring a good soil tilth are known as secondary tillage. Secondary tillage consists of lighter or finer operation which is done to clean the soil, break the clods and incorporate the manure and fertilizers. Harrowing and planking is done to serve those purposes.

Planking is done to crush the hard clods, level the soil surface and to compact the soil lightly. Harrows, cultivators, Guntakas and spade are used for secondary tillage.

c. Layout of seed bed:This is also one of the components of preparatory tillage. Leveling board, buck scrapers etc. are used for leveling and markers are used for layout of seedbed.

B. After cultivation (Inter tillage): The tillage operations that are carried out in the standing crop after the sowing or planting and prior to the harvesting of the crop plants are called after tillage. This is also called as inter cultivation or post seeding/ planting cultivation. It includes harrowing, hoeing, weeding, earthing up, drilling or side dressing of fertilizers etc. Spade, hoe, weeders etc. are used for inter cultivation.

2. Off-season tillage: Tillage operations done for conditioning the soil suitably for the forthcoming main season crop are called off-season tillage. Off season tillage may be, post harvest tillage, summer tillage, winter tillage and fallow tillage.

Special purpose tillage: Tillage operations intended to serve special purposes are said to be special purpose tillage. They are,

a. Sub-soiling: To break the hard pan beneath the plough layer, special tillage operation (chiseling) is performed to reduce compaction. Sub-soiling is essential and once in four to five years where heavy machineries are used for field operations, seeding, harvesting and transporting. Advantages of sub-soiling are, greater volume of soil may be obtained for cultivation of crops, excess water may percolate downward to recharge the permanent water table, reduce runoff and soil erosion and roots of crop plants can penetrate deeper to extract moisture from the water table.

b. Clean tillage: It refers to working of the soil of the entire field in such a way no living plant is left undisturbed. It is practiced to control weeds, soil borne pathogen and pests.

c. Blind tillage: It refers to tillage done after seeding or planting the crop (in a sterile soil) either at the pre-emergence stage of the crop plants or while they are in the early stages of growth so that crop plants (sugarcane, potato etc.) do not get damaged, but, extra plants and broad leaved weeds are uprooted.

d. Dry tillage: Dry tillage is practiced for crops that are sown or planted in dry land condition having sufficient moisture for germination of seeds. This is suitable for crops like broadcasted rice, jute, wheat, oilseed crops, pulses, potato and vegetable crops. Dry tillage is done in a soil having sufficient moisture (21-23%). The soil becomes more porous and soft due to dry tillage. Besides, the water holding capacity of the soil and aeration are increased. These conditions are more favourable for soil micro-organisms.

e. Wet tillage or puddling: The tillage operation that is done in a land with standing water is called wet tillage or puddling. Puddling operation consists of ploughing repeatedly in standing water until the soil becomes soft and muddy. Puddling creates an impervious layer below the surface to reduce deep percolation losses of water and to provide soft seed bed for planting rice. Puddling is done in both the directions for the incorporation of green manures and weeds. Wet tillage destroys the soil structure and the soil particles that are separated during puddling settle later. Wet tillage is the only means of land preparation for transplanting semi-aquatic crop plant such as rice. Planking after wet tillage makes the soil level and compact. Puddling hastens transplanting operation as well as establishment of seedlings. Wet land ploughs or worn out dry land ploughs are normally used for wet tillage.

Depth of ploughing

The desirable depth of ploughing is 12 to 20 cm for field crops. The ploughing depth varies with effective root zone of the crop. The depth of ploughing is 10-20 cm for shallow rooted crops and 15-30 cm for deep rooted crops.

Number of ploughing

Number of ploughing depends on soil conditions, time available for cultivation between two crops and type of cropping systems. Zero tillage is practiced in rice fallow pulses. Minimum number of ploughing is taken up at optimum moisture level to bring favourable tilth depending on need of the crop.

Time of ploughing

The optimum soil moisture content for tillage is 60% of field capacity.

Modern concepts in tillage:

Conventional tillage involves primary tillage to break open and turn the soil followed by secondary tillage to obtain seed bed for sowing or planting. With the introduction of herbicides in intensive farming systems, the concept of tillage has been changed. Continuous use of heavy ploughs create hard pan in the subsoil, results in poor infiltration. It is more susceptible to run-off and erosion. It is capital intensive and increase soil degradation. To avoid these ill effects, modern concepts on tillage is in rule.

1. Minimum tillage: It aims at reducing tillage operations to the minimum necessity for ensuring a good seed bed. The advantages of minimum tillage over conventional tillage are,

• The cost and time for field preparation is reduced by reducing the number of field operations.

• Soil compaction is comparatively less.

• Soil structure is not destroyed.

• Water loss through runoff and erosion is minimum.

• Water storage in the plough layer is increased.

Tillage can be reduced in 2 ways

1. By omitting operations which do not give much benefit when compared to the cost.

2. By combining agricultural operations like seeding and fertilizer application.

The minimum tillage systems can be grouped into the following categories,

1. Row zone tillage

Primary tillage is done with mould board plough in the entire area of the field; secondary tillage operations like discing and harrowing are reduced and done only in row zone.

2. Plough plant tillage

After the primary tillage, a special planter is used for sowing. In one run over the field, the row zone is pulverized and seeds are sown by the planter

3. Wheel track tillage

Primary ploughing is done as usual. Tractor is used for sowing; the wheels of the tractor pulverize the row zone in which planting is done.

In all these systems, primary tillage is as usual. However, secondary tillage is replaced by direct sowing in which sown seed is covered in the row zone with the equipment used for sowing.

2. Zero tillage (No tillage): In this, new crop is planted in the residues of the previous crop without any prior soil tillage or seed bed preparation and it is possible when all the weeds are controlled by the use of herbicides. Zero tillage is applicable for soils with a coarse textured surface horizon, good internal drainage, high biological activity of soil fauna, favourable initial soil structure and an adequate quantity of crop residue as mulch. These conditions are generally found in Alfisols, Oxisols and Ultisols in the humid and sub-humid tropics.

Till planting

Till planting is one method of practicing zero tillage. A wide sweep and trash bar clears a strip over the previous crop row and planter opens a narrow strip into which seeds are planted and covered. Here, herbicide functions are extended. Before sowing, the vegetation present has to be destroyed for which broad spectrum non selective herbicides like glyposate, paraquat and diquat are used.

Advantages

- Zero tilled soils are homogenous in structure with more number of earthworms.
- Organic matter content increases due to less mineralization.
- Surface run-off is reduced due to presence of mulch.

Disadvantages

• Higher amount of nitrogen has to be applied for mineralization of organic matter in zero tillage.

• Perennial weeds may be a problem.

• High number of volunteer plants and buildup of pests.

3. Stubble mulch tillage or stubble mulch farming

Soil is protected at all times either by growing a crop or by leaving the crop residues on the surface during fallow periods. Sweeps or blades are generally used to cut the soil up to 12 to 15 cm depth in the first operation after harvest and depth of cut is reduced during subsequent operations. When large amount of residues are present, a disc type implement is used for the first operation to incorporate some of the residues into the soil. This hastens the decomposition but still keeps enough residues on top soil.

Two methods for sowing crops in stubble mulch tillage are,

1. Similar to zero tillage, a wide sweep and trash bars are used to clear a strip and a narrow planter shoe opens a narrow furrow into which seeds are placed.

2. A narrow chisel of 5-10 cm width is worked through the soil at a depth of 15-30 cm leaving all plant residues on the surface. The chisel shatters the tillage pans and surface crusts. Planting is done with special planters.

Disadvantages of stubble mulch farming

• The residues left on the surface interfere with seed bed preparation and sowing operations.

• The traditional tillage and sowing implements or equipments are not suitable under these conditions.

4. Conservation tillage: The major objective is to conserve soil and soil moisture. It is a system of tillage in which organic residues are not inverted into the soil such that they remain on surface as protective cover against erosion and evaporation losses of soil moisture. If stubble forms the protective cover on the surface, it is usually referred to as stubble mulch tillage. The residues left on soil surface interfere with seed bed preparation and sowing operations. It is a year round system of managing plant residue with implements that undercut residues, losses the soil and kills the weeds.

Advantages

- Energy conservation through reduced tillage operations.
- Improve the soil physical properties.
- Reduce the water runoff from fields.

Main field preparation:

Tillage operations are generally classified in to two, preparatory cultivation and after cultivation. The preparatory cultivation or tillage is operations that are done before the cultivation. This preparatory cultivation is generally called as main field preparation. The main field preparation involves three processes, viz., primary tillage, secondary tillage and lay-out for sowing. Some of the important primary tillage implements are country plough, mould board plough, disc plough, chisel plough etc. Cultivators and harrows are generally used for secondary tillage purpose. However, in practical means, the first two (primary and secondary tillages) may not have any key difference, since; both operations are mainly carried out with same implement. Country plough and cultivators are used for both the purposes. After thorough ploughing, the field modified in to suitable way for planting such as ridges and furrows or beds and channels or pit according to the need of the crops. Such field modifications are mandatory for better crop production.

Lecture 6

CROPPING SCHEME AND CROPPING SYSTEM- DIFFERENT TYPES OF CROPPING SYSTEM: INTERCROPPING, MIXED CROPPING, INTENSIVE CROPPING, RELAY CROPPING, ALLEY CROPPING ETC., DEFINITION AND ADVANTAGES WITH EXAMPLES

Cropping systems, its definition, types, advantages and disadvantages

Management practices are developed for individual crops and recommendations are made for individual crops. The residual effects of individual crops are not considered in crop based recommendations. In this approach, resources are not utilized efficiently. To a farmer, instead of a crop, land is a unit and management practices should be for all crops that are to be grown on a piece of land. Cropping system is important component of farming system.

This system approach is applied to agriculture for efficient utilization of all recourses, maintaining stability in production and obtaining higher net return.

Cropping system: - Cropping system is important component of farming system. It represents cropping pattern used on the farm and their interaction with other farm resources, other farm enterprises and available technology which determine their make up.

Cropping pattern:-

Cropping pattern means the proportion of the area under various crops at a point of a time in a unit area. It indicates the yearly sequence and special arrangement of crops and fallow in an area.

Crop rotation: - Crop rotation refers recurrent succession of crop on the same piece of land either in a year or over a longer period of time.

Types of cropping system: - Depending on the resources and technology available, different types of cropping system adopted on farms.

1) **Monocropping / Monoculture**:-

Monocropping or Monoculture refers to growing of only one crop on a same piece of land year after year. It may due to climatologically and socio–economic condition or due to specialization of farmer growing a particular crop. Rice crop is grown in konkan region.

2) Multiple cropping:-

Growing of two or more crop on the same piece of land in one calendar year is known as multiple cropping systems. It is intensification of time and space dimension, i.e. more number of crops grown within a year and more number of crops grown on the same piece of land at any given period. It includes intercropping, mixed cropping and sequence cropping.

Intercropping: - intercropping is growing of two or more crop simultaneously on the same piece of land with a definite row pattern. For example, growing *setaria* + red gram in 5: 1 ratio i.e. after every five rows of *setaria*, one row of red gram is sown.

Intercropping was originally practiced as an insurance against crop failure under *rainfed* conditions. At present, the main objective of intercropping is high productivity per unit area in addition to stability in production.

Mixed cropping:- is the growing of two or more crops simultaneously on the same piece of land without any row pattern. It is common practice in most of the dryland tracks of india. Seeds of different crops are mixed in certain proportion and are sown.

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

Relay cropping:- Relay cropping refers to planting of the succeeding (next) crop just before harvesting of the preceding crop (first).

Ratoon cropping or rationing refers to raising a crop with regrowth coming out of root or stalks after harvest of crop.

Advantages :-

1. Insurance against total crop failure.

2. Better utilization of available resources.(land, laboure,solar energy)
3. Soil fertility improved.
4. Increases total crop productivity per unit area.
5. Soil erosion is minimizes.
6. One crop provides shelter to other.

Disadvantages:-

1. Care should be taken while selection of crop.
2. Difficult to carry field operation**.**
3. Weed control through herbicide is difficult.
4. More labore and input required.

Lecture 7

CROP ROTATION - OBJECTIVES TYPES AND ADVANTAGE

- Repeated cultivation of crops or crops and fallow in a certain sequence on the same land is called crop rotation.

Example: Rice- Wheat- Moong

- It is the reverse of land rotation.
- Here crop is rotated year after year.

Definition of crop rotation

It refers to recurrent succession of crops on the same piece of land either in a year or over a longer period of time. OR

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

Different crop rotation

1. Cotton – Groundnut
2. Rice – Gram/ Sunflower
3. Hybrid Jowar – Wheat/ Jowar/ Gram
4. Jowar – Sunflower – Groundnut
5. Sunflower – Potato – Groundnut
6. Groundnut – Wheat – Vegetables
7. Sorghum – Wheat – Green gram – Cotton –Groundnut
8. Sun hemp – Sugarcane – Groundnut

OBJECTIVES OF CROP ROTATION

1) To prevent the built up of insect pest, weeds and soil born diseases
2) To maintain soil fertility for the next crop
3) To conserve soil erosion which may cause from wind or water
4) To conserve soil moisture from one season for the next
5) To ensure a balanced programme of work throughout the season

PRINCIPLE OF CROP ROTATION

- Alternating growing of crops with differential ability to absorb nutrients from the soil or having **different root depth.** Shallow rooted crops must be followed by deep rooted crops in next season and vice versa.
- Alternating crops susceptible to certain diseases with those that are resistant (alternate host provision)
- A planned succession of crops that take it to account any detrimental or beneficial effects of one crop on the following crop. These effects may be due to toxic organic matter, soil structure, soil micro organisms or residual soil moisture.
- Alternating soil exhausting crops with crops that contribute to the improvement of soil fertility
- Alternating crops with different peak requirements of labour and water etc.
- Cereals must be followed by pulses and vice versa.
- Follow a legume forage crop, such as clover or alfalfa, with a high-nitrogen-demanding crop, such as corn, to take advantage of the nitrogen supply.
- Grow less of nitrogen-demanding crops, such as oats, barley and wheat, in the second or third year after a legume.

- Grow the same annual crop for only one year, if possible, to decrease the livelihood of insects, diseases, and nematodes becoming a problem.
- Don't follow a crop with a closely related species, since insect, disease, and nematode problems are frequently shared by members of closely related crops.
- If specific nematodes are known problems, consider planting non-host plants (such as grain crops for root-knot nematode) for a few years to decrease populations before planting a very susceptible crop such as carrots or lettuce. High populations of plant parasitic nematodes will also affect the choice of cover crops.
- Use crop sequences that promote healthier crops. Some crops seem to do well following a particular crop. Example: cabbage family crops following onions, or potatoes following corn.
- Use crop sequences that aid in controlling weeds. Small grains compete strongly against weeds and may inhibit germination of weed seeds, row crops permit mid-season cultivation, and sod crops that are mowed regularly or intensively grazed help control annual weeds.
- Use longer periods of perennial crops, such as a forage legume, on sloping land and on highly erosive soils. Using sound conservation practices, such as no-till planting, extensive cover cropping, or strip cropping (a practice that combines the benefits of rotations and erosion control).
- Try to grow a deep-rooted crop, such as alfalfa, safflower, or sunflower, as part of the rotation. These crops scavenge the subsoil for nutrients and water, and channels left from decayed roots can promote water infiltration.
- In regions with limited rainfall, the amount of water used by a crop may be a critically important issue— usually one of the most important issues. Without plentiful irrigation, growing high-water-use crops such as hay, as well as sunflower and safflower, may not leave sufficient moisture in the soil for the next crop in the rotation.

- Be flexible enough to adapt to annual climate and crop price variations, as well as development of soil pathogens and plant parasitic nematodes

ADVANTAGES

1. Rotation of crops **improves the fertility** of the soil and hence, brings about an increase in the production of food grains.
2. Rotation of crops helps in **saving on nitrogenous fertilizers**, because leguminous plants grown during the rotation of crops can fix atmospheric nitrogen in the soil with the help of nitrogen fixing bacteria.
3. Rotation of crops help in **weed control and pest control**. This is because weeds and pests are very choosy about the host crop plant, which they attack. When the crop is changed the cycle is broken. Hence, pesticide cost is reduced.
4. Crop rotation **adds diversity** to an operation.

FACTOR AFFECTING CROP ROTATION

1. **Climate**
2. **Type and nature of soil**
3. **Availability of inputs**
4. **Availability of labour**
5. **Situation of farm**
6. **Size of farm**
7. **Type of farming**

1. **Climate:** Climate is the one of most important factor which is affect the crop rotation either by wind, rain or other factors. In the High temperature region we should keep the heat tolerant crop in our crop rotation

2. **Type and nature of soil:** Type and nature of soil is also important factor which affects the crop rotation, some soil are fertile and some are low in fertility. While setting a Rotation the nature of the soil whether it is fertile or poor should be kept in mind. Such as Fertile soils, Medium soil, Poor soils

3. **Availability of inputs:** Availability of inputs at the place also affects the crop rotation like fertilizer, pesticide etc. Availability of the fertilizer affect in such a way that if the fertilizer are available easily at cheaper rates the duration of the rotation will be less and vice versa, available on sowing

4. **Availability of labour:** Availability of labour affects the crop rotation. The labour is required at the critical stages of crop. If the labour is not available at that time the crop may cause loss. While setting rotation the type of manual labor , power and its availability for working the different operation affect the crop rotation. Enhances farm utilization and is available at sowing

5. **Situation of farm:** The farm location is also very important factor which affect the crop rotation. The type of crop and rotation will affected when the farm is present near the city as compared to the countryside. If our farm near the city then we should grow the Vegetables and fodder to get more profit in market

6. **Size of Farm:** The size of farm affects the crop rotation. Small land holding is major problem in India that's why crop rotation is affected by the farm size. On small farm rotation will be different in comparison to the big farms.

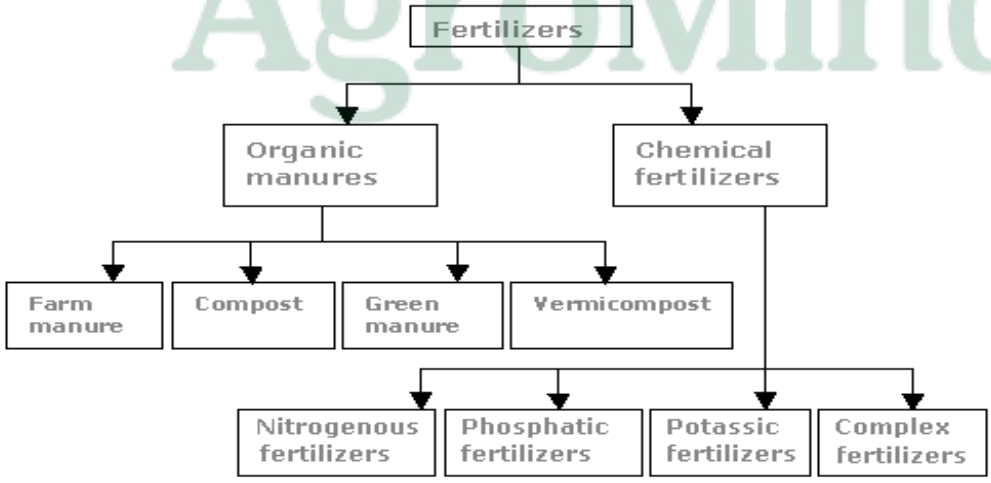
7. **Type of farming:** Type of farming also affect the crop rotation. The nature of the farming effect the rotation in such a way that the crops in vegetable farming will be different as compared to the arable farming, Arable farming is to growing crops, In vegetable farming grow vegetables such as Raddish/carrot-Pumpkin/Ladyfinger.

Lecture 8

CLASSIFICATION OF MANURES AND FERTILIZERS, GREEN MANURING

IMPORTANCE OF MANURES AND FERTILIZERS

- Organic manures bind the sandy soil and improve its water holding capacity.
- Organic manures open the clayey soil and help in aeration for better root growth.
- Organic manures add plant nutrients in small percentage and also add micronutrients, which are essential for plant growth.
- Manures increases the microbial activity which helps in releasing plant nutrients to available form.
- Organic manures should be incorporated before the sowing or planting because of slow release of nutrients.
- Fertilizers play an important role in crop production as they supply large quantities of essential nutrient to crops.
- Fertilizers are manufactured in forms that are readily utilized by plants directly or after rapid transformation.
- Fertilizers dose can be adjusted to suit the requirement as determined by soil testing.
- Balanced application of nutrient based on crop requirement is possible by appropriate mixing of fertilizers.
- Fertilizers applied as straight fertilizers (providing single nutrient) or complex and mixed fertilizers (supplies two or more nutrients) based on crop requirement.



ORGANIC MANURES

Organic manures include plant and animal by-products such as oil cakes fish manures and dried blood from slaughter houses. Before their organic nitrogen used by the crops it is converted through bacterial action into readily usable ammonical N and nitrate N. These manures are therefore, relatively slow acting, but they supply available N for a longer period.

Advantages

- Organic manures supply plant nutrients including micronutrients.
- Organic manuresimprove physical properties of the soil, water holding capacity, hydraulic conductivity and infiltration capacity of the soil.
- CO_2 released during decomposition combines with water and forms carbonic acid and act as CO_2 fertilizer.
- Organic manures supply energy (food) for microbes and increase availability of nutrients and improve soil fertility.
- Green manures have the additional advantage of fixing atmos-pheric nitrogen leading to nitrogen economy in crop production and green manures draw nutrients from lower layers and concentrate them in the surface soil for the use of succeeding crop.

Classification of Organic Manures

A. Bulky organic manures

(i) FYM

(a) Cattle manure, (b) Sheep manure, (c) Poultry manure

(ii) Compost

(a) Village/rural compost from farm-wastes(b) Town/urban compost from town refuses

(iii) Sewage and sludge

B. Concentrated organic manures

Oil cakes

(a) Edible oil cakes (i.e., used for cattle feeding) - (i) Mustard cake, (ii) Groundnut cake, (iii) Sesame cake, (iv) Linseed cake

(b) Non edible oil cakes (i.e., used as manures) - (i) Castor cake, (ii) Neem cake, (iii) Sunflower cake, (iv) Mahua cake, (v) Karanja cake

Slaughter house wastes

(i) Blood meal, (ii) Bone meal

Fish meal

Guano

Material obtained from the excreta and dead bodies of sea bird

C. Green manures

(a) Leguminous plant (example: Sunn hemp, Sesbania sp., mungbean, cowpea, guar, senji, berseem)

(b) Non-leguminous plant (example: Sorghum, pearl millet, maize, sunflower)

D. Green leaf manures

Green leaves of trees like neem, pungam, glyricidia, vadhanarayana etc.

BULKY ORGANIC MANURES

Bulky organic manures are those manures, which are generally bulk in quantities and poor in plant nutrients (low quantities of plant nutrients). Example: Farm yard manure, compost, sewage and sludge etc.

A. Farm Yard Manure (FYM)

It is the manure produced in the farm which is made up of excreta (dung and urine) of farm animals, the bedding materials provided for them and miscellaneous farm and house hold wastes. Straw, peat and saw dust, dry leaves etc., are used as bedding material for farm animal and accounts to 3–4 kg per animal per day. The bedding material is called 'litter' and it absorbs urine voided by animals. It is not a standardized product and its value depends on the kind of feed fed to the animal, the amount of straw used and the manner of storage. In general FYM contains 0.8% N, 0.41% P_2O_5 and 0.74% K_2O. The excreta of horses and sheep are drier than other and do not get compacted in the heap. There is considerable aeration, bacterial activity and rise in temperature in the manure. They are therefore called 'hot manures' in the temperate countries. Pig and cattle manure contain more moisture and compacted in the manure pit. Their decomposition is not as vigorous as that of hot manures

and the rise of temperature is also low. Therefore pig and cattle manures are called “cold manures”. The decomposition of cattle manures may be slower comparatively under temperate regions but it is rapid enough under tropical condition.

B. Compost

It is a manure derived from decomposed plant residues usually made by fermenting waste plant materials heaped or put in a pit usually in alternate layers with a view to bring the plant nutrients in a more readily available form.

Super compost: Compost fortified with super phosphate is called as super compost.Startersare thematerials added to the composting organic wastes, which provide the decomposing organism. Pig dung slurry is a valuable starter and provides necessary organisms. Even cow dung slurry can be used as starter. Generally ammonium sulphate and super phosphate are added to the layers at the time of furrowing the composting heap to enrich nitrogen and phosphorus status of compost respectively. Fertilizers accelerate and hasten the decomposition of organic matter or wastes.

C. Sewage and Sludge

In cities human excreta are flushed out with large quantities of water, which is known as sludge. It contains two components, one is solid portion called sludge and another is liquid portion called sewage water. In general, the sludges are rich in N and P, and low in K. The sewage water is used for irrigation after proper treatments.

Table: Nutrient Content of the Bulky Organic Manures

Manure	Percentage composition of		
	N (%)	**P_2O_5 (%)**	**K_2O(%)**
Cattle dung	**0.40**	0.20	0.20
Cattle urine	**1.00**	–	1.35
Sheep and goat dung	**0.75**	0.50	0.45
Sheep and goat urine	**1.35**	0.05	2.10
Sheep and goat manure	**3.00**	1.00	2.00
Poultry manure	**3.03**	2.63	1.40
Horse manure	**2.00**	1.50	1.50
Horse urine	**1.35**	–	1.25
Pig dung	**0.60**	0.50	0.40
Pig urine	**1.10**	0.10	0.45
Farm litter compost	**0.50**	0.15	0.50
Rural compost	**1.22**	1.08	1.47
Town compost	**1.40**	1.00	1.40
Water hyacinth compost	**2.00**	1.00	2.30
Vermicompost	**3.00**	1.00	1.50
Night soil	**5.50**	4.00	2.00
Paddy straw	**1.50**	1.34	3.37
Sugarcane trash	**2.73**	1.81	1.31
Sewage sludge	**1.5-3.5**	0.75-4.00	0.3-0.6

CONCENTRATED ORGANIC MANURES

Concentrated organic manures are those manures which are rich in particular nutrients (N) but relatively having low volume of organic materials. Example: Oil cakes, blood and bone meal, fishmeal, press mud etc.

A. Oil cakes

Oil cake is the residue left after the oil is extracted from oil containing seed. The manurial values of oil cake lie mainly in its nitrogen contribution though it is in small quantities. The nitrogen content varies between 3% and 9% (Table 12.4). The C:N ratio is usually 3–15 for most of the oil cakes.

Table: Nutrient Content of some Concentrated Organic Manures

Manure	**N (%)**	P_2O_5 (%)	K_2O(%)
Castor cake	**4.0-4.4**	1.9	1.4
Groundnut cake	**6.5-7.5**	1.3	1.5
Cotton seed cake (decorticated)	**6.9**	3.1	1.6
Cotton seed cake (undecorticated)	**3.6**	2.5	1.6
Linseed cake	**5.6**	1.4	1.3
Coconut cake	**3.4**	1.9	1.9
Neem cake	**5.2-5.6**	1.1	1.5
Safflower cake (decorticated)	**7.9**	2.2	1.9
Safflower (undecorticated)	**4.9**	1.4	1.2
Sesamum cake	**4.7-6.2**	2.1	1.3
Mahua cake	**2.5**	0.8	1.9
Niger cake	**4.7**	1.8	1.3
Pungam cake	**4.0**	1.0	1.3
Raw bone meal	**4.0**	20-25	–
Steamed bone meal	**4.7**	25-30	–
Basic slag	**4.0**	1.0	1.3
Fish meal	**4-10**	3-9	1.5
Blood meal	**10-12**	1-2	1.0
Meat meal	**9-11**	3.5	–
Horn and hoof meal	**10-15**	1	–
Press mud	**1-1.5**	4-5	2-7
Guano (Peruvian bird)	**11-16**	8-12	2-3

FERTILIZERS

Fertilizers are synthetic (commercially manufactured) or naturally occurring chemical compounds either dry solid or liquid that added to the soil to supply one or more plant nutrients for crop growth.

Classification

The fertilizers are classified based on whether the fertilizer supplies a single or more than one nutrient, their chemical nature and commercial mode of supply as straight, compound, complex and mixed.

Straight Fertilizers

When a fertilizer contains and is used for supplying a single nutrient, it is called a straight fertilizer. This is further classified as nitrogenous, phosphatic and potassic fertilizers depending on the specific macro nutrient present in the fertilizer.

A. Nitrogenous fertilizers: N fertilizers are those fertilizers containing N as major nutrient. It may be either a nitrate or ammonium or amide fertilizer depending on the form of nitrogen present.

Table Nutrient Composition of different N Fertilizers

Sources	Nutrient content (Percent) available							
	N	P_2O_5	K_2O	CaO	MgO	S	Cl	
Ammonium sulphate	**20.6**	-	-	-	-	24.0	-	$NH^{+}4$
Ammonium chloride	**25-26**	-	-	-	-	-	66	”
Ammonium nitrate	**33-34**	-	-	-	-	-	-	NH_4 and NO_3
Ammonium sulphate nitrate	**26.0**	-	-	-	-	-	-	”
Anhydrous ammonia	**82.0**	-	-	-	-	-	-	”
Calcium ammonium nitrate	**35**	-	-	8.1	4.5	-	-	”
Calcium nitrate	**15**	-	-	34	-	-	-	NO_3
Sodium nitrate	**16**	-	-	-	-	-	-	”
Urea	**46**	-	-	-	-	-	-	Amide
Calcium cynamide	**21**	-	-	-	-	-	-	”

B. Phosphatic fertilizers: They are classified into three groups, based on the solubility of phosphate contained in the fertilizer.

(i) **Water soluble phosphoric acid (Monocalcium phosphate) Ca $(H_2PO_4)_2$**

Single super phosphate 16% $Ca(H_2PO_4)_2$, H_2O

Double super phosphate 32% $2Ca\ (H_2PO_4)_2$, H_2O

Triple super phosphate 48% $3Ca\ (H_2PO_4)_2$, H_2O

(ii) **Citric acid soluble phosphoric acid (Dicalcium phosphate) ($CaHPO_4$)**

Basic slag -14-18% P_2O_5 (by-product from steel industry)

Dicalcium Phosphate -34-39% P_2O_5

(iii) **Insoluble phosphoric acid (Tricalcium phosphate)$Ca_3(PO_4)_2$**

Rock phosphate 20-40% P_2O_5

Raw bone meal 20-25% P_2O_5, Steamed bone meal 22%–30% P_2O_5

(C) Potassic fertilizers

Muriate of potash (KCI)	60%
Sulphate of potash (K_2SO_4)	48–52%
Potassium nitrate (KNO_3)	48% (N-13%)
Schoenite (K_2SO_4, $MgSO_4$) $6H_2O$	22–24%

Compound Fertilizers: Compound fertilizers are the commercial fertilizers in which two or more primary nutrients are chemi-cally combined. For example: DAP. DAP contains 18% N and 46% P_2O_5.

Table Compound Fertilizers

Fertilizer	N	P_2O_5	K_2O
Di ammonium phosphate (DAP)	18	46	-
Mono ammonium phosphate	11	48	-
Urea ammonium phosphate	28	28	-
Ammonium phosphate	16	20	-

Complex Fertilizers: Complex fertilizers are the commercial fertilizers containing at least two or more of the primary essential nutrients at higher concentration in one compound. The nutrients in complex fertilizers are physically mixed.

Table Complex Fertilizers

Fertilizer	N	P_2O_5	K_2O
Complex fertilizers	17	17	17 (MF)
	14	28	14 (MF)
	10	26	26 (IFFCO)
	12	32	16 (IFFCO)
	14	36	12 (IFFCO)
Nitro-phosphate-potash	15	15	15
Gromor	14	35	14

Mixed Fertilizers/Fertilizers Mixtures

They are physical mixtures of two or more straight fertilizers. Sometimes a complex fertilizer is also used as one of the ingredients. The mixing is done mechanically. The fertilizer mixtures are usually in powder form but techniques have been developed for granulation of mixtures so that each grain will contain all the nutrients mixed in the mixture.

(a) Salts containing secondary nutrients

Calcium, sulphur and magnesium are termed as secondary nutrients since they are required compara-tively less in quantity than primary nutrients (N, P, K) but more than micronutrients. They are added to the soil through some fertilizers, like ammonium sulphate, calcium ammonium nitrate and phosphatic fertilizers. Commercial fertilizers containing these secondary nutrients are: (i) Magnesium sulphate (Epsum) – 9.6% Mg and 13% S, and (ii) Calcium sulphate (Gypsum) – 9% Ca and 23% SO_4.

(b) Salts containing micronutrients

Copper, zinc, boron, manganese, molybdenum, iron and chlorine are termed as micronutrients since they are required in micro quantities. They are added to the soil through some commercial fertilizers.

Difference between Manures and Fertilizers:

Sr No	Characteristics	Manures	Fertilizer
1	Origin	Plant or animal origin	Chemical synthesized or manufactured
2	Nature	Organic in nature	Inorganic in nature
3	Type	Natural product	artificial product
4	Conc. Of nutrients	less concentrated	More concentrated
5	Material	Supply organic matter	Supply inorganic matter
6	Nutrient availability	slowly available	May or may not be readily available
7	Nutrients	Supply all the primary nutrients including Micronutrient	Supply specific type of nutrients one, two or three. micro nutrients may or may not be present
8	Effect on Soil Health	Improves physical condition of soil	Do not improve the physical condition of soil
9	Effect on plant growth	No bad effect when applied in large quantities.	Adverse effect on plant whenever there is deficiency or excessive application

Green Manuring

Green manuring is the act of growing of quick growing crop preferably legumes and ploughing in situ and incorporated into the soil. Whereas green leaf manuring is incorporation of green matter into the soil transported from elsewhere. The percentage N of some of the green/green leaf manures is given in following Table.

Table Nutrient Content of Green Manure Crops and Green Leaf Manures

Plant	Scientific Name	Nutrient content (%) on air dry basis		
		N	P_2O_5	K_2O
Green manure				
Sunn hemp	Crotolaria juncea	**2.30**	0.50	1.30
Manila agathi	Sesbania rostrata	**3.30**	0.60	1.20
Daincha	Sesbania aculeata	**3.20**	0.60	1.20
Pillipesara	Phaseolus trilobus	**2.80**	0.50	1.15
Sesbania	Sesbania speciosa	**2.71**	0.53	2.21
Kolinji	Tephrosia purpurea	**3.10**	0.52	1.18
Green Leaf manure				
Glyricidia	Glyricidia sepium	**2.76**	0.28	4.60
Pongamia	Pongamia glabra	**3.31**	0.44	2.39
Neem	Azadiracta indica	**2.83**	0.28	0.35
Gulmohur	Delonix regia	**2.76**	0.46	0.50
Vadanarayanan	Delonix elata	**3.51**	0.31	0.43
Subabul	Leucaena leucocephala	**3.50**	0.48	0.81
Peltophorum	Peltophorum ferrugenium	**2.63**	0.37	0.50
Weeds				
Parthenium	Parthenium hystorophorus	**2.68**	0.68	1.45
Water hyacinth	Eichhornia crassipes	**3.01**	0.90	0.15
Sarannai	Trianthema portulacastrum	**2.64**	0.43	1.30
Aduthoda	Aduthoda vesica	**1.32**	0.38	0.15
Ipomea	Ipomoea cornea	**2.01**	0.33	0.40
Calotrophis	Calotrophis gigantean	**2.06**	0.54	0.31
Cassia	Cassia fistula	**1.60**	0.24	1.20

(a) **Stem nodulating green manure -** Leguminous green manure plants produce root nodules and fix atmospheric N. Sesbania rostrata produces nodules on their stem besides root nodulation. This special feature adds their green manurial value. It is tropical legume of Senegal origin and thrives well under flooded and water logged conditions. It is capable of producing 22 tons of fresh biomass and could accumulate 150 kg N/ha in 45 days. It contains 3.3% N.

(b) **Dhaincha in reclamation of saline and alkali soils -** Green manuring practice in sodic soil has an unique importance since it adds acids in the reclamation process, besides improving the fertility status of the soil. Usually the fertility status of sodic soil is very poor because of its high pH and exchangeable sodium percentage. The soil organic matter content, a measure of available nitrogen, is very low i.e., 0.1-0.5% in sodic soil because sodium carbonate and sodium bicarbonate salts in solution dissolve the humus. Further the available nitrogen is much lower in the subsoil layers of the sodic soils.

Reclamation of alkali soils basically involves replacing Na on the exchange complex with more favourable cations. The solubility of lime, which is always present in alkali soils in significant amounts, is very low, because the potassium content of alkali soil is high. There is an intimate relationship between soil pH, partial pressure of CO_2 and calcium ion activity in calcareous alkali soils. Increase in CO_2 production in the soil enables to increase the soluble Ca status of soils. This in turn, replaces exchangeable Na, resulting in the improvement of alkali soils. Soil incorporation of easily decomposable plant material results in increased and rapid production of CO_2. For this reason, green manuring has been suggested as an important management practice for the reclamation of alkali soils.

Sesbania aculeata and Delonix elata are very effective green manures and green leaf manures respectively used for reclamation of sodic soils. Daincha (Sesbania aculeata) is highly resistant to both drought and water stagnation and salinity and alkalinity. It can be grown in soils with pH 4.5 to 9.5. It produces green matter of 20 t/ha in 90 days. Daincha contains 3.2% N and 34% Ca on dry weight basis which helps to replace Na from sodic soils. The acid juice (pH 4.0) and high seed protein content (58%) seems to be the cause of its resistance to sodicity stress. During the reclamation of sodic soils gypsum 50% of gypsum requirement (GR) has to be spread uniformly over the field. The surface soil is to be ploughed to mix the gypsum in the sodic soil. Irrigate the field with 10-15 cm depth of water and maintain the same water depth for 3-4 days. At this stage, the sodium content in clay particles are replaced by the calcium ions from the gypsum, allowing the sodium to wash out of the field as Leachate. The field has to be kept with stagnant water for 3–4 times after each drainage process. Apply the Delonix elata leaves and daincha @ 5 t/ha without allowing the soil to dry. After four to five days of incorporation of green leaves, the field crop like rice with preferably a tolerant variety.

Lecture 9 and 10

Cultivation of cereals (Rice, Maize, Sorghum, Pearl millet and minor millets)

RICE (*Oryza sativa* L.)

It is the staple food crop for more than 60 per cent of the world people. In some countries, attractive ready to eat products, which have, long shelf life *e.g.* popped and puffed rice, instant or rice flakes, canned rice and fermented products are produced. Protein is present in aleuron and endosperm (6–9%) and average is 7.5%. Rice straw is used as cattle feed, used for thatching roof and in cottage industry for preparation of hats, mats, ropes, sound absorbing straw board and used as litter material. Rice husk is used as animal feed, for papermaking and as fuel source. Rice bran is used as cattle and poultry feed and defatted bran, which is rich in protein, can be used in the preparation of biscuits. Rice bran oil is used in soap industry. Refined oil can be used as a cooling medium like cotton seed oil/corn oil. Rice bran wax, a byproduct of rice bran oil is used in industries. Rice bran oil is available in the market in the name of Porna for edible purpose (no cholesterol).

ORIGIN :

De Candolle (1886) and Watt (1862) thought that South India was the place where cultivated rice is originated. Vavilov (1926) suggested that India and Burma should be the origin of cultivated crop.

Species :

Rice belongs to genus Oryza and family Poaceae. The genus includes 24 species of which *O. sativa and O. glaberrima are cultivated. O. sativa has three sub species viz., Indica, Japanica* and *Javanica*.

1. ***Indica*:** Indigenous to India. It is adapted to subtropical-tropical regions. In India, the varieties are very tall, photosensitive, lodging, poor fertilizer responsive, moderate filling and late maturing. The morphological differences between the varieties are very wide and awnless.
2. ***Japanica*:** It is confined to subtropical temperate regions (Japan, China, and Korea). Varieties are very dwarf, erect, non-lodging, photo insensitive, early maturing, high yielding and fertilizerresponsive. The morphological difference between the varieties is very narrow

and awnless. Hence, crosses were made between Indica and Japanica—first cross was ADT 27 during 1964.

3. Javanica: It is a wild form of rice and is cultivated in some parts of Indonesia. Varieties are the tallest, erect, poor filling and awned.

Rice species and their characteristics.

Characteristics	**Sub species**		
	Indica	**Japonica**	**Javonica**
Cultivation	India	Japan	Indonesia
Height	Tall	Medium	Tall
Lodging	Easily	Not easily	Not easily
Tillering	High	Low	Low
Awns	Awnless or possess short and smooth awns	Awned or awnless	Awned
Grain type	Long to medium	Short and round	Large and bold

Botanical description :-

Rice plant grows to a height of half a meter to two meter but there are certain varieties which grow much taller. Rice plant can be divided into two main parts i.e. root system and shoot system.

i) Root system :- The primary embryonic root (radicle) comes out through the coleorhizae followed by 2 or more secondary roots all of which develop lateral roots. The embryonic roots later die and are replaced by secondary adventitious roots.

ii) Shoot system :- All plant parts visible above the ground level is collectively called shoot. It consists of culms, leaves and inflorescence (panicle)

a) Culms or stem :- It is made up of series of nodes and internodes. Each node bear leaves and bud. Buds near the ground level grow into tillers. The primary tillers give rise to secondary tillers, secondary tillers give rise to tertiary tillers.

b) Leaves :- The leaves of rice is sessile in nature. It is divided into leaf blade and leaf sheath.

c) Inflorescence (Panicle) :- Rice inflorescence is known as panicle. It is a group of spikelets. Rice is a self pollinated crop. Rice grain (Caryopsis) is a dry one seeded fruit.

DISTRIBUTION :

It grows from the tropics to subtropical and warm temperate countries up to 40°S and 50°N of the equator. Most of the rice area lies between equator and 40° N and 70° –140° E Longitude. Highest yield was recorded between 30° and 45°N of the equator. The average yield ranges from 2.0–5.7 t/ha in India, China and Egypt lying between 21° and 30° N. The countries near the equator show an average yield of 0.8–1.4 t/ha.

Rice growing areas in India can be grouped into 5 regions.

1. **Northeastern region:** This region comprises of Assam, West Bengal, South Bihar and Orissa. Rice is grown in the basins of Brahmaputra, Ganga and Mahanadhi rivers (known for the highest intensity of cultivation in the country). This region enjoys heavy rainfall and mostly rice is grown mainly under rainfed conditions.
2. **Southern region:** This region comprises of deltaic tracts of Godavari, Krishna, Cauvery and Tambraparani rivers and non-deltaic rainfed areas of Tamil Nadu and Andhra Pradesh. Rice is grown under irrigated conditions in the deltaic regions.
3. **West coast region:** This region comprises of Kerala and the coastal districts of Karnataka and Maharashtra. There is heavy rainfall during the monsoon period. Rice is grown under rainfed conditions.
4. **Central region:** This region comprises of Madhya Pradesh, Telengana region of Andhra Pradesh and parts of Karnataka. Rice is grown as rainfed crop by broadcasting in this region, except in Andhra Pradesh.
5. **Northern region:** This region comprises of Jammu and Kashmir, Punjab, Uttar Pradesh and North Bihar. These areas have low winter temperature and only a single crop of rice is raised from May-June to September-October.

Acreage : WB > UP > MP > Bihar > Orissa > AP

Total Production : WB > UP > AP > Punjab > TN

Average Yield : Punjab (3.39 t/ha) > Haryana(2.96 t/ha) > Tamil Nadu (2.69 t/ha)

CLIMATE AND SOIL :

Rice can be grown in different locations under a variety of climate. The Indica varieties are widely grown in tropical regions. Japonicas, which are adapted to cooler areas, are largely grown in temperate countries. Both Indica and Japanica rice varieties are grown in subtropical regions. However, the crosses between Indica and Japanica are grown through out the world. Rice needs hot and humid climate. It is best suited to regions, which have high humidity, prolonged sunshine and an assured supply of water.

Temperature, solar radiation and rainfall influence rice yield by directly affecting the physiological processes involved in grain production and indirectly through diseases and pests.

(*a*) ***Temperature*:** Extreme temperatures are destructive to plant growth and hence depended on the environment under which the life cycle of the rice plant can be completed. The critical low and high temperatures for rice are normally below 20°C and above 30°C respectively, which vary from one growth stage to another. Temperature affects the grain yield by affecting tillering, spikelet formationand ripening and it influences the growth rate just after germination and increases almost linearly with increasing temperature within a range of 22–31°C. At later stages, it slightly affects tillering rate and the relative growth rate. During reproductive stage, the spikelet number per plant increases as the temperature drops.

The critical temperatures for different growth stages of rice are given

Growth stage		*Temperature °C*	
	Low	*Medium*	*High*
Germination	10	20–35	45
Seedling and emergence	12–13	20–30	35
Rooting	16	25–28	35
Leaf elongation	7–12	31	35
Tillering	9–16	25–31	33
Panicle initiation	15	--	--

Anthesis	22	30–33	35
Ripening	12–18	20–25	30

(*b*) ***Solar radiation*:** The solar radiation requirements of rice crop differ from one growth stage to another. Shading during vegetative stage slightly affects yield and yield components. Shading during reproductive stage has a pronounced effect on spikelet number. During ripening, it reduces grain yield considerably because of decrease in the percentage of filled spikelets. Solar radiation at the reproductive stage has the greatest effect on grain yield. The minimum requirement of solar radiation is 300 cal/cm2/day.

(*c*) ***Day length*:** Rice is a short day plant. Long day prevents or delays flowering. *E.g.*, GEB 24 is a photosensitive and season bound variety. However the latest varieties released are photo insensitive.

(*d*) ***Rainfall*:** Under rainfed rice culture, rainfall is the most limiting factor in rice cultivation. When irrigation is provided, the growth and yield is determined by temperature and solar radiation. Water stress at any growth stage may reduce the yield. The rice plant is most sensitive to water deficit from the reduction division stage to heading.

(*e*) ***Wind*:** Moderate wind is beneficial for crop growth. High wind at maturity may cause lodging of the crop.

Soils:

Rice is a semi aquatic plant and grows best under low land condition. In India, it grows in all most all type of soils; alluvial, red, lateritic, laterite, black, saline and alkali, peaty and marshy soils, and in acid soils. But the soil having good retention capacity with good amount of clay and organic matter is ideal for rice cultivation. Clay and clay loam soils are most suited. It tolerates a wide range of soil reaction from 4.5–8.0. It grows well in soils having pH range of 5.5–6.5. It can be grown on alkali soil after treating them with gypsum or pyrites.

RECOMMENDED PACKAGE OF PRACTICES :

a) Traditional :

Cultivation Practices	**Region**
Transplanting	Konkan and Vidarbha region

Direct seeding	Non-traditional rice growing area of Marathwada and Western Maharashtra.
Dibbling	In scarcity zone (Zone-6) of the state.
Rahu	Used during natural calamities at the time of sowing.

b) Modern Important agronomical practices recommended for rice cultivation in Maharashtra State

Particulars	**Direct seeded**			**Transplanted**		
	Broad casting (Rahu)	**Drilling**	**Dibbling**	**Local**	**HYVs**	**Hybrids**
Seed rate (Kg/ha)	80	60-65	30	80	30-35	15-20
Age of seedling	---	---	---	25-30	21-30	10-25
Spacing (cm)	---	25-30	25x10	Random	15x15 20x15	15x15 20x15
No. of seedlings/ hill	---	---	---	---	**3-4**	**1-2**
Fertilizer dose (kg/ha) N	45	60-80	100	45	100	150
P2O5	15	40-50	50	15	50	50
K2O	15	40-50	50	15	50	50
Average grain yield (q/ha)	16-18	24-25	28-30	18-20	35-40	60-65

CULTURAL PRACTICES :

Systems of rice cultivation :

The main systems followed in India are as under.

I. Dry or semi-dry system (Rainfed upland cultivation)

II. Wet system (Low land cultivation)

III. Direct seeding of sprouted seed

IV. System if rice intensification (SRI).

I. Dry or semi-dry system (Rainfed upland cultivation) :

Dry system of cultivation :

Dry system is followed in the areas which receives annual rainfall 800 –1000 mm and there is no irrigation facilities. Under such situation, it is better to grow short-duration varieties.

A vast tract of rice in U.P., Bihar, Orissa, parts of T.N., and A.P. is under rainfed upland condition. In Maharashtra this system is followed in Osmanabad and Nanded districts of Aurangabad division and scattered on area of Nagpur divisions.

Semi dry system of cultivation :

In semi-dry system, rain water is impounded in the field after completion of weeding, interculturing and fertilizer application when the crop is about 1.5 to 2 months old. This type of cultivation is followed in Assam, West Bengal, eastern M.P., parts of Orissa and eastern Maharashtra in Chandrapur and Bhandara district.

Land preparation :

The fields are ploughed immediately after the harvest of previous crop. Where *rabi* crop is grown the fields are ploughed after the harvest of *rabi* crop in month of April-may with soil turning plough by taking advantage summer showers. Fields are left in this condition and harrowed with monsoon rains. F.Y.M. or compost is applied 2-3 weeks before sowing and incorporated in the soil with subsequent harrowings. Bunds are prepared around the field to check loss of rain water.

Seed and sowing :

Generally the sowing is carried out immediately after sufficient rains, when 12-15 cm deep soil layer becomes wet. The ideal time of sowing is between June and first week of July . In some part of the country sowing is carried out before the onset of monsoon.

Growing seasons :

In parts of eastern region & peninsular India, 2 or 3 crops are taken in a year due to favourable temp. throughout the year. However, in northern & western parts, crops are grown during *Kharif* season as winter temp. is fairly low.

Seed treatment :

The seed is to be treated for quick germination & to control disease & pest infestation. Following type of seed treatment is advocated for rice.

a) The seeds are dipped in 3% brine solution to prevent the crop from disease. The floating seeds are removed and seeds settled at the bottom are used for sowing.

b) Seeds are treated with thirum @ 3g/kg of seed to control blast, brown leaf spot, sheath blight disease.

Methods of sowing, seed rate and spacing :

Following methods are used for sowing.

a) Broadcasting :- It is a most common method followed under dry system. The seed is broadcasted over the surface of land and the mixed in the soil by light ploughing or harrowing. **About 100 kg/ha. seed is required for sowing**.

b)Sowing seed behind plough or drilling :- The seed is drilled with seed drill or behind plough with the help of funnel at 20 cm apart. About 60 kg seed is required for sowing one hectare area.

Fertilizer management :

About 10-15 tonnes of F.Y.M. or compost per ha should be applied 2-3 weeks before sowing and mix thoroughly into soil. Soil testing is necessary prior to fertilizer application.

- The crop should be fertilized with 60:30:30 kg NPK/ha. 25% nitrogen and full dose of Phosphorus and potash should be applied at the time of land preparation.
- Remaining 50% & 25% nitrogen should be given at tillering & panicle initiation stage respectively.
- Application of zinc sulphate @25 kg/ha. found to be beneficial. In spraying of 0.5% zinc sulphate can correct the zinc deficiency. Iron deficiency can be controlled by foliar spray of 0.5% $FeSO_4$.

Weed management :

- Weed competition is more in upland rice. It is more severe in direct seeded rice. A period of 30 to 40 days from sowing is considered as most critical for weed competition. If the weeds are not controlled at right time then there is reduction in yield upto 50% or even more.
- Weeds are effectively controlled by mechanical as well as chemical method. Two hoeings with blade or wheel hoe at 15-20 and 30-40 days after sowing, followed by hand weeding will control the weed effectively.
- Pre-emergence herbicide pendimethalin (Stomp) @ 1–1.5 kg/ha. or Oxadiagryl (Raft) 0.120 kg/ha. proves effective in controlling the weeds.

II) Wet or Low land system of cultivation :

Wet or Low land system of cultivation is followed where adequate irrigation facility is available. The field is brought to a soft condition by puddling and sprouted seeds are directly sown or seedlings are transplanted in the puddled field.

Preparation of nursery :

Nursery is prepared on well drained, fallow land near the source of irrigation. In general 1/10 of nursery area is required to provide seedling for one ha. area.

Seed rate :

For coarse varieties 45 to 50 kg seed/ha.

For fine varieties 35 to 40 kg seed/ha.

The nursery is prepared by following methods.

a. Wet nursery

b. Dry nursery

c. Dapog Nursery

a. Wet nursery :

Wet nurseries are preferred under irrigated conditions. Nursery land is ploughed in dry condition and again puddled by ploughing 3 to 4 times in 5-6 cm. standing water. Apply F.Y.M. or compost @ 10-15 tonnes/ha. at the time of first puddling. The field is leveled after final puddling. After 1 to 2 days prepare narrow beds of 120 to 125 cm width and of any convenient length. Construct the drainage channel of 30 cm wide in between beds. Apply 0.5 kg N, 0.5 kg P_2O_5 and 0.5 kg K_2O per 100 m^{-2} before final leveling of the nursery beds. Broadcast 2-3 handfuls of dry or sprouted seeds per sq. m. on seed bed. For sprouting, healthy seed should be soaked for 24 hours in clean water. Then the seed is removed from the water and incubated in a warm, moist place for about 36 hours. Seed beds should be saturated with water upto 5 days. Then gradually increase the level of water upto 5 cm. Drain out the excess water in case of heavy rains during first week of sowing. Top dressing with 1 kg urea per 100 Sq. m. should be done 15 days after sowing. Seedling become ready for transplanting at the age of 20-25 days.

b) Dry nursery :

It is followed in the areas of non-assured water supply. The land selected for dry nursery should be moisture retentive. Plough and harrow the land till good tilth is obtained. Apply F.Y.M. or compost @10 -15 tonnes/ha. and mix thoroughly into the soil. Prepare the raised beds of 120 cm. width at bottom and 90 cm width at top, 10-15 cm in height and of any convenient length depending upon slope of land. 30 cm wide channel should be kept in between two beds. Use the same fertilizer dose as in wet nursery. Seed is sown at a depth of 2 cm in rows at 8 to 10 cm apart. Cover the seeds with a thin layer of soil immediately after sowing. Special care should be taken for water management in these beds. Allow the water to run in channels first and then raise level of water slowly to saturate soil of beds. Do not flood water in beds. Apply 1 kg urea per 100 m^{-2} as top dressing 15 days after sowing.

c) Dapog method :

This method of raising seedling has been introduced in India from Philippines. In this method nursery is sown on a concrete floor or on raised beds of soil covered with polythene sheets or banana leaves. This method is adopted it he areas of assured water supply and when early transplanting is to be done. A small area of 25-30 m^2 is sufficient to raise the seedling for one ha area. Pre-germinated seeds are broadcasted uniformly over the polythene sheet or banana leaves. @ 3 kg seed/sq.m. Sprinkle water on the seeds 3-4 times a day till fourth day to keep the seed bed wet. Press the seeds gently with hand or with wooden flat board 1-2 times a day till first 3 days, so that roots remain contact with the water. When the seedling attain 2 cm height a constant film of water should be maintained. In about 12-14 days seedling become ready for transplanting. The nursery is cut into strips and rolled like a mat with roots outwards. Loose the interlocked roots carefully before transplanting. Transplant 3-4 seedling per hill.

Advantages :-

i. Half of the time in raising of seedling.
ii. Less area is required.
iii. No seed bed preparation is required.
iv. No fertilizer is required
v. Labour cost of raising nursery is less.
vi. Crop flowers 4 days earlier.

Disadvantages :-

i. Seedling are delicate and thin, slender

ii. Seed rate is high

Field preparation :

The fields are ploughed immediately after the harvest of previous crop. Summer ploughing helps in exposing the eggs of harmful insects, pests and rhizomes of weeds. Where *rabi* crop is grown the fields are ploughed after the harvest of *rabi* crop in month of April-may with soil turning plough by taking advantage summer showers. Stubbles of the previous crop, weeds and other plant remains should be picked up and thrown out of the field. Bunds are prepared around the field before puddling. Apply well decomposed F.Y.M. or compost 10-15 tonnes per ha. and mix thoroughly into the soil.

Puddling :

Keep the field flooded or saturated with water for 15 days before transplanting. Puddling is done by running the deshi plough or puddler either bullock or power driven in standing water. Puddling helps to create favourable physical, chemical & biological conditions.

Transplanting :

Age of the seedling :

It largely depends upon the duration of variety, Management practices & method of raising nursery. At the time of transplanting the seedling should have 5-6 leaves and it should attain the height of 12-15 cm. In *kharif* season 21-25 days old seedling and in *rabi* season 30 to 35 days old seedlings are ideal for transplanting.

Time of transplanting :

For better yield in *kharif* season ideal time for transplanting is first fortnight of July. There is 15-20% reduction in the yield if transplanting is delayed by 15-20 days. The reduction in the yield is upto 50-75% if transplanting is delayed by 60 days.

In North western India, June transplanting is better. Transplanting beyond June reduces grain yield due to exposer of crop to low temp. at flowering. In south India transplanting can be done upto third week of July. For *Rabi* crop last week of December to middle of January is the optimum time for transplanting.

Spacing :

In general *kharif* crop should be transplanted at spacing of 20 x15 cm or 15x15 (for early varieties) cm. 2-3 seedling are transplanted per hill to a depth of 2-3 cm. If the seedlings are over aged, then 4-6 seedling per hill are planted.

Advantages :

i. Optimum plant population at desired spacing can be achieved.

ii. Weed competition is less.

iii. Manuring, irrigation and disease pests control is easy and cheap.

III) Broadcasting of sprouted seeds :

This method is followed in areas where there is shortage of labours & lobour wages are high. The field is prepared and puddled in the same manner as that for transplanting. The seed are soaked in water and kept at room temp. for 24 hours. Remove the seeds from water and put it in a clean and moist bag. Fold the bag tightly and keep it in a shady place for 36 hours. After every 12 hours, stir the seeds for air circulation and sprinkle the water on seed. During this period the seeds get sprouted Then the sprouted seeds with radicle length of 1-2 mm are broadcasted on the puddle field @ of 100 kg seed per ha.

MANURES AND FERTILIZERS :

Manures and fertilizers are essential for enhancing crop growth and yield. At the time of preparatory tillage apply well decomposed F.Y.M. or compost @ of 10-15 tonnes per ha. and mix thoroughly into the soil. Response of applied nitrogen is higher in *rabi* than in *Kharif* season. Nitrogen plays important role in the growth, development and yield of rice. High yielding varieties are more responsive to nitrogen fertilization. The general recommended fertilizer dose for rice is 100 kg N, 50 kg P_2O_5 and 50 Kg K_2O /ha. Nitrogen is given in three split doses. The entire dose of Phosphorus, Potash and 40% nitrogen is given at the time of paddling. Remaining 40% nitrogen is given at tillering stage and 20% at panicle initiation stage.

Deficiencies of Zn, Fe and B have been reported in India. The appearance of rusty brown spots, discolouration of older leaves are the common symptoms of zinc deficiency. Zinc deficiency leads to khaira disease. In zinc deficient soil 20-25 kg zinc sulphate per ha. Should be applied at the time of last puddling. In case Iron deficiency spray the crop with 0.5% $FeSO_4$ and for Born deficiency spray the crop with 0.2% Borax with lime (twice the weight of borax).

Green manuring :

Green manuring in situ and green leaf manuring assumed importance in the recent years. Green manuring crop like Sunnhemp, Dhaincha, Mungbean, and Guar can add 42-91 Kg N/ha. Green manuring crop can be grown in the field and incorporated in the soil after 45-50 days after sowing. Incorporation of Glyricidia @ 10 t/ha at the time of puddling proved better for increasing rice yield.

Bio-fertilizer :

Bio-fertilizer such as blue green algae or Azolla are capable of providing 20-25 kg N/ha. If added as partial supplements to inorganic fertilizer.

Water management

WATER MANAGEMENT :

Until the transplanted seedlings are well established, water should be allowed to stand in the field at a depth of 2-3 cm. Thereafter about 5 cm of water may be maintained up to the dough stage of the crop. Water should be drained out from the field 7 to 15 days before harvest depending on the soil to encourage quick and uniform maturity.

Quantity of water needed for growing rice is determined by climatic, soil and water-management factors. Amount of water consumed by rice for producing 1kg grains is far greater than that required for most of the crops. In tropical and subtropical climates, daily water required for meeting evapotranspiration, percolation and seepage losses would vary from 5 to 12 mm/day depending on the season and soil-related variability. Total water requirement to grow a mid-early (110-day duration) rice variety is estimated to be between 800 and 1,500 mm, which includes 250 mm water required for land preparation and 50 mm for nursery raising. Water required to complete tillage and prepare land for transplanting is much less than the actual amount of water used for this purpose. The same holds true for the various stages of crop growth as well. This results in water losses by surface run–off, percolation and seepage. When all losses are accounted for, the water-use efficiency in most irrigated systems is 30-40% in wet season and 40-60% in dry season.

INTERCULTURING :

The interculturing is given 30 days after transplanting with rotary or Karjat or Japanese hoe. The interculturing operations helps in controlling the weed and increasing aeration to the roots.

WEED CONTROL :

Though there is less problem of weeds in transplanted rice, sometimes weeds emerge when the soil is exposed to atmosphere as submergence is not possible continuously. Weeds should removed once at 20 days after transplanting and second time at 50-60 and days after transplanting. A number of herbicides have been found effective in controlling the weeds.

CROP ROTATION :-

A) Irrigated areas :

i. Rice-Wheat
ii. Rice-Potato-Black gram
iv. Rice-Wheat- Green gram
v. Rice-Potato-Green gram
vi. Rice-Pea- Green gram
vii. Rice-Wheat-Jute
viii. Rice-Field Pea-Sugarcane
ix. Rice - Groundnut

B) Un-irrigated areas :

i. Rice-Field Pea
ii. Rice- Chickpea
iii. Rice- Lentil
iv. Rice – Field bean

System of rice Intensification (SRI method)

System of rice intensification is developed in Madagascar in 1980. This method is most ideal for poor farmers with relatively more family labourers with less land capital. The average yield obtained in SRI is higher than the conventional transplanting method. SRI practice produce more tillers with a positive correlation between tillering and grain filling. The plant has deeper and more effective roots system.

Advantage/merits over conventional method:-

i. Water requirement is less.
ii. Seed required is 5 kg/ha which reduces the cost of seed.
iii. Yield is more than conventional method.

iv. Crop mature earlier than conventional method.

v. More number of grain per panicle than conventional method.

Nursery management :

A mat nursery is prepared for SRI method. Raise beds 120 cm wide are prepared covered with 100 guage polythene sheet by making holes for drainage. Apply 2.5 cm layer soil and FYM mixture in 2:1 proportion. Distribute the sprouted seed at the rate of 50 gm/sq.m. for fine grain varieties and 100 gm/sq.m. for coarse gain varieties uniformly on the seedbed and cover it with another thin layer of soil and FYM mixture. Then cover the seedbed with paddy straw. Watering is done regularly to keep the seed bed moist.

Field preparation :

The field is prepared similar to that of conventional planting. Perfect land leveling is required. The small drainage channels are prepared at two to three meters interval.

Transplanting :

About 8 to 10 days old rice seedlings, having two leaves with seed intact are transplanted. Banana leaf sheath can be used for lifting and carrying the seedlings to main field. Single seedling is planted at 25 X 25 cm spacing. The seedlings should not be planted too deep into the soil.

Use of organic manure :

Incorporate well decomposed F.Y.M or compost @ 10 tonnes per ha in the soil at the time of puddling.

Water management :

Regular water application is necessary to keep the soil moist. At early growth stage flooding of field should be avoided. The water should not be allowed to stagnate at any stage. Intermittent wetting and drying for adequate aeration is essential. However during grain filling stage 1-3 cm water may be maintained in the field.

Weed Management :

Weed infestation is severe in this method Hoeing with rotary weeder or cono weeder is effective in controlling the weeds. Hoeing should be done in both the directions starting from 10 days after planting. About four such hoeings are given at 10 to 15 days interval. One or two hand weedings may be carried out to remove the weeds closer to rice plants.

Sawant's Integrated Rice Agrotechnology (SIRA)/ **Four Point Agro Technique** :-

Sawant's Integrated Rice Agrotechnology has been developed for small-scale resource poor rice farmers. It has following four practices

Practice 1 :- Recycling rice crop residues :- Blackish rice hull ash is recycled @ 0.5 to 1 kg/sq.m. It provides the useful nutrient silicon for growth and health of the rice seedling. Incorporate Paddy straw @ of 20kg/100 sq.m. at the time of puddling.

Practice 2 :- Using Agro forestry Approach, incorporating limited Glyricidia green manuring @ 3 t/ha helps to maintain organic matter in soil and helps in initial growth of rice seedlings for 2-3 weeks after transplanting.

Practice 3 :- Controlled transplanting @ 25 hills/sq.m. helps in saving rice seed, seedlings and labour expenses.

Practice 4 :- Deep placement of one Urea-DAP briquettes in each 4 hill squares. It saves not only the input cost, but also there is an increase in the yield of rice grain and straws. (Deep placement of Urea-Diammonium phosphate (Urea-DAP) Briquettes after controlled transplanting of rice seedlings @ 170 kg Urea- DAP briquettes per hectare (Each briquette 2.5 gm, Placement 7 to 10 cm in Soil, @ 56 kg/N and 30 kg P2O5 per hectare dose)

Drum seeder:

Drum seeder is equipment used for direct sowing of seed. Drum seeder is of 175 cm long with drum length of 30 cm which allows spacing between row to row 20 cm. The sprouted seeds can be used in the drum. Drum seeder is made up of Plastic material so it is light in weight so two persons can draw this seeder easily. Also the adjustment for seeding and spacing is possible. Drum seeder detachable so it can be easily transported from plot to another plot. Price of Drum seeder is Rs.3500/- only.

VARIETIES :

Season-wise varieties/ hybrids

Season	Varieties/hybrids
Kharif	Karjat-184, Karjat 2, Karjat –3, Karjat 4, Karjat-5, Karjat-6, Karjat-7, Palghar 1, Palghar 2, Panvel 1, Panvel 2, Panvel 3, Phondaghat 1, Ratnagiri 24, Ratnagiri 711, Ratnagiri 73, Ratnagiri 1, Ratnagiri 2, Ratnagiri 3, Ratna , Jaya, Mahsuri. Walai, Bela, Patni, Damga, Botwel, Sahyadri, Sahyadri – 2, Sahyadri – 3, Sahyadri-4, Proagro, Suruchi, Swarna, Gujrat-11, Rupali, SKL 6, SKL 7, PKV Ganesh, SYE 1, SYE 4, SYE 5, HMT Sona, Rupali, PKV Khamang, PKV Makrand, PKV HMT , SYE 75, Chinoor, Amb-157, Kolamba, Chibbur K-42, Waksal- 207, Zinia-31, Satya, Suhasini, Surya, ACK 5, Indrayani, Pawana, Kundalika, VDN 12327, RDN-185-2, Phule Radha, Bhogawati, Jalgaon 5 , Sahyadri, Sahyadri – 2, Sahyadri – 3, Sahyadri-4, Ratnagiri 24, Ratnagiri -73, Ratnagiri-1, Darana, Tulajapur-1, Prabhawati, Ambika, Sugandha, Terana, Parag.
Rabi	Karjat-184, Karjat –3, Karjat 4, Karjat-7, Ratna , Jaya, Bela, Sahyadri – 2, Sahyadri-4, SKL 6, SYE 1.

Sr. No.	Name of the variety	Yield (q/ha.)
a.	Early duration:- Ratnagiri -1, Ratnagiri -24, Ratnagiri -73, Ratnagiri -711,Sakoli -6, Sindhewahi -1, Karjat -184, Karjat -3, Karjat- 4, Ratna, Kalinga 1 & 2	40-45
b.	Midlate duration:- Ratnagiri -4, Palghar -1, Karjat -6, Panvel-1&3, Jaya, Vikram, Phalguna, RP-4-14, Sindhewahi-75, Sindhewahi -4, Sindhewahi -2001, PKV-Ganesh, PKH-HMT, IR -8,	45-50
c.	Late duration :- Karjat-2, Ratnagiri- 3, Sakoli-8, Pankaj, Sindhewahi-5	50-55

Hybrid Rice :

Hybrid rice produces more tillers and more number of grains per panicle and therefore hybrids having 15% more yield than the highest yielding inbred varieties. The package of

cultivation practices is practically same as for any high-yielding, dwarf variety except the following.

i. Seed rate :- 20 kg/ha

ii. Nursery preparation :- Sparse sowing @ 15-20 g/m^2 to ensure healthy seedling with 4-5 tillers in 20-25 days.

iii. Transplanting :- Transplant 1- 2 seedling/hill at a spacing of 20 cm x15 cm or 15cm x 15 cm.

iv) Nutrient management :- 120-150 kg N, 60 Kg P_2O_5 60 Kg K_2O per ha. N in three split doses.

v) Varieties : Sahyadri, Sahyadri-2, Sahyadri-3, Sahyadri -4, APRH 2, PHB 71, PA 6201, HRI120

vi. Yield :- 60 - 70 q/ha

Golden Rice :-

Golden rice is a variety of rice produced through genetic engineering to biosynthesize beta-carotene, a precursor of pro-vitamin A. Golden rice was created by transforming rice with two beta- carotene biosynthesis genes from daffodil and from the soil bacterium *Erwinia uredovora.*

Vitamin A deficiency is found in mostly children and pregnant women, relying on rice as a staple food. Genetic modification to make rice produce rich in provitamin-A (beta-carotene) is seen as a simple and less expensive alternative to vitamin supplements.

Basmati Rice :-

The scented fine quality rice is popularly known as Basmati rice. It is characterized by pleasant aroma, long slender grains, extreme elongation on cooking. Punjab, Haryana & Western U.P. are traditional basmati growing areas of the country. Basmati 370 & Taraori basmati are the widely cultivated traditional varieties. Then efforts are made and world's first high-yielding, semi-dwarf basmati variety **Pusa Basmati –I** was developed.

INSECT PEST MANAGEMENT :

Yield losses due to insect pests in rice are estimated about 30%. Important insect pests are mention below.

1. Stem borer

Nature of damage :- Damage is caused by the larva of this insect results in **'Dead heart'** and '**White head'** The larvae bore and feed inside the stem.

Control Measures :-

i. Destruction of the stubbles of the previous crop

ii. Grow tolerant varieties like Ratna, RP 4-14, IR -20, IET 3116, IET 3117

iii. Seeding root dipping in 0.05% choloropyriphos solution before transplanting

iv. Apply Carbofuran @ 16.50 kg/ha or phorate @10 kg/ha in 3-4 cm standing water in the field 20 -25 days and again at 50 -60 days after transplanting.

2. Gall Midge :-

Nature of damage :- Meggots cause damage by transforming regular tiller into tubular galls commonly called as **silver shoot.**

Control Measures :-

i. Grow tolerant varieties like Phalguna, Vikaram, Pratap, IET 6080, IET 7008

ii. Destroy affected tillers.

iii. Apply Carbofuran @ 16.5 kg/ha or phorate @10 kg/ha in 3-4 cm standing water in the field 10 days and again at 20 days after first application.

3. Brown plant hopper (BPH) :-

Nature of damage :- Both Nymphs and adult suck sap from stem. Infested plants turn yellow followed by complete drying commonly known as **hopper burn**.

4. Green leaf hopper :-

Nature of damage :- Both Nymphs and adult suck sap from leaves. Leaves turn brown from the tip downwards exhibiting hopper burn symptoms. It transmit the viral disease **'Tungro'**

Control Measures for Brown plant hopper & Green leaf hopper:-

i. Grow resistant varieties like IET 7575, IET 6315,MTU 4870, Triveni for BPH and IR-8, IR- 20, Vijaya, IET 7301 for green leaf hopper.

ii. Avoid close planting

iii. Avoid excessive doses of nitrogenous fertilizer

iv. When 5-10 hopper /hill are seen spray Monocrotophos 36WSC 0.05% or Fenitrothion 50 EC 0.05% or Malathion 50 EC 0.1%

5. Gundhi bug OR earhead bug :-

Nature of damage – Both nymphs and adults cause damage by sucking the juice from the developing grains. The panicles show empty & half-filled grains.

Control measures:- Clean cultivation, destruction of grasses. Apply Melathion dust @ 20 kg/ha..

6. Leaf folder :

Nature of damage – Larvae fold the leaves. Feed green tissue inside the fold.

Control measures:- Spray 0.15% malathion or 0.15% carbaryl or 0.05% monocrotophos.

7. Case worm :

Nature of damage – Damage caused by larval feeding & by their cutting off of the leaf tips for making leaf cases.

Control measures:- Remove and destroy tubular cases.Spray 0.05% monocrotophos.

Disease management :

Reduction in due to various diseases have been estimated about 10-15%. In severe cases it may go from 50 to 90%. Important diseases are mention below.

1. Blast :-

Symptoms - Spindle shaped spot with grey centre and dark brown margin are seen on leaf and leaf sheath. Grains remain empty.

Control measure:- Growing of resistant varieties *viz*., Ratnagiri -24, IR- 8, Karjat -1, Seed treatment with Thirum @ 3 g/kg seed. Foliar sprays of tricyclazole (0.01%) OR Copper oxychloride 0.3%.

2. Brown leaf spot :-

Symptoms - Oval shape spots on leaves. Brown with gray or whitish centre when fully developed.

Control measure:- Seed treatment with Thirum @ 3 g/kg seed. Spraying of Copper oxychloride 0.25%.

3. False smut :-

Symptoms - A sporadic disease. The fungus transforms individual grains into greenish spore balls of velvety appearance.

Control measure:- Growing of resistant varieties *viz*., IR-22, IR-26, IR -28, Vijaya, Spraying of Propiconazole 0.1%.

4. Bacterial leaf blight :-

Symptoms - Lesions start as water soaked strips along leaf margins. Lesions enlarge & turn yellow within few days.

Control measure:- Seed soaking for 12 hours followed by hot water treatment at 52-54^{0}C for 30 minutes. Grow resistant varieties, Spraying of Copper oxychloride 0.25%. alternately with streptocyclin (250 ppm)

5. Tungro disease:-

Symptoms - Older leaves turn light yellow to orange yellow. Stunted plant, small panicles with few spikelets.

Control measure:- Grow resistant varieties *viz*., IR -50 and Co 45, Control of leaf hopper.

HARVESTING AND THRESHING :

The right stage for harvesting is just when ears are nearly ripe and the straw is still slightly green. Crop generally become ready for harvesting 25 to 30 days after flowering when 90% grains in panicle mature. The harvesting should not be delayed. Timely harvesting ensures good grain quality, as less grains are broken during milling. Harvesting is carried out by manual labour. Plants should be cut close to the ground level and dried in the field for 2-3 days. Later on taken to the threshing yard for threshing.

The most common method of threshing is striking bundles on the raised wooden platform, trampling by bullocks, rubbing with bare human feet. Now a days pedal or Power driven thresher are used for threshing. The harvested grains should be dried under shade to bring down the moisture content to around 14% for storing and milling.

YIELD :

i. Early varieties :- 40-45 q/ha
ii. Mid-late & late varieties :- 45 to 55 q/ha
iii. Hybrid varieties :- 60-70 q/ha

MAIZE (*Zea mays* L.)

Family : Poaceae 2n=20

Maize is the third most important cereal in India after rice and wheat which contributes nearly 9 % in national food basket. Maize is one of the important cereal crops in the world's agricultural economy both as food for men and feed for animals. Because of its higher yield potential compared to other cereals, it is called as "Queen of Cereals".

In addition to staple food for human being and quality feed for poultry and animals, it serves as a basic raw material for the industry for production of starch for textile, pharmaceutical, cosmetic industries, high quality corn oil, protein, alcoholic beverages, food sweeteners etc. It is used as an ingredient in more than 3000 products.

In India, the maize is used as human food (23%), poultry feed (51 %), animal feed (12 %), industrial (starch) products (12%), beverages and seed (1 % each).

Raw materials Corn meal, starch, syrup, oil, Ethanol, etc. Beverage Vinegar distilled, beer and whiskey, malt, malt syrup, malt extract, etc.

- **Dishes :** corn meal, corn flakes, candies, baby formula, ice cream, custer, jelly, chocolates, Corn Syrup : Glucose syrup, high-fructose corn syrup, high maltose corn syrup, etc.
- **Soft drinks :**
- **Non – food :** bio fuel, corn stalk fiddle, paper, textile, film, toothpaste, pharmaceuticals, paint and varnish, paper products,

Maize grain contains proteins (10%), carbohydrates (70%), oil (4%), albuminoides (10.4%), crude fibre (2.3%) and ash (1.4%). Maize grain has significant quantity of vitamin A, nicotinic acid, riboflavin and vitamin E. Maize is low in calcium, but fairly high in 'P. Maize protein 'Zein' is deficient in two essential amino acids *viz*., Lysine and 'Tryptophane'.

CLASSIFICATION

Classification is largely based on the character of the kernels. It is classified into seven groups (Kipps, 1959).

1. **Flint corn (*Zea mays indurate*):** Starchy endosperm enclosed with hard hammy endosperm. Kernel size is large with flat bottom and round at the top.High proportion of starch. Colour may be white or yellow. This is the type mostly grown in India.
2. **Dent corn (*Z. mays indentata*):** Because of formation of dent on the top of kernel having white or yellow, it is called as dent corn. Maize kernels have both soft and hard starches. The hard starch extends on the sides and the soft starch is in the centre and extends to the top of the kernel. Depression or dent in the crown on the seed is the result of drying and shrinkage of soft starch. This type is widely grown in USA.
3. **Pop corn** (***Z. mays averta*):** Kernel size is small. Hard and corneous endosperm is present.
4. **Sweet corn (*Z.mays saccharata*):** The sugar and starch make the major component of the endosperm that results in sweet taste of kernels. It is mainly grown in Northern half of USA. The cobs are picked up green for canning and table purpose.
5. **Flour corn (*Z. mays amylaceae*):** It resembles to the flint corn in appearance and ear characteristics. The grains are composed of soft starch and have little or no dent (called as "soft corn"). It is widely grown in USA and South Africa.
6. **Pod corn (*Z. mays tunicata*):** Each kernel is enclosed in a pod or husk in an ear, which enclosed in husks, like other types of corn.
7. **Waxy corn** (***Z. mays cerabina*) *:*** The kernel looks to have waxy appearance and gummy starch in them, because of amylopectin. Starch is similar to that of tapioca starch for making adhesive.

ORIGIN

Mexico and Central America.

CLIMATE

It is essentially a tropical crop. It is a C4 short day plant. Though it is a tropical crop, it has got high adaptability to wider climate (55°N–45°S). It can be grown up to 2500 m above MSL. This crop is not suitable when night temperature drops below 15.6°C. Maize requires moist and warm weather from germination to flowering. Most suitable temperature for germination is 21°C and for growth is 32°C. Extremely high temperature and low RH at

flowering desiccate the pollen resulting in poor pollen grain formation. Temperature more than 35°C reduces the pollen germination. Temperature < 15°C delays silking and tasseling. Rainfall of 500–750 mm of well distributed rain is required for growth.

SOIL

Maize is best adapted to well-drained sandy loam to silty loam soil. Water stagnation is extremely harmful to the crop, therefore proper drainage is must. Maize cannot thrive on heavy soils especially on low lands. pH ranges from 5.5–7.5. The alluvial soils of Uttar Pradesh, Bihar and Punjab are very suitable for growing maize crop. Salinity and water logging are harmful at seeding stage. Continuous water logging for 3 days reduce the yield by 40–45%.

GROWTH STAGES

- Seedling stage : 1–14 days (from sprouting to 2–4 leaves)
- Vegetative phase : 15–39 days (30–35 days is knee high stage)
- Flowering phase : 40–65 days
- Maturity stage : 66–95 days (including soft and hard dough stage)
- Ripening : 96–105 days

VARIETIES

Hybrids: The duration of hybrids is 100-105 days. Some of the important hybrids are Deccan, Ganga Safed, Ganga-2, Ganga-4, Ganga-5, Ganga-7,9, Histarch and Sangam,

Promising Composites: The duration of composites is 100-105 days. *E.g.*, Amber, Vijay, Kisan, Sona, Vikram, Jawahar (5.0–5.5 t/ha). Short duration composites are K1(80–85 days) and Co1 (105 days).

List of winter season maize cultivars/hybrids

Sr. No.	State	Cultivar
1.	Delhi	H: PMH 3, Buland, NK 61, Pro 311, Bio 9681, Seed Tech
2.	Punjab	H: PMH 3, PMH-1 , Buland, Sheetal , Pro 311, Bio 9681, NK
3.	Haryana	H: PMH 3, Buland, ,HM 5, NK 61, Pro 311, Bio 9681, Seed

4.	Uttar Pradesh	H: PMH 3, Buland, Pro Agro 4212, Pro 311, Bio 9681, NK
5.	Rajasthan	H: Pro 311, Bio 9681, Seed Tech 2324, HM8
6.	Andhra Pradesh	H: The late maturing hybrids of Kharif e.g. Kargil 900 M, Seed Tech 2324, Pro 311, Bio 9681, Pioneer 30 v 92, Prabal, 30 V 92, 900 M
7.	Tamil Nadu	H: COHM 5, Prabal , Pro 311, Bio 9681, Seed Tech 2324, 30 V
8.	Maharashtra	H: Prabal, Pro 311, Bio 9681, Seed Tech 2324, 30 V 92, 900 M
9.	Karnataka	H:Nithya Shree, DMH 1, DMH 2, 900 M, Bio 9681, Prabal, Pro 311, Bio 9681, Seed Tech 2324 C: NAC 6004, 30 V 92
10.	Bihar	H: Rajendra Hybrid 2, Rajendra Hybrid 1, Pro 311, Bio 9681, Seed Tech 2324, 30 V 92, 900 M C: Hemant, Suwan & Lakshmi
11.	Jharkhand	H: Pro 311, Bio 9681, Seed Tech 2324C: Suwan
12.	Chhattisgarh	H: PEHM 1, Pioneer 30 V 92 & 30 R 26, Bio 9681, Pro 4640 & 4643, 900M NEH Region H: Pro 311, Bio 9681, Seed Tech 2324 C: NLD white

CROPPING SYSTEM

Some of the important cropping systems in India are maize-potato, maize- berseem, maize–chickpea/ safflower (rainfed) and maize–potato–wheat. Tamil Nadu, the maize is cultivated with green gram, onion and cotton in cropping system. The important rainfed intercropping are maize + green gram, maize + groundnut, maize + soybean, maize + cowpea and maize + red gram. In North India, short duration maize varieties like Kathri and Sathi (65–75 days) is grown as intercrop in sugarcane in Uttar Pradesh.

TIME OF SOWING

In India, it is grown in 3 seasons. Yield of maize is more during *rabi* and spring season. It is cultivated in 85% of rainfed area during *kharif* (June–July). During *rabi*, it is cultivated in peninsular India and Bihar and during spring season, it is cultivated in north India under irrigated condition.

Optimum sowing time of maize

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

SYSTEM OF MAIZE CULTIVATION

I. Irrigated maize

It is cultivated in 22% of the total area under maize cultivation.

Field preparation: The crop does not require fine tilth. Field is ploughed to a depth of 25–30 cm using mould board plough, followed by 3–4 ploughing with desi plough or harrow. In clay soils, the main problem is the formation of hardpan. Chiseling reduces the hardpan formation and there is increase in yield of 25–30%.

Varieties:

- Co1-Composite,105–110 days, suited for Coimbatore, Erode, Pudukottai and Thanjavur.
- K1-Composite, 80–85 days, highly tolerant to drought, suited for Pudukottai district.

Hybrids:

- **CoH1 :** 90–95 days duration, suited for all locations and highly drought tolerant and resistant to downy mildew.
- **CoH2 :** 100–105 days, suited for all locations. It is resistant to downy mildew.
- **CoH3 :** 90–95 days
- **CoBC1** : 55–65 days, for dessert and canning, suited for all areas of Tamil Nadu, green fodder yield up to 32 t/ha. (Multiple cobs 2–3, 7 pickings at interval of 2 days).

Land shaping: Formation of ridges and furrow system (at 60 cm interval) is good due to good drainage and less water logging.

Method of sowing: Mostly direct seeding is adopted. Sowing/dibbling behind country plough is also adopted.

Seed treatment: The seed treatment is done with any fungicide followed by Azospirillum (500 g). Seed treatment with 500 g of Azospirillum followed by soil application of Azospirillum @10 pockets (2 kg/ha) with FYM at 50 kg/ha can be followed.

Seed rate: The seed rate for composite is 20 kg/ha and for hybrids, it is 15 kg/ha.

Spacing: 60 × 20 cm (83,333 plants/ha). For getting maximum yield of irrigated crop adopt 1.1 lakh plants (60 × 15 cm) with 200:100:80 kg NPK/ha (N and K application in 3 splits) + 25 kg ZnSO4/ha.

Seed rate and plant geometry

Sr. No.	Purpose	Seed rate (kg/ha)	Spacing (cm)	Plant population
1.	Grain	20	60 x 20	83333
			75 x 20	66666
2.	Sweet corn	8	75 x 25	53333
			75 x 30	44444
3.	Baby corn	25	60 x 20	83333
			60 x 15	111111
4.	Pop corn	12	60 x 20	83333
5.	Green cob (normal maize)	20	75 x 20	66666
			60 x 20	83333
6.	Fodder	50	30 x 10	333333

FERTILIZER MANAGEMENT :

Among the cereals, it requires huge amount of fertilizers. If there is no soil test recommendation, a blanket recommendation of NPK at 120:60:60 kg/ha is recommended for irrigated maize, besides application of 12.5 t of FYM/ha and 12.5 kg micronutrient mixture. Apply fertilizer 5 cm below the soil and 10 cm away from the root zone. 100% P and K should

be applied as basal. 'N' should be applied in 3 splits *viz*., 25% basal, 50% on 25 DAS and 25% on 45 DAS. In all the cereal crops, there is two peak stages of uptake, where as in maize, there are three peak stages of uptake. For transplanted crop, 'N' should be applied at 50% basal and 25% each at knee high stage and taselling stages.

Ist peak 30–35 days (Knee high stage)

IInd peak 50–60 days (Tasselling)

IIIrd peak 70–80 days (dough stage).

ZnSO4: Zn' deficiency cause "White bud" in Maize. Apply ZnSO4 at 25 kg/ha at the time of sowing. If not possible, foliar spray of 0.5% ZnSO4 at critical stages is recommended.

WATER MANAGEMENT :

It requires 500–600 mm of water. Critical stages for irrigation are taselling and silking. Peak consumption of water also occurs during this period (taselling and silking). In Clay/clay loam soils, totally 8 irrigations are required. For light soils, two more irrigations are needed.

- **Germination phase :** Two irrigations 1st after sowing, 2nd as life irrigation 4th day)
- **Vegetative phase :** Three irrigations at 12th day, 25th day and 36th DAS.
- **Flowering phase :** Two irrigation on 48th and 60th day
- **Maturity phase :** 1 irrigation on 72nd day

WEED MANAGEMENT:

The crop—weed competition is upto 45 days. Application of pre emergence herbicides like Simazine and Atrazine at 0.25 kg/ha, followed by one hand hoeing and weeding on 30–35 DAS is recommended. For intercropping systems, atrazine should not be used. For maize + pulse intercropping system, pre-emergence application of pendimethalin 1.0 kg a.i./ha followed by one hand weeding on 30–35 DAS is recommended. Spraying should be done within 3 days. There should be adequate soil moisture. The soil should not disturbed immediately after application. For maize + soybean/pulse intercropping system, pre-emergence application of alachlor at 2.0 kg a.i./ha (Lasso 50% EC), followed by one hand weeding is recommended.

THINNING AND GAP FILLING:

Thinning is done by keeping one healthy seeding/hill on 7–8 DAS. Gap filling is done where seedlings are not germinated (dibble 2 seeds/hill) and immediately pot water it. The crop should be earthed up after application fertilizer at 30–35 DAS to prevent lodging.

HARVESTING AND GRAIN SHELLING:

The grain cob is harvested, when cob sheath turns brownish and grains become hard. They do not contains more than 20% moisture and they are piled up for 24 hours and then dried in the sun for 5–6 days to reduce the moisture to 10–12%. The green stalks are harvested separately and used as fodder.

Hand shelling is a common practice, but efficiency is very poor. Now, corn sheller of greater efficiency, which is manually driven, tractor drawn, electricity operated is available. The left over plants are used as green fodder or straw.

Yield

- 5 tonnes of grain yield and 10 tonnes/ha of straw yield can be obtained.
- In case of Baby corn, about 6 tonnes/ha of cob yield with 25 tonnes/ha of green fodder yield

SORGHUM (*Sorghum bicolour* L.) Family : Gramineae

The grate millet sorghum is called as *Sorghum bicolour* L. Moench. **Sorgo** means raising above the other crops. Sorghum is one of the four major food grains of the world. It occupied an area of 43.7 million ha with production of 62.8 million tonnes.

ECONOMIC IMPORTANT :

Food : Earlier sorghum was used as staple food for about 10 % of the population, presently it decreased to about 7.47 per cent.

Feed : Sorghum grains are continued to be a staple grain feed in those area where no other crops can be raised profitable *viz*., maize, rice, wheat and where irrigation facilities cannot be increased. Sorghum is usually mixed with maize grain, ground well and form a important feed for cattle and poultry.

Green fodder : Forage sorghum is the ideal crops which can give higher fodder at less moisture. In northern states there is very heavy demand for forage sorghum and it is likely to spread to other area because of increase in the consumption of dairy products and other animal products.

Dry fodder : Sorghum is continued to be the important dry fodder source because of its high palatability nature under stress condition eg. K-3 sorghum.

INDUSTRIAL USE :

Extraction of starch : Demand for sorghum will increase if it can compete with maize market price and supply.

Syrup : Demand is met from cane sugar which is more economical than usage of sweet sorghum.

Liquor : No information is available.

Alcohol : Extraction of alcohol from sorghum is several times expensive compared to sugarcane juice which is turn is more expensive than that of molasses.

Undesirable qualities: It contains high amount of **Niacin**, which interface with the synthesis of Tryptophane, which is the precursor for synthesis of IAA. "***Pellagara***" is nutritional disorder due to presence of high amount of Leucine: iso-leucine ratio (3.4). When it is reduced, yield is also reduced. This disease is common in Africa. It contains considerable amount of oxalic acid, which interface with absorption of Ca and metabolism of Ca. Phytin 'P' is not utilized due to high oxalic acid. Oxalic acid also affects the Fe uptake. Low digestibility and low palatability is due

to presence of phenolic compounds and glycosides, tannin and lignin. Sorghum contains "cynogenic glucoside" called 'Dhurin'. This glucoside is converted into HCN in the stomach of ruminants. It causes bloating and reduce the transfer of O2 to the blood steam and causes death of the animal. It is called "***sorghum poisoning"/*(*sorghum effect*)**. HCN content is more than 100 ppm in the early stage. Critical level is 50 ppm. It (50 ppm) normally occurs during 60-65 DAS or at heading stage. If it is harvested earlier, it should be dried and fed to cattle. "***Sorghum injury***"—Sorghum stubbles/roots have high C:N ratio (50:1), *i.e.*, it contains low amount of 'N'. Hence, microbes take the soil 'N' for decomposition than from the decomposed stubble, which causes temporary immobilization of soil 'N'. Hence, succeeding crop after sorghum is affected due to N deficiency in the early stage called sorghum injury. Succeeding crops need higher N.

ORIGIN :

- Cultivated sorghum probably originated in East Central Africa, in or Ethiopia or Sudan.
- In India sorghum seems to have been cultivated earlier to the Christian era. It is also believed that India may be an origin for sorghum.

DISTRIBUTION :

- Sorghum is widely cultivate in USA, India, Nigeria, China, Argentina, Maxico and Sudan. It is grown to some extent in all countries of the world except in the cool North-Western part of Europe.
- Global production is about 58.15 million tonnes (2001). India has the largest share (32.3%) and ranks first in world's area in sorghum. USA ranks first (13.07 million tonnes) and India ranks second (7.42 million tonnes) in total production.
- In case of productivity of sorghum, Argentina ranks first (43.75 q/ha) and USA ranks second (43.70 kg/ha).
- In India Maharashtra, Karnataka, Andhra Pradesh, Gujrat and Rajasthan are the important sorghum growing states. In this states sorghum is cultivated in Kharif (rainfed) and rabi (post rainy crop) seasons excepts in Rajasthan.
- In India, Maharashtra ranks first in sorghum area (50.94 lakh ha) and production (39.88 lakh tonnes). It is followed by Karnataka in both area and production. In Tamil Nadu, the sorghum area is 4.92 lakh ha with a production of 4.97 lakh tonnes. The productivity of sorghum is highest in Tamil Nadu (10.10 kg/ha).

CLASSIFICATION :

A] EARLIER CLASSIFICATION OF SORGHUM :

i. ***Sorghum durra* :** Tall types, called as periyamanjal cholam Variety Co-1

ii. ***Sorghum cernuum* :** Popular types in Bellary district of Andra Prasehd called as thella jona.

iii. ***Sorghum subglabrescens* :** Shorter types, called as china manjal cholam, Varieties are Co-4, Co-12, Co-18, K-4 and K-9.

iv. ***Sorghum roxburghii* :** This types has looses penicles, called as thalai virichan cholam, vareties are Co-19, Paiyur-1

v. ***Sorghum dochna* :** Fodder types cholam, vareties are K-1, K-3.

B] COMMERCIAL CLASSIFICATION OF SORGHUM :

It is based on usage (i) Grain sorghum, (ii) Sorgho or sweet sorghum, (iii) Forage sorghum and (iv) Broom corn or special purpose sorghum.

a) Grain Sorghum :

1. Kafirs : They have thick, juicy stalk, awnless cylindrical heads. Seeds are white, pink or red with medium size grain eg. Co-4.

2. Millos : Dwarf stalk than khafirs and are less juicy. The heads are bearded, short, compact with very brown chaff. The seeds are large and yellow or white. The plants tiller considerably eg. Co-18, Co-22

3. Feterita : Theses types posses few leaves, slender relatively dry stalks, compact heads and very large chalk white seeds. Eg. Co-25, Co-26.

4. Durra : They have dry stalk, flat seeds and very pubescent glumes. Durra is the chief types in North Africa, near East and India.

5. Shallu : They are tall, slender dry stalked with loose heads, pearly white seeds. The loose heads dry quickly. Do not harbour worms and make it difficult for birds to eat grains. It is widely grown in India eg. Co-19, Paiyur-1.

b) Sorgo or Sweet sorghum :

They are characterized by abundant sweet juice in the stalks, which is usually at height of 1.5 to 3.0 m. They are suited for silage and fodder. Juice is used for preparation of syrup. Seeds are small, coloured (white or shades of brown), bitter and unpalatable. Sweet sorghum is grown in countries where sugarcane cannot be cultivated and sugar is imported eg. Iran.

c) Grass sorghum (Forage sorghum) :

Grass sorghums are grown for pasture or forage. Sudan grass and Johnson grass are two type of grass sorghum. Sudan grass has slender leaves and stalk and loose heads with small brown seeds. Johnson grass (*Sorghum halapense*) is similar to Sudan grass except in being larger and it is perennial with underground stem. Johnson grass may become a serious weed. So it should be avoided. Both grasses have slender stem, open head and vigorous tillering capacity.

d) Specific purpose sorghum :

i. Broom corn : They produce heads and fibrous seed branches of 30 to 90 cm long that are used for making brooms and whisk brooms. The stalk ranges from 1 to 4 metres in height and are dry, not sweet and of limited value for forage.

ii. Waxy corn : Waxy sorghums are grown commercially for waxy type of starch.

ii. Pop sorghum : Pop sorghum is used for popcorn.

MORPHOLOGY OF SORGHUM PLANT :

- Sorghum is a C_4 and short day plant. Mostly self-pollinated crops and occasionally cross naturally with Johnson grass, Broom corn, Sudan grass.
- Anthesis starts from top of the panicle and extends downwards gradually taking about a week for complete flowering.

GROWTH STAGES :

- **Seedling stage :** Emergence of coleoptiles indicates seedling stage.
- **Grand growth period :** From seedling to panicle initiation
- **Boot leaf or flag leaf stage :** This stage occurs 40-45 days after sowing. Flag leaf is a final leaf.
- **Flowering :** This stage occurs 70-75 days after sowing.
- **Soft dough :** Endosperm filled with watery fluid. It is called milky stage.
- **Hard dough :** Three fourth of grain weight is accumulated.
- **Physiological maturity :** Grain attain maximum dry weight.

CLIMATIC REQUIREMENT :

Sorghum requires warm climate but can be grown under a wide range of condition. It is grown from sea level to as high as 1500 meters. Sorghum plants can tolerate high temperature throughout their life cycle better than any other cereals crops. It can tolerate drought condition

very well because it remains dormant during moisture stress condition but resumes growth when favourable condition reappears. It has high resistance to desiccation, low transpiration ratio and large number of fibrous roots. It can also tolerate water logging condition better than any other cereals except rice.

It is grown as *kharif* crop in northern India. Western and Southern parts of country it is grown also as *rabi* crop. The minimum temperature for germination of sorghum seeds is 7-10 ^{0}C. It needs about 26-30 ^{0}C temperature for optimum growth. Sorghum is a short day plant. Flowering is hastened by short days and delayed by long days. The time of heading in sorghum is influence by temperature as well as photoperiod. Higher day temperature and sunshine for 4 to 5 weeks after sowing increases yield.

SOIL :

It is grown in a variety of soils. Soils with clay loam or loam texture, having good water retention capacity are best suited for its cultivation. It does not thrive well in sandy soils but does better on heavier soils. It does well in pH range of 6.0 to 8.5 as it tolerates considerable salinity and alkalinity. The black cotton soils of Central India are very good for its cultivation.

LAND PREPARATION :

Deep ploughing to a depth of 20-25 cm with mould board plough soon after harvest of rabi crop and keeping soil exposed to sun until onset of monsoon is a common practice. It should be followed by 2-3 harrowing. If necessary planking should be done to brake the clods and to level the field. Before last harrowing well decomposed F.Y.M. or Compost should be added in the field and mixed well with the soil by last harrowing.

VARIETIES :

From National Centre for Sorghum (NRCS), Hyderabad several varieties were evolved.

- **Kharif season :** CSV-10, CSV-11, CSV-13, SPV-462, Co-26.
- **Rabi season :** M 35-1, SPV-913, CSV-14R, Swathi
- **Improved Varieties :** Swati, Selecton-3, SPV- 669, PVK- 400, PVK -801, PVK 809, Prabhani Moti, CSV-1(Swarna), CSV -15
- **Hybrids :** CSH-12R, CHS-13R, CSH-8R CSH - 5, CSH – 6, CSH –9, CSH –10, CSH – 14, CSH – 16, CSH –17, CSH – 18

MPKV, Rahuri developed varieties :

Rabi sorghum varieties released for alternate uses like **hurda popping and papad purpose at State level**.

1. Phule Uttara: Released in 2005 for special purpose like hurda.
2. Phule Panchami: Released in 2010 for special purpose like grain poping.
3. Phule Rohini: Released in 2015 for special purpose like papad.
4. Phule Madhur: Released in 2015 for special purpose like hurda(Free threshability at dough stage).

Sweet sorghum varieties/hybrid released for syrup/ ethanol purpose

1. SSV 84 : Released in 1990 for Ethanol/Syrup/Jaggary at National level.
2. CSV 19 SS : Released in 2004 for Ethanol/Syrup/Jaggary at National level.
3. Phule Vasundhara (RSSH 50) : Released in 2015 for Ethanol/Syrup/Jaggary at State level.

Forage sorghum varieties released for single cut during kharif season.

1. Phule Amruta: Released in 2003 for Single cut forage at State level.
2. Phule Godhan (CSV 30 F) : Released in 2013 for Single cut forage at National level.

V.N.M.K.V. Parbhani :

- **CSH-25, Parbhani Joyti, PVK-400, PVK-801, Parbhani Moti,**

SOWING TIME :

In India sorghum is grown in following three season

i. Kharif – June –July
ii. Rabi – Mid-September –Mid-October
iii. Summer - Mid-January –Mid-February.

In northern India sorghum is sown only in *kharif* season.

SPACING AND SEED RATE :

The plant population of 1.8 – 2.0 Lakh /ha is optimum. The recommended spacing to achieve this plant population is 45 cm between rows and 10-12 cm between plants within rows. Seed rate of 8-10 kg is recommended to obtain required plant population.

SOWING METHOD :

It is sown by drilling and dibbling method. In drilling method sowing is carried out by 45 cm seed drill. Dibbling is done at 45 x 10-12 cm spacing. The seeds should be sown at a depth of 3-4 cm.

Seed treatment :

- Seed treatment with Thirum @ 3.0 g/kg of seed to control head smut disease.
- Sorghum seeds are treated with 300 mesh fine sulphur powder @ 4 gm/kg of seed to control grain & loose smut disease.
- Seeds are treated with Brine solution 30% (300 g NaCL in one litre of water) to control ergot disease.
- Seeds are treated with 50% Carbofuron @ 100 g/kg of seed for the control of shoot fly in delayed sowing of hybrid sorghum.

NUTRIENT MANAGEMENT :

The fertilizer dose differs from type and nature of crop. The recommended dose of manures and fertilizers for sorghum is below.

Crop	Recommended doses		Time of application (N:P:K kg/ha)		Remarks
	Manures (t/ha)	N:P:K (kg/ha)	Basal dose	Top dress	
Rainfed	6-7.5	50-25-0	50-25-0	-	NPK at sowing
Irrigated	12-15	120-60-60	60-60-60	60	60 kg N at 30 Days

Zinc and Iron are the commonly deficient micro nutrient in sorghum. The foliar application of $ZnSO_4$ & $FeSO_4$ @ 2% & 0.15% respectively twice has shown beneficial results.

Thinning and Gap filling :

Thinning & gap filling is necessary for maintaining optimum plant population. First thinning should be done 10-15 days after sowing & second when the crop is 20-25 days old. At the time of second thinning one healthy and vigorously growing plant should be kept at each hill. Gap filling should be done immediately after germination.

Weed management :

Keeping the sorghum fields free of weeds from 2^{nd} week after germination till 5^{th} week is good. If sufficient moisture is available, spraying atrazine @ 500 g/ha (atrazine 0.25 kg/ha) as

pre-emergence within three days after receipt of soaking rain followed by one late hand weeding/inter cultural operation may be done. For sorghum based intercropping system with pulses, pre-emergence application of pendimethalin (Stomp 30 EC) at 3.0 lit/ha followed by one hand weeding at 35 DAS is recommended.

Striga: There are three species of striga *viz*., *Striga asiatica, S. lutea, S. hermonthica* (*witch weed*). It is a semi-root parasite in sorghum and reduces the yield markedly. The control measures for striga in sorghum are as follows:

- Post emergence application of 2,4-D Na salt at 2.0 kg/ha at 25–30 DAS
- Intercropping with red gram
- Crop rotation with trap crops like cotton, sunflower, groundnut, cowpea, etc., which induce germination of weed seeds, but they are not themselves parasitized
- Heavy application of N and FYM and flooding the field
- Spraying Urea 10% solution on 25–30 DAS
- Using germination stimulants like Strigol and ethylene gas

WATER MANAGEMENT :

Sorghum is fairly drought tolerant crop. The water requirement is 450 to 500 mm. Irrigation is scheduled at 0.6 IW/CPE ratio. Seedling (15 to 20 DAS), panicle initiation (30 DAS) and flowering (60 to 65 DAS) are most important critical stages for irrigation. A mild stress at the time of grain formation is preferable.

CROPPING SYSTEM :

Sorghum fit well in multiple crop rotation and mixed cropping.

This crop is rotated with many crops as under

South India	North India
1. Soghum –Cotton	1. Soghum –Wheat
2. Sorghum-Tobacco	2. Soghum –Wheat-Green gram
3. Groundnut-Sorghum (Rabi)	3. Soghum – pea
4. Sorghum-Ragi-Groundnut	4. Soghum – gram
5. Soghum –Cotton- Groundnut	5. Soghum –Potato-wheat

The crop like mung, Udid, Copea, Tur are mixed with this crop in *kharif* season as crop mixture by sowing 2-4 lines of these crops followed by 8-12 lines of Jowar

HARVESTING, THRESHING AND STORAGE :

The crop is harvested when it shows following signs of maturity

1. When the grain becomes hard and have less than 25% moisture.
2. A blackish spot develops at the top of the grain.
3. The earhead bearing peduncle turns yellowish.

At this stage the crop is harvested. The leaves of local varieties may turn yellowish, but the leaves of hybrid varieties remain green at this stage also.

The crop is harvested by nipping earheads or cutting the plants at ground level. Then the earhead are dried in the sun and they are either threshed by trampling under the feet of bullocks or by running the stone roller on them or by using threshing machine. After threshing the grain are separated by winnowing. Grains are sun dried to the moisture content of 12-13 % and stored in gunny bags or in bins.

YIELD :

- **Rainfed crop :** 25-30 q/ha grain and 80-100 q/ha of dry fodder
- **Irrigated crop :** 50 q/ha grain and 100-125 q/ha of dry fodder

QUALITY OF SORGHUM GRAIN :

Sorghum grain contains 70 per cent carbohydrate, 13 per cent protein, 3 per cent fat, 3 per cent fibre and 20 per cent ash.

RATOON SORGHUM

It is highly amenable for ratooning. The varieties suited for ratooning are CO 25, CO 26, CSH 5 and K. Tall.

Ratooning technique: The main crop is harvested leaving 15 cm stubble in the field and first formed two sprouts are removed from the main crop and allowed only the latter formed two sprouts to grow. Two tillers per hill are allowed.

Hoeing and weeding: The weeds are removed immediately after harvest of main crop. Hoeing and weeding is done on 15th and 30th day after cutting.

Application of fertilizers: Application of 100:50:0 kg NPK/ha is recommended. N is applied in two splits doses *viz*., 1st dose on 15th day after cutting and second on 45th day after cutting. P2O5 is applied along with first application of N.

Pest and disease management: Since the ratoon crop invites pests and diseases in early stages, plant protection measures have to be resorted to.

Water management: Irrigation is given immediately after cutting the main crop. Irrigation should not be delayed for more than 24 hours after cutting. Then, irrigation is given 3rd or 4th day after cutting and subsequent irrigations are given once in 7–10 days. Irrigation is stopped 70–80 days after ratooning.

Harvest: Similar to sown crop but duration is 10–15 days lesser than main crop.

Yield: The yield of ratoon crop is about 25-30 q/ha.

The varieties recommended for ratoon crop are CSH-1, CSH-5, CSH-6. The variety CSH-9 is not recommended for taking ratoon crop.

PEARL MILLET (OR) BAJRA (*Pennisetum glaucum*)

It is a stable food crop of about 100 million peoples in rural areas of India and Sub Saharan Africa. Roti or Chapatti, which are unleaved flat breads prepared using pearl millet flour are common in Asia. Porridges and cooked grains are also used. In northern India, it is prepared during winter while wheat becomes common in summer diet. It is also used for fried preparations, foods such as fermented products and beer. Varieties of pancakes are prepared using pearl millet flour in Africa and pearl millet beer is used throughout Africa. Fura or cheese is the traditional African snacks prepared using steamed pearl millet flour and cream. It is used as fodder in Africa and Asia. Oxalic acid content is very high. So it is not relished by cattle. It is rich in protein (12.6%) and fat (5%), fiber (1.2%) and 60–70% of Carbohydrate. It is normally rich in Ca, Vitamin Riboflavin and Carotenoids. In Central America, it is mainly cultivated for forage purpose. It is also grown as pasture grass of the 150 sps of *Pennesitum*, *P. glaucum* is the cultivated species for grain and *P. purpurea* is the forage species.

Origin-Africa

Stages: There are four crop stages namely

- Seedling stage (1–18 days),
- Tillering stage (19–35 days),
- Flowering phase (36–55 days) and
- Maturity phase (56–85 days)

Climate:

It is a rapid growing, warm weather crop and it has resistance for drought. The best temperature is between 20 and 28°C. It can withstand even desiccation. It is highly suitable for the areas having rainfall ranges from 400–750 mm. Even 150 mm of rainfall is sufficient. Rainfall during vegetative phase is highly favourable, while rainfall at flowering is not conducive, as it washes off the pollen and there is a poor seed setting. The crop grows better in light showers followed by bright sunshine. Usually bajra is grown, where it is not possible to grow sorghum because of high temperature and low rainfall. It is grown as kharif crop in Northern India, while in Tamil Nadu, Karnataka and Punjab, it is grown under irrigated condition during summer.

Soil:

It is grown in a wide variety of soils, but being sensitive to water logging. It grows well in well drained sandy loams. It is sensitive to acidic soil. It is grown successfully in black cotton soil, alluvial soils and red soils of India.

Time of sowing:

In India, it is grown in three seasons *viz*., kharif (rainfed-June–October), winter (rainfed–November-February) and summer (rain fed–March-June).

Region/ State	Recommended Hybrid	Recommended Variety
Rajasthan	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173, HHB 67	MBC 2, PC 443, JBV 3, PC 383, ICMV 221, Raj 171
Gujarat	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173, HHB 67	MBC 2, PC 443, JBV 3, PC 383, ICMV 221, Raj 171
Haryana	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173, HHB 67	MBC 2, PC 443, HC 20, JBV 3, PC 383, HC 10, ICMV 221, Raj 171
Punjab	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173	PCB 164, ICMV 221, Raj 171
Delhi	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173	JBV 3, PC 383, ICMV 221, Raj 171
Uttar Pradesh	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173	JBV 3, PC 383, ICMV 221, Raj 171

Madhya Pradesh	KBH 108, GHB 905, 86M89, MPMH 17, Kaveri Super Boss, Bio 448, MP 7872, MP 7792, 86M86, 86M66, RHB-173	JBV 4, JBV 3, PC 383, ICMV 221, Raj 171
Maharashtra	Kaveri Super Boss, Pratap, PKV Raj, Shine, MP 7792, 86M86, PAC 909, 86M64, 86M53	ABPC-4-3, PC 612, Parbhani Sampada, Samrudhi, ICMV 221, Raj 171, ICMV 155
Tamil nadu	Kaveri Super Boss, Pratap, Co 9, Shine, MP 7792, 86M86, PAC 909, 86M64, 86M53	PC 612, CoCu 9, Samrudhi, ICMV 221, Raj 171, ICMV 155
Andhra Pradesh	Kaveri Super Boss, Pratap, Shine, MP 7792, 86M86, PAC 909, 86M64, 86M53	PC 612, Samrudhi, ICMV 221, Raj 171, ICMV 155, Ananta
Karnataka	Kaveri Super Boss, Pratap, Shine, MP 7792, 86M86, PAC 909, 86M64, 86M53	PC 612, Samrudhi, ICMV 221, Raj 171, ICMV

CULTIVATION PRACTICES

A. NURSERY

Preparation of land

- For raising seedlings to plant one ha select 7.5 cents near a water source. Water should not stagnate.
- Plough the land and bring it to the fine tilth.

Application of FYM

- Apply 750 kg of FYM or compost and incorporate by ploughing. Cover the seeds with 500 kg of FYM.

Forming raised bed

- In each cent mark 6 plots of the size 3 m x 1.5 m with 30 cm channel in between the plots and all around.
- Form the channel to a depth of 15 cm.
- Spread the earth excavated from the channel on the beds and level.

NOTE: The Unit of 6 plots in one cent will form one unit for irrigation.

Removal of ergot affected seeds and *Sclerotia* to prevent primary infection

- Dissolve one kg of common salt in 10 litres of water.
- Drop the seeds into the salt solution
- Remove the ergot and sclerotia affected seeds which will float.
- Wash seeds in fresh water 2 or 3 times to remove the salt on the seeds.
- Dry the seeds in shade.
- Treat the seeds with three packets (600g) of the *Azospirillum* inoculant and 3 packets (600g) of phosphobacteria or 6 packets (1200g) of Azophos.

Treatment of the nursery bed with insecticides

Apply phorate 10 G 180 g or Carbofuran 3 G 600 g mixed with 2 kg of moist sand, spread on the beds and work into the top 2 cm of soil to protect the seedlings from shoot fly infestation.

Sowing and covering the seeds

- Open small rills not deeper than 1 cm on the bed by passing the fingers over it.
- Sow 3.75 kg of seeds in 7.5 cents (0.5 kg /cent) and use increased seed rate up to 12.5 kg per ha in shootfly endemic area and transplant only healthy seedlings.
- Cover the seeds by smoothening out the rills with hand. Sprinkle 500 kg of FYM or compost evenly and cover the seeds completely with hands

NOTE: Do not sow the seeds deep as germination will be affected.

Irrigation to the seed bed

- Provide one inlet to each unit of 6 plots to allow water in the channels.
- Allow water to enter the channel and rise up in it. Turn off the water when the raised bed is wet.

Note: The seedlings should not be kept in nursery for more than 18 days. Otherwise the establishment and yield will be affected adversely. Ensure that cracks should not develop in the nursery. This can be avoided by properly adjusting the quantity of irrigation water.

B. MAIN FIELD

Field preparation

- Plough with an iron plough twice and with country plough twice. Bring the soil into fine tilth.

- **Chiseling for soils with hard pan:** Chisel the soils having hard pan formation at shallow depths with chisel plough at 0.5m interval, first in one direction then in the direction perpendicular to the previous one, once in three years.

Application of FYM or compost

- Spread 12.5 t/ha of FYM or compost or composted coir pith uniformly on unploughed soil.
- Incorporate the manure by working the country plough and apply *Azospirillum* to the soil @ 10 packets per ha (2000 g) and 10 packets (2000g) of phosphobacteria (or) 20 packets (4000g) of azophos with 25kg of soil and 25 kg of FYM.

Forming ridges and furrows/beds

- Form ridges and furrows (using 3 ridges) 6 m long and 45 cm apart. If pulses is intercropped, form ridges and furrows 6 m long and 30 cm apart.
- If ridge planting is not followed, form beds of the size 10 m^2 or 30 m^2 depending upon water availability.
- Form irrigation channels.
- To conserve soil moisture under rainfed condition, sow the seeds in flat and form furrows between crop rows during inter cultivation on third week after sowing.

Application of fertilizers

Apply NPK fertilizers as per soil test recommendations as far as possible. If soil test recommendation is not available follow the blanket recommendation of 70:35:35 kg N, P_2O_5, K_2O/ha for all varieties. For hybrids, apply 80 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha. Apply the recommended N in three splits as 25:50:25 per cent at basal, 15 and 30 DAS and full dose of phosphorus and potassium basally. Combined application of *Azospirillum* and phosphobacteria or Azophos along with 75 per cent of the recommended level of N and P is recommended for rainfed conditions.

Method of application: For transplanted crop, open a furrow more than 5 cm deep on the side of the ridge (1/3 distance from the bottom), place the fertilizer and cover. For the direct sown crop, mark the lines more than 5 cm deep 45 cm apart in the beds. Place the fertilizer below 5 cm depth and cover up to 2 cm from the top before sowing. In the case of intercropping with pulses, mark lines more than 5 cm deep 30 cm apart in the beds. Apply fertilizer only in the rows in which pearl millet is to be sown and cover up to 2 cm.

When *Azospirillum* inoculant is used for seeds, seedlings use only 50 kg N/ha for variety, 60 kg N/ha for hybrid, as soil application in other words, reduce 25% N of soil test recommendations.

Application of micronutrient mixture

Apply 12.5 kg/ha of micronutrient mixture formulated by the Department of Agriculture. Mix the mixture with enough sand to make 50 kg and apply on the surface just before planting/after sowing and cover the seeds. Broadcast the mixture on the surface to seed line. If micronutrient mixture is not available apply 25 kg of zinc sulphate per ha. Mix the chemical with enough sand to make 50 kg and apply as above.

MANAGEMENT OF MAIN FIELD

Transplanted crop

- Pull out the seedlings when they are 15 to 18 days old.
- Adopt the spacing 45 x 15 cm for all the varieties.
- Plant seedlings on the side of ridge, half way from the bottom. Depth of planting should be 3 to 5 cm.
- Root dipping with bio-fertilizers: Prepare the slurry with 5 packets (1000 g)/ha of *Azospirillum* inoculant and 5 packets (1000g/ha) of phosphobacteria or 10 packets of Azophos (2000g/ha) in 40 lit. of water and dip the roots of the seedlings 15-30 minutes before planting.

Direct sown crop

- Soaking of pearl millet seeds either in 2% Potassium chloride (KCl) or 3% Sodium Chloride (NaCl) for 16 hours followed by 5 hours shade drying improves germination and stand.
- Adopt the spacing of 45 x 15 cm for all varieties. If pulse is intercropped, adopt a spacing of 30 x 15 cm for pearl millet and 30 x 10 cm for pulses. One pair row of pearl millet is alternated with a single row of pulse crop.
- In the furrows in which fertilizers have been applied, place 5 kg of seed, allowing them to fall 4-5 cm apart (Use higher seed rate of 5 kg to offset mortality). The optimum population should be 1, 45,000 per ha. Use increased seed rate up to 12.5 kg per hectare in shoot fly endemic area and remove the shoot fly damaged seedlings at the time of thinning.

- Where pulse seeds are to be sown, drop pulse seeds to fall 5 cm apart and cover.

Weed management

- Apply the pre-emergence herbicide Atrazine 50 WP @ 500 g/ha, 3 days after sowing or transplanting as spray on the soil surface using Back-pack/Knapsack/Rocker sprayer fitted with flat type nozzle using 900 l of water/ha.
- Apply herbicide when there is sufficient moisture in the soil.
- Hand weed on 30 - 35 days after sowing if pre-emergence herbicide is applied.
- If pre-emergence herbicide is not applied hand weed twice on 15 and 30 days after sowing.

Thinning and gap filling

In direct sown crop after 1st weeding at the time of irrigation, gap fill and thin the crop to a spacing of 15 cm between plants; cowpea crop to 20 cm between plants and other pulses crops to 10 cm between plants.

Top dressing of fertilizers

• Top dress the nitrogen at 15 and 30 days after transplanting or direct sowing.

• In transplanted crop, open a furrow 5 cm deep with a stick or hoe at the bottom of the furrow, place the fertilizer and cover.

• In the case of direct sown crop apply the fertilizer in band. If intercropped with pulses apply the fertilizer to pearl millet crop only.

• After the application of fertilizer, irrigate the crop.

Water management

It is highly drought tolerant and hence, 2-3 irrigations are sufficient. Flowering and grain filling are the critical stages and about 300-400mm of water is sufficient to complete its life cycle.

NOTE: Irrigation schedule is to be adjusted depending upon the prevailing weather conditions.

Harvesting the crop

Symptoms of maturity: Leaves will turn yellow and present a dried appearance. Grains will be hardened.

Harvesting: Cut the earheads separately. Cut the straw after a week, allowing it to dry and stack it in the field till it can be transported.

Yield : Rainfed Crop : 12 to 16 q/ha Irrigated crop : 25 to 35 q/ha

Threshing, cleaning, drying and storing

Dry the earheads. Thresh in a mechanical thresher or spread it and drag a stone roller over it or cattle threshes. Dry the seeds below 10 per cent and mix 100 kg of grains with 1kg of activated kaolin to reduce the rice weevil and rice moth incidence. Spray Malathion 50EC 10 ml/ lit @ 3 lit of spray fluid/100 m2 over the bags during storage godowns, For grain purpose the grain should be dried well below 10% moisture and stored in gunny bags.

FINGER MILLET (RAGI) *Eleusine coracana* L. Gaertn.

It is cultivated mainly in Asia and Africa. It is staple food crop in many hilly regions of the country and it is grown both for grain and forage. In Northern hills, grains are eaten in the form of chapaties and in South India, grain flour is used for preparing gruel, cakes or unleavened bread, puddings, porridges, sweets etc. Germinating grains are malted and fed to infants and good for pregnant woman. It is considered as nutritive food for adults of different ages. Grains contain 9.2% protein, 1.29% fat, 76.32% carbohydrates, 2.24% minerals 3% ash and 0.33% Ca. It also contains vitamins A and B with small amount of P. It is good for persons suffering from diabetes. Green straw is suitable for making silage.

Origin: India. It is cultivated in India, Africa, Sri Lanka, Malaysia, China and Japan.

Soil and Climate: It is grown in wide variety of soils and it thrives well in well-drained loam or clay loam. It tolerates salinity better than other cereals. It is a tropical and sub-tropical crop, grows from sea level to 2100 m on hill slopes and it is grown in areas having average rainfall 50–100 cm. In higher rainfall areas, it is raised as transplanted crop.

Seasons: It is cultivated in three seasons namely *kharif, rabi* and *summer*. *Kharif* and *Rabi* crops are rainfed, while summer crop is irrigated. In Karnataka, Andhra Pradesh and Tamil Nadu, it is grown in *rabi* (September-October) as irrigated crop.

Varieties: Varieties cultivated are Godavari, Indaf 5, Sarada, PR 202, BR 407, EC 4840, CO 7, CO 11, CO 12.

Particulars	*Indaf* 5	CO 11	CO 12	CO 13
Duration (days)	105–100	90–95	110–120	95–100
Grain yield (kg/ha)				
Irrigated	4000	4750	4750	3600
Rainfed	2500	3250	3250	2300
Straw yield (kg/ha)				
Irrigated	7500	8750	8750	10000
Rainfed	5200	6250	6250	7500

Growth stages	*80 days crop*	*100 days crop*	*120 days crop*
Vegetative phase (nursery)	1–16	1–18	1–20
Vegetative phase (main field)	1–18	1–20	1–22
Flowering	19–40	21–55	23–69
Maturity	Beyond 40	Beyond 55	Beyond 69

Variety	Yield (q/ha)	Remark
Dapoli No. 1	12-15	Suitable for Konkan region, red colour grain
Dapoli Safed-1 (Konkan safed)	13-15 q/ha (mid-late 120 to 125 days)	White colour grain, contain proteins, iron and high content of magnesium
Dapoli No. 2	18-20 q/ha (mid-late 120 to 125 days)	Produced by tissue culture. Fe 162.5% and Ca 5.99% content more as compared to other cultivar.

Main field preparation and planting: The field is ploughed thoroughly to get a fine tilth with mould board plough. FYM or compost or composted coir pith at 12.5 t/ha is incorporated. Planting 30 days seedlings at 2/hill at a depth of 3 cm with a spacing of 15 cm × 15 cm or 20 cm x 15 cm is done by Thomba method.

Application of NPK is done as per soil test or a blanket recommendation of 80:40:0 or 60:30:30 of NPK kg/ha is recommended.

Half N and full P and K are applied basally. The remaining half N is top dressed 30th day after transplanting coinciding the weeding.

Water management: Generally, in heavy and light soils, totally 9 irrigations are required. Depending upon the duration of the crop (80, 100 and 120 days) and stage of the crop, one or two or three irrigations may be skipped or given. The critical stages are tillering and preflowering stages.

Weed management: Application of Butachlor 2.5 l/ha or Fluchloralin 2 l/ha or pendimethalin 2.5 l/ha as pre-emergence with 900 l of water is done and if sufficient moisture is not available, irrigation is done immediately. If pre-emergence herbicide is not applied, hoeing and hand weeding is done on 15th and 30th day after transplanting. For rainfed directed seeded crop, application of post emergence herbicide like 2,4-DEE or 2,4-D Na salt at 0.5 kg/ha is done on 10th day after sowing depending on moisture availability.

Cropping system: It is intercropped with legumes like field beans, cowpea, and fodder sorghum or occasionally with other millets. About 4–5 rows of *ragi* with a row of field bean is very common in Karnataka and Andhra Pradesh. Ragi is sequenced with groundnut, horse gram, cotton, tobacco or sesame.

Pest and disease management: To control mosaic virus, spraying Monocrotophos 36 WSC 0.05% is recommended. To control blast, spraying of carbendazim 250 g/ha is recommended. If needed, 2nd and 3rd spray may be given at 15 days interval after 1st spray. To control root aphids, dimethioate at 3 ml is mixed with 1 of water and drenching is done.

Harvesting: It does not mature uniformly and hence harvest is done in two stages. 1st harvest is done when ear head of main shoot and 50% of ear heads turn brown. Cutting and drying the ear heads is done. Then, threshing and cleaning is done. Second harvest is done seven days after first harvest. All the ear heads including green ones are cut with sickles first then the straw is harvested. Curing is done by heaping the harvested ear heads in shade for one day without drying to make greener ear heads to mature. Then drying, threshing and cleaning are done. Harvested heads are threshed using conventional beating with sticks and treading under the feet of animals. Machine threshing is also common in some areas.

Yield : 15 to 20 q/ha

SMALL/MINOR MILLETS

The small millets or minor millets have potentiality to grow even under adverse ecological condition and very poor agro-climate regions where main food crops cannot be grown. The five small millets are:

i. Italian or Foxtail millet (Kakun, Rala) : *Setaria italica*

ii. Kodo millet (Kodra) : *Paspalum scrobiculatum*

iii. Proso or common millet (Vari, Cheena) : *Panicum millaceum*

iv. Little millet (Kutaki or Sava) : *Panicum milliare*

v. Barnyard millet (Bhagar) : *Echinochloa frumentacea*

ITALIAN or FOXTAIL MILLET (Kakun, Rala)

It is generally grown as rainfed crop. Grains are cooked like rice and it contains 12.3% protein, 4.7% fat, 60.6% carbohydrates and 3.2% ash. Grain flour is used in the form of chapaties. Grains are fed to cage birds. Straw is thin stemmed and is liked by cattle (not good for horses). In China, it is important next to rice and wheat and provides approximately 15–17% of the total food consumed in China.

Origin: China

Soil and climate: It can grow in poor soils but requires fairly fertile soils for good yields. Light soils including red loams, alluvial and black cotton soils are all suitable for its cultivation but it thrives best on rich, well-drained loam soils. It is cultivated in tropical and temperate regions up to 2000 m altitude. It requires moderate temperature and grows successfully with 50–75 cm rainfall. Although water requirement is less, it has no capacity to recover after long spell of drought

KODO MILLET (Kodra)

It is a highly drought tolerant crop and it can be grown in areas where rainfall is scanty and erratic. It has coarsest food grains covered with horny seed coat, which should be removed before cooking. Immature and molded grains are poisonous. It can be easily preserved and it proves as good famine reserve and recommended as a substitute for rice to patients suffering from diabetes. Grain contains 8.3% protein, 1.4% fat, 65.6% carbohydrates and 2.9% ash.

Origin: India

Soil and climate: It is grown from gravelly and stony upland poor soils to loam soils and it comes well under adverse conditions and even in poor soils, some yield can be obtained. It thrives best

on well drained sandy loam to loamy soils. It makes rapid growth in warm and dry climate and requires rainfall of 400–500 mm.

PROSO OR COMMON MILLET (VARI)

The common millet offers better prospects for intensive cultivation in dry land areas and evades drought by its quick maturity. Grain contains 12.5% protein, 1.1% fat, 68.9% carbohydrate, 2.2% crude fibre and 3.4% ash. It is rich in lysine (4.6%), which is inadequate in most cereals. It is used as cooked grain, flour for making chapaties, perched grains etc. It makes good poultry feed and straw is a good fodder.

Origin: India

Soil and Climate: Well drained loam or sandy loam, free of kankar and rich in organic matter is ideal for cultivation of common millet. It can be grown both in rich and poor soils having variable texture ranging between sandy loam and clays of black cotton soils. It is a warm climate crop grown extensively in warm regions of the world and it is a highly drought resistant and can be grown in areas where there is scanty rainfall. It can withstand water stagnation to certain extent.

BARNYARD MILLET (BHAGAR)

It is a very drought resistant crop and also capable of withstanding water logging condition. Grains are consumed just like rice and used in making rice pudding. Grain contains 6.2% protein, 9.8% crude fiber, 65.5% carbohydrates and 4.4% ash. It is mostly eaten by poor class people and sometime brewed for beer. It is used as feed for cage birds and straw makes good fodder for cattle.

Origin: India

Soil and climate: It can be grown in soils of marginal fertility and partially water logged condition. It thrives well in sandy loam to loamy soils. It can be grown from sea level to 2000 m msl. Warm and moderately humid climate is good.

Table 15.9. Packages of Practices for Small Millets

Particulars	*Italian millet*	*Kodo millet*	*Common millet*	*Little millet*	*Barnyard millet*
Season and varieties	June-July CO 5, K 3, CO 6	K1, CO 3, APK 1 Niwas1, Pali	PV196 and 162, K1, CO 2, CO 3, CO 4 and K 2	CO 2, CO 3 K 1, CO 3	IP 149, VL 1 CO 1, K 1, PT 8, IPI 49
(Rainfed)	Sep.–Oct. CO4, CO5, CO6, K2				
Seed rate (kg/ha)	Line planting –10 and broadcasting-12.5	Line planting –10 and broadcasting – 12.5			
Seed drill	Gorru seed drill is recommended				
Seed treatment	2 g thiram or carbendazim				
FYM (t/ha)	12.5				
Nitrogen (kg/ha)	44 (basal)				
Phosphorus (kg/ha)	22 (basal)				

Particulars	*Italian millet*	*Kodo millet*	*Common millet*	*Little millet*	*Barnyard millet*
Spacing (cm)	22 × 10	45 × 10	25 × 10	25 × 10	25 × 10
Weeding	15 DAS- 1st weeding 40th DAS- 2nd weeding				
Thinning	20 DAS				
Yield (kg/ha)	1200–1800	1500–1800	1200–1500	700–1300	1250–1750
Harvesting	The whole plant or ear head is sickled, staked and dried and threshed with stone roller or trampling under feet of bullocks				

Lecture 11 and 12

CULTIVATION OF PULSES (PIGEON PEA, GREEN GRAM, BLACK GRAM, HORSE GRAM, COWPEA AND MOTH BEAN)

PIGEON PEA/ RED GRAM (*Cajanus cajan*)

It is the second most important pulse crop, next to gram. There are two species *viz*., *C. cajan var. flavous–Tur* (*Early*), *C. cajan var bicolour–Arhar* (*late*). It is primarily used as dal, while the tender green seeds are consumed as vegetable, crushed dried seeds as animal feed and green leaves as fodder. Stem is used as fuel wood and to make huts and baskets, used for paper pulp. Leaves can be used to feed silkworm and plants are used to culture lac insect. It serves as windbreak and live fence. Venezuela local soft drink known as 'Chicha' is made and canned for export by freezing. It accounts for 12% pulse area, 17% pulse production and 90% world production.

Origin**:** India

Soil and Climate: It is grown in wide range of soil from sandy loam to clay loams. Best soils are fertile, well drained loamy soils, Suitable pH range is 5–8. It grows up to 1500 m msl and well distributed rainfall of 500–900 mm in tropics and subtropics is sufficient. It requires temperature range of 10–40°C and the optimum temperature is 20–28°C.

Season and Varieties: It is grown in kharif (June-August) and rabi (September-November).

- CO 5, CO 6, Vamban 1, Vamban 2 – Resistant to sterility mosaic
- BSR 1, SA1 and CO 4 – Suitable for bund planting.

Hybrids: ICPH 8 from ICRISAT – yield is 4 t/ha.
COH 1, COH 2

Spacing: The depth of seeding is 5 cm. The seed rate is 20–30 kg/ha. For bund planting, the seed requirement is 50 g/100 m row. In vertisols, broad bed furrows (BBF) are best with 90 cm beds and 60 cm shallow furrow.

- Long and medium duration varieties : 75 × 30 cm
- Short duration : 45 × 30 cm
- Rain fed : 90 × 30 cm

Seed treatment: The seeds are treated with Carbendazim or Thiram @ 2 g/kg seed 24 hours before sowing (or) *Trichoderma virdie* @ 4 g/kg of seed (or) *Pseudomonas fluorescence* @ 10

g/kg. Fungicide treated seeds should be again treated with 3 pockets bacterial culture 15 minutes before sowing

Fertilizer management : For a production level of 2 t grain and 6 t stalks, red gram removes 132 kg N, 20 kg P2O5 and 53 kg K_2O per ha. Phosphorus is the most limiting nutrient and response is about 6–10 kg grain/kg of applied P. Application of 12.5 kg N + 25 kg P2O5/ha basally before sowing under rain fed conditions and 25 kg N + 50 kg P2O5/ha under irrigated conditions id recommended. Soil application of 25 kg DAP/ha and foliar application of 25 kg DAP/ha with 25 kg S as gypsum (110 kg/ha) or 2% urea in two sprays at flower commencement and 15 days after may be given for getting higher yield.

Weed management: Application of Fluchloralin at 1.5 l/ha (or) pendimethalin 2 at 1/ha on 3 DAS, followed by one hand weeding may be given on 30–35 DAS. If no herbicide is applied, two hand weeding's on 15 and 35 DAS are recommended.

Water management: Water use efficiency of legumes is 500 kg water/kg DMP, while for cereals, it is 300–350 kg water/kg DMP. Water requirement of red gram is 500–600 mm. To produce 1 t of grain, 200–250 mm water is used. Irrigation should be given for the stages *viz*., immediately after sowing, 3rd DAS, bud initiation, 50% flowering and pod development stages. Water stagnation at any stage should be avoided.

Cropping Systems

Intercropping: The important cropping systems are sorghum + red gram, ragi + red gram, red gram + black gram and red gram + groundnut at 1:6 ratio.

Crop rotation: This crop is rotated with maize/rice-red gram, red gram-wheat.

Harvesting: Harvesting is done the plants when 80% of the pods are matured. Then, the plants are stacked for a few days. The pods are separated with sticks and grains are separated from husk and dried to optimum moisture level (10–12%).

Yield: Yield ranges from 2 to 4 t/ha.

PLANT PROTECTION MEASURES

Disease :

The important diseases of Pigeon pea are Wilt, Sterility mosaic disease, Phytophthora blight, Alternaria blight, Powdery mildew. Symptoms of these disease and their suitable control measures are given below:

1. Wilt :

Symptoms:

Xylem gradually develops black streaks, dark purple bands appear on the stem surface plants extending upwards from the base. Main stem of such plants is split open, intensive blackening of the xylem can be seen. In humid weather, a pinkish mycelial growth is commonly observed the basal portions of the wilted plants. It may be seen in seedling, flowering & vegetative stage.

Control Measures

- Seed Treatment with *Trichoderma viride* @ 10 g/kg of seed or Thirum (2 gm) + Carbendazim (1gm) / kg of seed;
- Soil application - *T. viride* – 2 .5 kg/ ha + 50 kg of well decomposed FYM or sand at 30 days after sowing.
- Mixed cropping with sorghum;
- Uproot wilted plants;
- Avoid over or under watering plants;
- Amendment of soil with oil cakes, appliances of trace elements such as boron, zinc and manganese and heavy dose of green leaf manure crops
- Grow resistant varieties like Amar, Azad, Asha (IPCL - 87119), Maruthi, C-11, BDN-1, BDN - 2, NP - 5, JKM - 189, C - 11, JKM - 7, BSMR - 853 & BSMR - 736 etc.

2. Sterility mosaic disease :

Symptoms :

It is caused by mosaic virus & spread from plant to plant under field conditions through Eriophyid mite. Leaves become small and cluster near branch tips & reduced in size. Plants are pale green and bushy in appearance, without of flowers and pods. Diseas ed plants are usually in groups. It may be seen in Vegetative growth & Pre - flowers stage

Control Measures

- Spray Fenazaquin 10 EC (Magister) @ 1 ml/lit er of water on 45 and 60 DAS;
- Rogue out the infected plants in the early stages of growth;
- Crop rotation with non host crop like tobacco, sorghum, pearl millet, cotton;
- Grow resistant varieties like Pusa - 885, Asha, Sharad (DA11), Narendra Arhar1, Bahar , BSMR - 853, BSMR 736, Rajeev Lochan, BDN - 708.

3. Phytophthora blight

Symptoms:

Foliage blight symptoms are circular or irregular water soaked lesions on leaves. The lesions on stems and branches increases rapidly, girdles, cracks and dries the stem. Infected stem and branches break easily in the wind.

Control Measures

- Seed treated with Metalaxyl 35 WS @ 3 g/ kg of seed
- Good drainage in the fields and the plants should be protected from stem injury
- Crop rotation should be followed
- Grow resistant varieties like ICPL 7916/ 12055/12114/12161, JKM - 189, JA - 4 etc.

4. Alternaria blight

Symptoms:

Symptoms appear on all aerial part of plants are small, circular, necrotic spots that develop quickly, forming typical concentric rings. The spots are initially light brown and later turn dark brown. In severe infection, defoliation and drying of infected leaves, branches and flower buds.

Control Measures

- Spray the crop with Mancozeb 75 WP @ 2 g/liter or Carbendazim 50 WP @ 1g/liter of water;
- Cultivation of pigeonpea on ridges with proper drainage system and avoiding the sowing in heavy soil helpful in disease management;
- Grow resistant varieties like DA - 2, MA 128 - 1, MA 128 - 2

Insect-Pests

1. Pod borers

Nature of Damage : It is widely distributed and is the most injurious pest of early and medium maturing varieties. The larvae, after hatching, feed on tender leaves and twigs but a pod formation they puncture pods and feed on developing grains. It may be seen in vegetative & podding stage.

Control Measures

- Use H. armigera pheromone trap @ 12/ha
- Spray the crop with Emamectin benzoate 5% SG @ 220 g/ha. or Indoxacarb 15.8% SC @ 333 ml/ha
- The caterpillar should be picked by hand after shaking the plants and destroyed in the early stages of attack.

2. Tur Pod fly

Nature of damage : Stripes can be seen on the surface of the affected grains, while the attacked pods are somewhat twisted or deformed. In case of severe damage, as many as 80 percent pods and 60 per cent grains may be damaged.

Control Measures

- Spraying Neem seed kernel extract (NSKE) 5 per cent at 50% flowering stage to manage the insect's populations;
- Pest can be controlled by spraying the crop with Monocrotophos (Nuvacron) 36 SL 1 liter in 800 - 1000 litres of water per hectare.

3. Plume Moth

Nature of damage: The larvae damaged seeds as well cause flowers, buds and pods to drop. The caterpillar is greenish - brown in color and fringed with short hairs and spines. It also enters into the pod and feeds on developing grains.

Control Measures

- Apply the Neem oil 2%
- Spray the crop with Azadirachtin 0.03 % WSP 2500 - 5000 g/ha or Emamectin benzoate 5% SG @ 220 g/ha or Indoxacarb 15.8% SC @ 333 ml/ha .

4. Pod-sucking bugs

Nature of damage: Damaged seeds become shriveled, and develop dark patches. Shedding of green pods.

Control Measures

- Soil application of carbofuran 3G @ 15 kg/ha at sowing;
- Spray the crop with Ha NPV 3 x1012 POB/ha in 0.1% teepol;
- Immature bugs can be handpicked and destroyed;
- The main natural enemies of bugs are egg parasitoids, ants and birds reported reduce feeding by green shield bugs;
- Spraying with aromatic plants (e.g. gums, lantana, Neem-based pesticides).

GREEN GRAM (*Vigna radiata*) (Moong, Mung, Golden gram)

It is relished for easy digestibility as dhal or split seeds and green pods are used as vegetables. Haulms are used as fodder. Husk and split beans are useful as livestock feed. It makes a good cover crop and soil binder. It is excellent green manure (1.5% N and easily decomposed when incorporated). It contains24% protein, 1.15% fat and 62.6% carbohydrate. Seeds are boiled and used in soups, made into porridge with rice or wheat. Sprouted seeds are consumed as salad, which are rich in vitamins. Flour is used in cakes and deserts and starch is used in making noodles. The low content of oligosaccharides results in low flatulence. Being a short duration crop, it is well fitted in many intensive crop rotations.

Origin**:** India and Central Asia.

Distribution:

It is cultivated in India (45% world production), Myanmar, Pakistan, Thailand, Sri Lanka, Indo-China, Indonesia and China. In India, it is cultivated in Andhra Pradesh, Orissa, Madhya Pradesh, Maharashtra, Bihar and Gujarat.

Soil and climate:

Ideal soils are well drained loam or sandy loam and saline alkali soils are not suitable. Optimum pH range is 6.5–7.5. An annual rainfall of 600-750 cm is sufficient for the crop growth. It is grown from sea level to 2000 m. Optimum temperature requirement is 28°–30°C. It is a short day plant.

Field preparation:

The land is prepared to get fine tilth and beds and channels are formed. To tide over surface soil crusting, application of lime @ 2t/ha along with FYM at 12.5 t/ha or composted coir pith is practiced to get additional yield of 15–20%.

Season and varieties:

It is grown as kharif and summer crop in north India, but in South and South West India, it is grown as rabi crop. The important varieties cultivated in India are Type 44, Pusa Baisakti, Jawahar-45, K-851, Sheela, PS-16, Pant Mung-1 and Mohini (S8), Pusa Vaishakhi, Vaibhav, Phule M-2, Kopargaon, Jalgon-781, TAP-7.

Seeds and seed treatment:

Seed rate is 20 kg/ha for pure crop, 10 kg/ha for mixed crop, 25 kg/ha for rice fallows and 50 g/100 m length for bund sowing. The seeds are treated with carbendazim or thiram @ 2 g/kg

of seed, then after interval of 24 hours, treated with 3 packets (600 g) suitable strains of Rhizobium biofertiliser with rice gruel 15 minutes before sowing. Instead of chemical, the seeds are treated with *Trichoderma viride* @ 4 g/kg or *Pseudomonas fluorescence* @ 10 g/kg followed by biofertilizer.

Fertilizer application:

In general, 1 t of green gram removes 43 kg N, 3–4 kg P and 10–12 kg K.

Application of fertilizers is done basally before sowing as below:

Rainfed: 12.5 kg N + 25 kg P2O5/ha

Irrigated: 25.0 kg N + 50 kg P2O5/ha

For rice fallow crop, 2% DAP at the time of first appearance of flower and 15 days later or spray 40 ppm NAA at the time of first appearance of flower and 15 days later is recommended.

Sowing:

Dibbling the seeds is done adopting spacing of 30 × 10 cm (for line sown crop). Broadcasting may be done in the standing crop 5–10 days before the harvest uniformly at optimum moisture condition (seeds should get embedded in the waxy mire) under rice fallow condition. Dibbling is done at 30 cm spacing on wetland bunds as bund crop.

Water management:

For line sown pure crop, irrigation is given immediately after sowing followed by life irrigation on the 3rd day and then, at interval of 10–15 days depending on soil moisture conditions.

For wetland bund crop, pot watering is done daily for a week after sowing. Flowering and pod formation stages are critical periods. Water stagnation should be avoided at all stages. In some places, sprinkler irrigation is followed especially for summer crop.

Weed management:

Application of fluchloralin 1.5 l/ha or pendimethalin 2.0 l/ha as pre-emergence (3 DAS) followed by one hand weeding on 30 DAS is recommended. If herbicides are not applied, two hand weeding on 15th and 30th DAS is recommended.

Cropping systems:

Intercropping is common practice where one or two rows of green gram with maize, pearl millet, sorghum, pigeon pea, cotton and sugarcane. It is rotated with wheat and potato in India.

Harvesting:

The plants are harvested when 80% of the pods are matured and the plants are stacked for few days before threshing.

Yield:

The average yield is 700–900 kg/ha for rain fed condition, 1500 kg/ha for irrigated and 500 kg/ha for rice fallow condition.

BLACK GRAM (URD) (*Vigna mungo*)

Being a short duration crop, it fits well in many intensive crop rotations. It is also used as green manure crop. It is mainly consumed as dhal or split seeds (husked and unhusked) and husked dal is ground into a fine paste and allowed to ferment with rice flour to make 'dosa' and 'Idli' (a south Indian favourite food). The peculiarity of black gram is when ground with water develops mucilaginous character giving additional body to the mass. It contains 25% protein, 1.83% fat, 61.0% carbohydrate. It is a chief constituent of 'papad'. Haulms are used as fodder. Husk and split beans are useful as livestock feed. It possesses deep root system, which binds soil particles and prevents erosion.

Origin: India**.**

Distribution: It is cultivated in India, Pakistan, Bangladesh, Myanmar and Sri Lanka. In India, it is cultivated in Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu, Uttar Pradesh and Orissa.

Soil and climate: Ideal soils are well drained loam or sandy loam. Optimum pH range is 5.5–7.5 It is generally grown in areas which receive annual rainfall of 800 mm and areas of 1800 m msl.

Field preparation: The land is prepared to get fine tilth using disc plough and country plough and beds and channels are formed. To tide over surface soil crusting, application of lime @ 2 t/ha along with 12.5 t/ha FYM or composted coir pith is done to get additional yield of 15–20%.

Season and varieties: It is grown as kharif and summer crop in north India, but in South and South west India, it is also grown as rabi crop. The important varieties cultivated in India are Type-9, Type-27, Type-56, Pusa-1, Mosh-48, Pant-430, Gwalior-2, Khargone-3, Ujjain-4, Naveen, Krishna, Sarla and UG218

Seed treatment: Seed rate is 20 kg/ha for pure crop, 10 kg/ha for mixed crop, 25 kg/ha for rice fallows and 50 g/100m length for bund sowing. Chemical seed treatment is done with carbendazim or thiram @ 2 g/kg of seed then after interval of 24 hours, the seeds are treated with 3 packets (600g) suitable strains of Rhizobium biofertiliser with rice gruel 15 minutes before sowing. Instead of chemical, the seeds are treated with *Trichoderma viride* @ 4 g/kg or *Pseudomonas fluorescence* @ 10 g/kg followed by biofertilizer. For Pre-monsoon sowing, the seeds are treated with paste made of ash (500 g/kg of seeds) + 3% gum and drying is recommended for 5 hours.

Fertilizer application:

Application of 12.5 kg N + 25 kg P2O5/ha for rainfed crop and 25.0 kg N + 50 kg P2O5/ha for irrigated crop as basally before sowing is recommended.

Sowing: Dibbling the seeds is done adopting spacing of 30 × 10 cm (for line sown crop). Broadcasting may be done in the standing crop 5–10 days before the harvest uniformly at optimum moisture condition (seeds should get embedded in the waxy mire) under rice fallow condition. Dibbling is done at 30 cm spacing on wetland bunds as bund crop.

Water management: Irrigation is given as in the case of green gram**.** In some places, sprinkler irrigation is followed especially for summer crop. Application of 0.5% KCl as foliar during vegetative stage, if there is moisture/water stress.

Weed management: Application of fluchloralin 1.5 l/ha or pendimethalin 2.0 l/ha as pre-emergence (3 DAS) followed by one hand weeding on 30 DAS is recommended. If herbicides are not applied, two hand weeding on 15th and 30th DAS is recommended.

Cropping systems: Intercropping is common practice where one or two rows of black gram with maize, pearl millet, sorghum, pigeon pea, cotton and sugarcane. This crop is rotated with maize–wheat-black gram, maize-potato-black gram, rice-wheat-black gram in north India.

Harvesting:

The plants are harvested when 80% of the pods are matured and the plants are stacked for few days before threshing.

Yield:

The average yield is 600-700 kg/ha for rainfed condition, 1000–1300 kg/ha for irrigated and 500 kg/ha for rice fallow condition.

COWPEA (*Vigna anguiculata*)

Origin : Africa

Importance :

This crop is known as drought hardy nature, its wide and droopy leaves keeps soils and soil moisture conserved due to shading effect. It is also known as black-eyed pea or southern pea etc. and has multiple uses like food, feed, forage, fodder, green manuring and vegetable. Cowpea seed is a nutritious component in the human diet, and cheap livestock feed as well. Both the green and dried seeds are suitable for canning and boiling as well.

Nutritive value : Protein - 22-24% Carbohydrate - 55-66 % Iron - 0.005% Calcium - 0.08 – 0.11 % Essential amino acids (lysine, leucine and phenylalanine)

State-wise recommended varieties State Recommended varieties :

- M.P. Gujarat : cowpea-3, V-240, Gujrat : cowpea-4, UPC-622 T.N. : Vamban-1, Co-6, UPC-628
- Karnataka : KBC-2, IT-38956-1, PKB-4, PKB-6
- Rajasthan : RC-101, RCP-27 (FTC-27)
- Punjab : CL-367, UPC-622, VRCP-4 (Kashichand) C.G. Khalleshwari U.P. UPC-622, Swarna harita (IC285143), Kashi chandan, UPC-628, Pant lobia-1
- Jharkhand : UPC-628 Haryana : Hisar cowpea 46 (HC 98-46)
- U.P. : Pant lobia-1, UPC-628
- Maharashtra : Konkan Sadabhar, Konkan Safed

Varieties –

- **(a) Grain:** C-152, Pusa Phalguni, Amba (V-16) (M), Ramba (V240)(M), Swarna (V38) (M), GC-3, Pusa Sampada (V-585), Shreshtha (V-37) (M), Konkan Sadabhar, Konkan Safed

(b) Fodder: GFC 1, GFC 2, GFC 3,-Kharif season, GFC-4 Summer (25-35 tonnes/ha), Bundel Lobia-1,UPC-287 and UPC-5286 , Russian Giant, K-395, IGFRI- 5450 (Kohinoor), C-88(20-35 tonnes/ha in Punjab), UPC 5287, UPC-4200 (NE India), UPC 618, UPC 62, UPC 622, UPC 625 UPC 628, Konkan Chara Chawali No. 1.

Climatic requirements :

Cowpea is warm weather and semi-arid crop, where temperature ranging from 20 ^{0}C to 30 ^{0}C. Minimum temperature for seed establishment is 20 ^{0}C and above 32 ^{0}C temperatures development of root is cease. For maximum production day temperature 27 ^{0}C and night temperature 22 ^{0}C required. It is sensitive to cold and below 15 ^{0}C temperature yield adversely affected. It can grow under shade of tree but can not tolerate cold or frost.

Soil Type & Field Preparation :

Well drained loam or slightly heavy soil are best suited. In colder climate somewhat sandy soil preferred as crop mature earlier in them. It can grow successfully in acidic soil but not in saline/alkaline soil. In hard soil, one deep ploughing followed by two or three harrowing and planking are sufficient. In normal soil only two harrowing & planking is enough. For summer season crop give a irrigation immediately after harvesting of Rabi crop.

Sowing Time :

- ***Kharif***- With onset of monsoon ranging from early June to end of July,
- ***Rabi***- October-November (southern India),
- **Summer** - 2nd to 4th week of March (grain), February (Fodder), Hills: April-May, Green manuring- Mid June to 1st week of July

Seed Rate : For pure crop: 20-25 Kg/ha(grain), for fodder and Green Manure-30-35 kg./ha. During summer 30 kg/ha for grain and 4- kg/ha for fodder and green manuring.

Spacing: Row to row—30(Bushing) to 45 cm (spreading), Plant to Plant-10 (Bushing) to 15 cm (spreading)

Method of sowing : Sowing of cowpea is done by broadcasting, line sowing and dibbling of seeds based on the their purpose and season. Line sowing has been better over broadcasting method of sowing. However, for fodder and green manure crop broadcasting method considered better .In high rainfall area, formed 30 cm wide and 15 cm deep drainage channel at every 2 meter interval to drain excess rain water. Sowing of seed a depth of 3-5 cm.

Seed Treatment : Treat the seed with Thirum (2gm.) +Carbendazim (1gm.). It is also desirable to treat the seed with Rhizobium culture @10g/kg seed.

Crop rotation :

Grain/vegetable	Fodder
Cowpea-Wheat-Mung	Sorghum + cowpea-berseem-maize + cowpea
Cowpea-Potato-urd/bean	Maize-berseem/oat- maize + cowpea
Maize/Rice-Wheat-Cowpea	Sudan grass- berseem/oat- maize + cowpea
Maize-Toria-Wheat-Cowpea	Cowpea-berseem-maize + cowpea
Rice-Rice-Cowpea	
Rice-Cowpea	

Intercropping :

Growing one or two rows of cowpea in widely spaced crops and incorporating the biomass after picking pods can increase soil fertility and yield of companion crop. The improvement in this system can further be made by pairing the rows of main crops and taking one or two rows of cowpea in between two paired rows of either of pigeonpea, maize and sorghum. Here, we can get 5-7 q/ha grain yield of cowpea without any adverse effect on main crop yield. It can also be grown as floor crop in coconut garden and intercrop in tapioca in Kerala and as sole crop in single or double crop rice fallows in rabi or summer season respectively.

Manure & Fertilizer :

Apply FYM/compost- 5-10 t/ha as basal with last ploughing. 15-20 kg N/ ha as starter dose in poor soils (organic carbon pod filling>vegetative. Crop can tolerate flooding upto 2 days at flowering and pod setting thereafter, a marked decrease in yield and its attribute.

Weed Control :

For higher yield crop should be free from weed upto 25 to 30 day crop stage. Application of pendimethaline @ 0.75 - 1 kg.a.i./ha combined with one hand weeding at 35 days after sowing is beneficial.

Harvesting, Threshing & Storage :

Green pods for use as vegetable can be harvested 45-90 days after sowing depending on the variety. For grains, the crop can be harvested in about 90-125 days after sowing when pods are fully matured. The crop should be then dried and threshed, threshed grain should be dried in sun before storage. For fodder, the cutting of the crop depends upon the need and the stage of growth of the component crop sown with it. Generally it should be done 40-45 days after sowing.

Yield :

A good crop of cowpea yields about 12-15 q of grain and 50-60 q of straw per hectare. If the crop is raised for fodder purpose 250-350 q of green fodder is obtained per hectare.

Plant Protection Measures

Diseases :

Bacterial Blight :

Symptoms : The germinating seedling turn brown-red and die. Irregular to round spots brown in colure with chlorotic halos, appear on leaves, and later spread to stem. Stem may break, pods are also infected leading to shrivelled seeds.

Control Measures : i) Grow resistant varieties; ii) Use healthy and disease free seeds; iii) In case of severe infection, crop may be sprayed with 0.2 % (2g/liter) copper oxychloride (Blitox).

Cowpea Mosaic

Symptoms : It is caused by a virus transmitted by aphids. The affected leaves become pale yellow and exhibit mosaic, vein banding symptoms. The affected leaves become reduced in size and show puckering. Pods are also reduced and become twisted. **Control Measures** : i) Use healthy seed from healthy crop; ii) For controlling aphids spray Oxydemeton methyl 25 EC (Metasystox) @ 1 ml/liter or Imidacloprid 17. 8 SL @ 0.2 ml/ liter of water and repeat the spray after 10 days of first spray.

Powdery mildew :

Symptoms : Powdery mildew are visible on all the aerial parts of the affected plants. Symptoms first start from leaves and then spread to stem, branches and pods. This white growth consists of the fungus and its spores. Affected leaves become twisted and smaller in size.

Control Measures : i) After harvest, collect the plants left in the field and burn them; ii) The disease can be controlled by spray of wettable sulphur @ 3g/liter or carbendazim @1 g/liter of water.

Insect-Pest

Cowpea pod borer :

Nature of Damage : The caterpillar rolls the leaves and web these with the top shoot. Caterpillar bore into the pods and feed on the seeds, if flower and pods are not available larvae feed on foliage.

Control Measures : i) Collect and destroy the eggs and young larvae; ii) The young caterpillar can be killed by dusting 2% methyl parathion @ 25-30 kg per hectare or spray of quinalphos @2 ml/liter of water; iii) Fix 3 feet stick in the field @10/ha bird parches to attract predatory birds.

Hairy caterpillar :

Nature of damage: It is major insect of cowpea. It is cut juvenile plants and eat away all the green matter of the leaves.

Control Measures : i) Collect and burn the eggs and burn the eggs and larva of insect; ii) The young caterpillar can be control by spray of Chloropyriphos or Quinolphos @ 2ml/liter of water.

Aphids and Jassids :

Nature of Damage : The adult and nymphs of these pests suck the juice from the leaves and the damage is more severe when the plants are young. As a result of sucking of sap, the leaves turn brown and crumbled and the plant look sick.

Control Measures : i) Spray of Oxydemeton Methyl 25 EC (Metasystox) @ 1 ml/ liter or Dimethoate 30 EC @ 1.7 ml/ liter of water.

Bean fly /Stem fly :

Nature of damage : Bean fly causes the characteristics swelling of stem at ground level where the maggots burrow onto the stem. The maggots puppets at the base of the plant and the stem grows it often cracks. The petiole often shows dark streaks where the maggots have move through and damage tissue.

Control Measures : i) Keeping the field clean from legume debris; ii) Application of Phorate (Thimet) 10 G @ 10 kg per hectare in furrows at the time of sowing is effective for avoiding infestation.

HORSE GRAM/Kulthi [*Macrotyloma uniflorum* (Lam) Verdc]

Origin - Peninsular India

Importance Horse gram is an important crop of south India. Its grain is used for human consumption as 'dal' as well as in preparation of so called 'rasam' and also as a concentrated feed for cattle. It may also be used as green manure. This crop is generally grown when the cultivator is unable to sow any other crop for want of timely rains and also grown in vacant space of citrus orchard. Crop Status Horse gram is mainly cultivated in the states of Karnataka, Andhra Pradesh, Orissa, Tamil Nadu, M.P., Chhattisgarh, Bihar, W.B., Jharkhand, and in foot hills of Uttaranchal and H.P., in India. It is also cultivated in other countries mainly Sri Lanka, Malaysia, West Indies etc.

State-wise varieties:

- Maharashtra : Dapoli-1, Seena, Man (yield 6 to 8 q/ha)
- Rajasthan : KS-2, Pratap Kulthi (AK-42)
- A.P. : Palem-1, Palem-2, Paiyur-2, PHG-9 T.N. Paiyur-2
- Karnataka : PHG-9, GPM-6, CRIDA-1-18 R
- Gujarat : Pratab Kulthi-1 (AK-42), GHG-5
- Uttarakhand : VL- Gahat-8, VL Gahat-10 C.G. Indira Kulthi-1 , (IKGH01-01)

Climate requirement :

Horsegram is extremely drought-resistant crop. Moderately warm, dry climatic conditions are suitable for its optimum growth. It does not grow well on higher altitudes because of cool and wet climate. Horsegram can be cultivated up to an altitude of 1000 m above the sea level. The temperature range of 25-30°C and relative humidity between 50 and 80% is optimum for its growth. Heavy rains during the initial stages of crop growth affect nodule formation owing to poor aeration in the soil. A well-distributed rainfall of about 800 mm is sufficient for its successful cultivation, but it performs well even under low rainfall areas.

Soil Type & Field Preparation :

Generally grown on lateritic soil (poor in fertility) in south India. The crop can be grown on wide range of soils from light to heavy soils which are free from alkalinity. The crop needs minimum field preparations. Only 1-2 ploughings followed by planking provides desirable seed-bed.

Sowing Time :

The main season for sowing horse gram is late August-November. As a fodder crop it is sown during June-August. In Maharashtra, horse gram is sown as a kharif crop, mixed with bajra or sometimes Niger and also in the Rabi in rice fallows.

Seed Rate & Spacing :

Generally sown as broadcast with 40 kg/ha seed rate for dual purpose i.e. grain and fodder. For line sowing 18-20 kg/ha is enough for grain crop.

Row Spacing: 40-45 cm during kharif and 25-30 cm during rabi and about 5 cm plant to plant spacing.

Seed treatment :

Seeds must be treated with seed treating fungicide to reduce infection by fungal pathogens found in the soil. Horse gram seeds are treated with carbendazim (bavistin) 2g for every kg of seeds. Now-a-days bio fungicide like Trichoderma viridi is recommended for pulses at the rate of 4g per kg seed. After fungicide treatment seed should be inoculate with Rhizobium and PSB culture @ 5-7 g/kg of seed.

Fertilizer management :

25:50:60 kg NPK per ha as basal application at the time of sowing 2-5 cm below and in the side of the seed with the help of ferti.-seed drill is enough for good management of crop.

Water Management :

Irrigation should be apply at before flowering and pod formation stage.

Weed Management :

Due to luxuriant growth an early weeding/hoeing is enough for weed. Application of Pendimethalin @ 0.75-1 kg a.i./ha as pre emergence application. After that, one hand weeding at 20-25 days after sowing.

Harvesting & threshing :

As usual with other kharif pulses of Vigna group, clean seed should be sun dried for 3-4 days to bring their moisture content at 9-10% to be safely stored in appropriate bins.

Yield :

By adopting improved package of practices one can harvest 6-10 qtls of grain/ha depending upon the monsoon behaviour.

KIDNEY BEAN / MOTH BEAN (Matki, Dew bean)

B.N. :- **Phaseolus aconitifolius** ***Family :- Leguminoceae***

ORIGIN: India

ECONOMIC IMPORTANCE :-

1. It is an important pulse crop in desert region
2. It is a multi purpose crop and grown for grain as well as for fodder.
3. It is also grown as a green manure and cover crop
4. Improves soil fertility by fixing the atmospheric nitrogen
5. Namkin and papad are made from grain
6. Whole grain is eaten after soaking and frying
7. The green pods are used as vegetable.
8. The hay used for feeding cattle
9. It has spreading habit and protects soil against wind erosion.
10. It contain 23-26% protein, 59% carbohydrates.

GEOGRAPHICAL DISTRIBUTION :- It is cultivated in India, Malasia, Thailand, China, Africa and Southern USA. India is a major producer of mothbean. In India it grown in Rajasthan, Maharashtra, Haryana and Gujarat, Punjab.

BOTANICAL DESCRIPTION :- Plant is annual, much branched, spreading and hairy with a more or less erect main stem, up to 30 cm tall. Pods are thin, hairy, beaked, 2-6 cm long. Pods contain 4-9 rectangular small seeds, which are grey, black or mottled

.

SOIL AND CLIMATE:- It is generally cultivated on poor, light soils. Light sandy loam soils are considered best for it. with neutral pH. It prefers well distributed moderate rainfall. It is a warm weather crop

FIELD PREPARATION :- Needs minimum land preparation. Two ploughing or harrowing, followed by planking provide the desirable seed bed.

VARIETIES :- Maru Vardhan (RMO 225), Jwala, Jadra, CAZRI Moth 1, CAZRI Moth 2, CAZRI Moth 3

SEED AND SOWING :-

Sowing time	:	July
Seed rate	:	15-18 kg/ha
Spacing	:	30 cm in between rows
Method of sowing	:	Sowing behind the country plough in lines and Broadcasting
Seed treatment	:	Seed should be treated with Thirum @ 3 g/kg of seed. Being legume it is also treated with Rhizobium culture.
Depth of sowing	:	4-5 cm

MANURES AND FERTILISERS :- FYM : 8 to10 t/ha, 10 kg N and 20 kg/P 2O5 as basal dose

CROPING SYSTEM :- It may be grown alone or mixed with millets or cotton

Harvesting :- The matured plants are cut with sickle, dried and threshed.

YIELD :- 2-5 q/ha

Lecture 13 and 14

CULTIVATION OF OILSEEDS- GROUNDNUT,SUNFLOWER,SESAMUM, SOYBEAN, CASTER AND NIGER

GROUNDNUT (*Arachis hypogaea* L.)

It is also known as peanut, monkeynut or moongfali. Botanical name of groundnut is *Arachis hypogaea* which is derived from Greek word *Arachis* means legume and *hypogaea* means below ground, referring to formation of pods in the soil.

Groundnut plays an important role in the dietary requirement of resource poor woman and children. Groundnut kernels are also used for the preparation of food products like chikkis, groundnut milk, butter, curd including different bakery products. Groundnut cake obtained after extraction of oil, is used as valuable organic manure and feeding material for livestock. It consists of 7.3% N, 1.5% P2O5 and 1.3% K2O. The peanut haulms contain crude protein 8– 5%, lipids 1–3% and minerals 9–10%. These are used as cattle feed either in fresh or in dried stage or preparing hay or silage. The peanut shells or pod walls which constitute nearly about 25% of total pod weight are used as bedding material for poultry or as mulching material during summer season to reduce the evaporative losses. Shell material is also used as filler material for making mixed fertilizers and as insulation material for buildings or as fuel in boilers.

Average nutritive value of groundnut (per 100 g kernels)

Carbohydrate (g) 26.1	Ca (mg) 90	Protein (g) 25.3
Niacin (mg) 19.9	Fat (g) 40.1	Fe (mg) 2.5
Minerals (g) 2.4	Thiamine (mg) 0.90	Moisture (g) 3.0
Riboflavin (mg) 0.13	Fiber (g) 3.1	Carotene (µg) 37
P (mg) 350	Energy (Kcal) 567	

GEOGRAPHICAL ORIGIN:

Groundnut (*Arachis hypogaea* L.)is believed to be the native of Brazil to Peru, Argentina and Ghana, from where it was introduced into Jamaica, Cuba and other West Indies islands. The plant was introduced by Portuguese into Africa from where it was

introduced into North America. It was introduced into India during the first half of the sixteenth century from one of the Pacific islands of China, where it was introduced earlier from either Central America or South America

Climatic requirements :

Climatic conditions such as temperature and rainfall significantly influence the groundnut production. Warm and moist conditions are very favorable than cool and wet climate, which results in slow germination and seedling emergence, increasing the risk of seed rot and seedling diseases. Temperature is a major environmental factor that determines the rate of crop development. Temperatures above 35°C inhibit the growth of groundnut. Optimum mean daily temperature to grow is 30°C and growth ceases at 15°C. For rapid emergence, soil temperature above 21°C is needed. The optimum temperature for the most rapid germination and seedling development is about 30°C.

A minimum 100 - day optimum temperature growing season is necessary for successful groundnut crop production. Adequate and well distributed rainfall during the growing season, especially during flowering, pegging and pod formation stages, is essential for maximum yield and quality of groundnut. Groundnut is grown in areas receiving 600 to 1500 mm of rainfall. However, the crop can be grown successfully with a rainfall of 1250 mm.

The amount of rainfall required:

- Pre-sowing operations (preparatory cultivation) 100 mm
- Sowing 150 mm
- Flowering and pod development 400-500 mm

The groundnut crop cannot stand

- Frost for long
- Severe drought
- Water stagnation

Soil and field preparation

Groundnut can be grown on all types of soils such as sandy, sandy loam and heavy black soils. Most suitable soils for groundnut production are well-drained, light-textured, loose sandy-loam or sandy clay loam soils with good drainage, having reasonable high calcium, pH 5.5 to 7.0 and a moderate organic matter. The ill drained acidic (pH <5.5), alkaline (pH >7.8) and saline soils are not suitable for groundnut production. Soils having pH less than 5.5, need to be corrected by furrow application of lime @ 2 t/ha.

Field preparation for groundnut depends on the soil type and onset of monsoon for rainfed crops and the previous crops grown for irrigated crop. The soils are usually ploughed twice with the summer rains or after application of irrigation water for winter/summer sowing followed by two to three harrowings and pulverizing well to obtain a good tilth for optimum germination. Optimum depth of ploughing is 15 -20 cm. If too deep ploughing is done, it leads to development of pods in deeper layers which makes the harvesting difficult. Summer ploughing is advantageous to kill weed seeds and hibernating insects and diseases organisms by exposing them to the heat of summer. In terrace and flat lands of high rainfall areas, raised beds of 10-15 cm height are to be prepared to avoid water-logging problems.

Seed quality and treatment

Groundnut pods for seed purpose are shelled either by hand or by using hand decorticator about a week in advance of sowing. The viability of seed will be lost if shelled long before seeding. After and during the shelling split or damaged, shriveled immature and infected seeds should be removed and only well-filled seed should be used for sowing. The seed must be tested for their germination and should be treated with mancozeb or carbendazim @ 2-3g/kg kernel to control seed borne diseases. The seed can also be treated with *Trichoderma viride* @ 10 g/kg seed or it can be applied @ 10 kg/ha as soil application.

To prevent the seed damage from soil insects at initial stages, depending upon per cent infestation chloropyriphos @ 12.5-25 ml/kg seed can be used. Spreading and

semi-spreading types groundnut varieties have dormant seeds just after harvest which usually require a resting period of 60-70 days. Dormancy can be broken by exposing seeds to ethrel solution of 250 ppm. Bunch type varieties can be used immediately after harvesting for sowing. Thereafter, the kernels should also be treated with suitable *Rhizobium* and PSB cultures (3 packets of each).

Sowing time and sowing

In India, groundnut is mainly grown in during *kharif, rabi* and summer seasons.

- *Kharif* groundnut is sown from June to November mostly in the states of Gujarat,
- Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Rajasthan, Madhya Pradesh and Uttar Pradesh.
- *Rabi* groundnut is grown from November to April mostly in central, eastern and southern parts of the country. It is mostly grown in rice fallow situations under residual moisture conditions or with limited irrigation facility and in river-bed fields of Orissa, Assam and West Bengal.
- Groundnut is also grown as irrigated crop during January to May/June as summer crop mostly in Gujarat, Maharashtra and some parts of Andhra Pradesh, Karnataka, Tamil Nadu and Rajasthan.

The groundnut is generally sown in flat beds. Some of the improved methods to get higher yield over the conventional method are given below:

1. Criss-cross sowing :

Criss-cross method can improve yield by about 18% as compared to conventional sowing by maintaining uniform distribution of seed and optimum number of plants/unit area. The seed rate used in this method is same as in conventional method. In this method, total seed lot is divided into two equal halves; first half of the seed is sown in one direction adopting 30 cm spacing between rows and then the remaining half in the perpendicular direction with the same spacing.

2. Broad-bed and furrow method (BBF) :

BBF method is useful in areas having deep vertisol with high rainfall. This system consists of raised beds of 1.2 m width and 15 cm height with two furrows of 30

cm width on either side. Each raised bed would accommodate four rows with 30 cm spacing between rows. On an average, 15% higher yield of groundnut has been reported from the medium black soil over the flat bed.

3. Ridge and furrow method :

Groundnut is generally sown on flat beds using a seed drill but sowing on either sides of the ridge helps the plants to prevent from come in direct contact with the excess water. Furrows are more advantageous as they increase moisture recharge in the soil by colleting water and simultaneously help in draining away excess water.

4. Polythene Mulching in groundnut

Polythene mulching in groundnut has been attributed as one of the major improved cultivation practices for enhanced productivity in China. Because of its contribution in increasing groundnut production in China, polythene mulching is called as the "White Revolution". Polythene mulching was introduced in China in 1978 from Japan. Polythene mulching has been found to be effective not only in increasing the yield but also in increasing seed oil content, protein content, and the level of eight essential amino acids. In China, the polythene mulching was found to increase yield between 18 to 49% depending on soil fertility conditions.

When grown under polythene mulch system, groundnut is sown approximately 10 days earlier and it matures about 10 days earlier than under non-mulched condition. With the polythene mulching groundnut producing areas could be extended to the northern cooler region. Polythene mulching increases the soil temperature by retaining the heat from the sun. The increased accumulated temperature shortens the crop period. During the hot season it also protects the soil from direct sunlight. Its impermeability to hot air ensures optimum temperature for the middle growth phase of groundnut . It also helps in retaining soil moisture by preventing evaporation loss of soil moisture. Besides these, polythene mulching helps in improving soil texture, increase in soil microorganisms activity and microclimate. Polythene mulch also prevents late set pegs from penetrating the soil thus saving nutrients for earlier set pods. Polythene mulching has been found effective in controlling weeds.

There are also some disadvantages of using polythene mulching. All the polythene film used in mulching cannot be retrieved, thereby causing environmental pollution. Residual film in the soil may interfere with the root development of the next crop. Sowing with polythene mulch takes much more time, labor and the cost of cultivation. It has also been found that seeds produced under polythene mulch condition are less viable.

Although polythene film of 0.004 to 0.014 mm thickness can be used, a thickness of 0.007 mm is optimum and more economical. The thinner (less than 0.005 mm) film does not well maintain the soil temperature and moisture and does not stop late set pegs from penetrating the soil. A film of light transmittance of more than 70 percent is optimum.

Recommended varieties

Recently released varieties for different states:

Maharashtra	Konkan Gaurav, Konkan Trombe Tapora, Kokan Bhuratna, TAG-24, Phule Pragati, TG-26, TLG-45, Phule Unap, Ratneshswar, AK-265, AK-303
Andhra Pradesh	Kadiri-5, Kadiri-6, Kadiri-7, Kadiri-8, Kadiri-9, Kalahasti, Narayani, Prasuna, Abhaya, Greeshma, Vijetha, ICGV-00350
Gujarat	GG-6, GG-7,GG-16,GG-20, TG-26, GJGHPS-1, Prutha, JL-501, TG 37 A
Tamil Nadu	TMV-13, VRI-6, VRI-7, AK-265, Ajeya, ICGV-00348, ICGV-0350, Vijetha, GG-16
Karnataka	AK-265, Ajeya, ICGV-00348, ICGV-91114, VRI-6, VRI-7, GG-16, TGLPS-3, Vikas, Kadiri Haritandhra
Rajasthan	HNG-10, HNG-69, HNG-123, GG-7, GG-20, TBG-39, TG 37 A, TAG-24, Girnar-2, PM-1, PM-2, Prataprajmoongphali, Durga
Madhya Pradesh	JGN-3, JGN-23, AK-159, GG-8
Haryana	ICGS-1, MH-4, Prakash, HNG-10, Mukta
Punjab	SG-99, M-548, TG 37 A, GG-21, Girnar-2, HNG-10, HNG-69
Odisha	Smruti, ICGV-91114, TG-51, Vijetha, Girnar-3, TG –38 B, Vasundhara, TG-37A, Devi
West Bengal	TG-51, Vijetha, Girnar-3, TG–38 B, Vasundhara, TG-37 A

Uttar Pradesh	TG 37 A, GG-21, Girnar-2, HNG-10, HNG-69, Prakash, Utkarsh NEH region TG-51, Vijetha, Girnar-3, TG–38B, Vasundhara, GPBD-5
Jharkhand	Girnar-3

Spacing and seed rate

Inadequate crop stand is one of the major factors limiting the productivity of groundnut. Optimum plant population depends on plant type (bunch or spreading), soil, moisture and management practices. Higher plant population reduces the number of branches per plant while lower plant population increases the number of branches/plant. Number of pods/plant increases with increase in number of branches/plant. Seed rate depends upon the size of kernels, test weight (100-kernel weight), inter-and- intra-row spacing. The usual seed requirement of bunch type groundnut is 100-110 kg/ha while a seed rate of 95-100 kg/ha for semi-spreading and spreading varieties is adequate. The most common spacing recommended for bunch type varieties is 30 cm x 10 cm to achieve a plant population of 3.33 lakh/ha. For runner type, the most common spacing recommended is 45 cm x 10 cm or 30 cm x 15 cm to achieve a plant population of 2.22 lakh/ha in rabi/summer groundnut.

Manures and fertilizers :

For every one ton of pods and 2 tonnes of haulms produced by the groundnut crop, about 63 kg N, 11 kg P_2O_5, 46 kg K_2O, 27 kg CaO and 14 kg MgO is removed from 1 ha land. Groundnut, beings a leguminous crop, is capable of fixing atmospheric nitrogen by the root nodule bacteria. Application of nitrogenous fertilizers is not required but lower does of nitrogen would be sufficient to raise a good crop. In general, for obtaining high yield of groundnut application of well decomposed farmyard manure @ 10 t/ha at least 21 days before sowing followed by recommended doses of NPK (25:50:0 kg NPK/ha) through urea, single super phosphate and muriate of potash, respectively is recommended depending upon the initial soil fertility status and nature of crop. For a rainfed crop, entire doses of nitrogen, phosphorus and potassium should be applied by placement at seeding in the furrow below the seed at sowing.

For an irrigated crop, nitrogen may be applied in two equal splits at sowing and 30 days after sowing. Acid soils are deficient in Ca, S and Mg. To set good yield, the availability of Ca in the fruiting zone must exceed a defined critical level during the time of pod development.

Soil application of 250 kg/ha gypsum is sufficient to overcome the deficiency of Ca and S and increase the pod yield. Soil application of 10 kg Mg/ha as MgSO4 corrects Mg deficiency.

3. Recommended doses of NPK for different states

State	Situation	N-	P -	K (kg/ha)
Andhra Pradesh	Rainfed	20	40	20
	Irrigated	30	60	45
Gujarat	Rainfed	12.5-25	25-60	0
	Irrigated	25-37.5	50-70	0
Karnataka	Rainfed	15	30	25
	Irrigated	25	75	25
Madhya Pradesh	Rainfed	20	40	20
Punjab	Irrigated	15	40	25
Rajasthan	Rainfed	20	60	0
	Irrigated	20	60	0
Maharashtra	Irrigated	20	40	0
Uttar Pradesh	Rainfed	15	30	45
West Bengal	Irrigated	15	30	45
Tamil Nadu	Rainfed	11	22	33
	Irrigated	22	44	66

Correction of micronutrient deficiencies

A schedule for correcting micronutrient deficiency is given in the table 4 below:

Table 4. Schedule for controlling micronutrient deficiencies

Micronutrient	Form and rate of allocation to soil	Spray schedule
Boron	Borax 5-20 kg/ha	0.2% borax
Copper	Copper sulphate 5-10 kg/ha	0.1% copper sulphate + 0.05% lime
Manganese	Manganese sulphate 10-50 kg/ha	0.6% manganese sulphate +0.3% lime
Zinc	Zinc sulphate 10-50 kg/ha	0.5% zinc sulphate + 0.2 % lime
Molybdenum	Sodium or ammonium molybdate 0.5-1.0 kg/ha	0.01% ammonium molybdate
Iron	Ferrous sulphate 10 kg/ha	0.5% ferrous sulphate+ 0.02% citric acid

Weed management :

Weeds cause much damage to the groundnut crop during the first 35 days of its growth. The most critical period of weed competition is from 3-6 weeks after sowing. The average yield loss due to weeds is about 45%. When once pegging begins (40 DAS), there should not be any disturbance to pegs through manual or mechanical weeding.

Management

- A good crop cover by adopting right spacing between rows and within the row will smother the weed growth.
- Mulching the soil surface in between rows with crop residue material like straw etc. may prevent the germination of weed seeds and at the same time smothers the established young weeds.
- Adopting proper crop rotation practices will help in overcoming the dominance of certain weeds and lessening the weed competition in groundnut crop.
- Intercropping practice in groundnut crop not only provide the monetary and land utilization advantages but also help in smothering the weeds with good crop cover over the land surface.
- Hand pulling of weeds though primitive is an efficient way of controlling weeds especially in groundnut.

- Hand weeding is done twice, first around 20 days after sowing and second at about 35 days after sowing.
- Intercultivation usually starts around 10 days after emergence and continues up to 35 DAS at 7– 10 days interval till pegging begins.
- Cost effective weed management under rainfed conditions is repeated inter-cultivation (harrowing) up to 35 days after sowing followed by hand weeding.

Herbicides can also be recommended for use in groundnut:

Herbicide	Rate of application (kg a.i./ha)	Time of application
Pendimethalin	1.0-2.0	Pre-emergence
Oxyfluorfen	0.25-0.50	-do--
Quizalofop ethyl	0.050	Post-emergence
Imazethapyr	0.050	-do-

- Integrated weed management involving the above two appears most effective and economical, provided the crop is not subjected to prolonged drought or soil moisture stress during the crop period.

Water management :

Groundnut crop is mostly cultivated during *kharif* under rainfed conditions. Irrigated groundnut accounts for over 20% of the total area under the crop in the country and it yields around 4.2 t/ha.

- There is no necessity for irrigation or rainfall up to 25 days after emergence of groundnut.
- Flowering (20-40 DAS), pod formation and development (40-70 DAS) and pod filling and maturation (70-100 DAS) are most sensitive to soil moisture stress.
- Scheduling irrigation at 25% DASM during moisture sensitive stages and at 50% DASM during other stages results
- An IW/CPE ratio of 1.0 at moisture sensitive stages and 0.6 during other stages leads to high water use efficiency.

- If irrigation water is not limiting, then a total of 8 irrigations are adequate for optimal yield i.e. pre–sowing irrigation followed by an irrigation at 25 DAS, 4 irrigations at 10 days interval and final two irrigations at 15 days interval.
- At times of deficit supplies, an irrigation at 25 DAS followed by 2 at 15 days interval between 45 and 75 DAS appears to be minimum requirement and it can minimize yield losses due to soil moisture stress. The first irrigation is given at 25 DAS to create moisture stress in the soil which is desirable:
    - to get the good root system.
    - to reduce excessive vegetative
    - encourage the better nodulation
    - induce heavy flowering in a single flush (synchronous flowering)
- Keeping the total quantity of irrigation water applied constant, high frequency irrigation increase the pod field of groundnut on sandy and sand
- Depending on soil type, evapotranspiration and crop duration, water requirement of groundnut ranges between 450 and 650 mm.
- The crop is usually irrigated by check basin method. Border strip is more suitable than other methods. Sprinkler irrigation.

Cropping systems

Crop sequences: In general, groundnut should be rotated with cereals like pearl millet, sorghum, maize, wheat, rice or other minor millets. This will check the build up of pests, white grubs, nematodes, soil borne diseases, leaf spots and also maintain soil fertility. Some of the promising crop sequences recommended for different states are given in table 1

Table 1. Promising crop sequences recommended for different states involving groundnut

State	Rainfed (Monocropping)- two years	Residual moisture (Double cropping in one year)	Irrigated (Double or triple cropping in one year
Andhra Pradesh	Groundnut-sorghum	Groundnut-bengal gram	Groundnut-maize
	Groundnut-millet	Groundnut-safflower	Groundnut-wheat
	Groundnut-tobacco	Groundnut-sesame	Groundnut-onion
Gujarat	Groundnut-sesame	Groundnut-fodder sorghum	Groundnut-mustard-green gram
		Groundnut-mustard	Groundnut-wheat-green gram
Karnataka	Groundnut-sorghum	Groundnut-safflower	Groundnut-wheat
			Groundnut-maize
			Groundnut-sunflower
Maharashtra	Groundnut-sorghum	Groundnut-safflower	Rice-potato-groundnut
		Groundnut-fodder maize	Groundnut-*rabi*sorghum
			Groundnut-safflower
Tamil Nadu	Groundnut-sesame	Groundnut-sesame	Rice-rice- groundnut
	Groundnut-cotton		Groundnut-rice-green gram
			Groundnut-maize
Rajasthan	Groundnut-pearl millet	Groundnut-barley	Groundnut-wheat-green gram
		Groundnut-mustard	Groundnut-wheat
Madhya Pradesh	Groundnut-sorghum	Groundnut-safflower	Groundnut-wheat/ mustard
Orissa	Groundnut-sorghum/pearl millet	Groundnut-bengal gram	Groundnut-rice/ragi
		Groundnut-sesame	Groundnut-coriander/cumin

Table 2.Some intercropping systems in different states.

State	Intercropping system	Ratio to base crop (groundnut)
Andhra Pradesh	Groundnut + pearl millet	3 : 1
	Groundnut + cowpea	6 : 1
	Groundnut + red gram	6 :1 or 8 : 1 or 10 : 2
	Groundnut + castor	5 : 1 or 7 : 1
Gujarat	Groundnut + sesame	1 : 1
	Groundnut + sunflower	1 : 1
	Groundnut + red gram	3 :1
	Groundnut + castor	1 : 1
Karnataka	Groundnut + red gram	4 : 1
	Groundnut + cotton	3 : 1 or 5 : 1
	Groundnut + sorghum/ragi	6 : 1
Maharashtra	Groundnut + sorghum	4 : 1 or 6 : 2
	Groundnut + red gram	6 : 1 or 10 : 2
Madhya Pradesh	Groundnut + red gram	8 : 2 or 10 : 2
	Groundnut + soybean	4 : 1 or 6 : 1
	Groundnut + sesame	4 : 1
Tamil Nadu	Groundnut + black gram/green gram	6 : 1
	Groundnut + cotton	5: 1
	Groundnut + castor	7 : 1
	Groundnut + sesame	6 : 1
Rajasthan	Groundnut + pearl millet	4 : 1
	Groundnut + sesame	4 : 1

Harvesting, drying and storage :

As groundnut is an indeterminate crop, hence synchronous maturity of its pods cannot be obtained. Therefore, harvesting should be done when 75-80% o pods are fully mature. The important indications of maturity are yellowing of foliage, necrotic spotting of leaves, dropping of old leaves, pods become very hard and tough, they give cracking sound when split open with fingers, the inside of the shell turning dark, with netted venation, seed coat develops pink or red coulour (normal colour of the varieties) and raising of soil to the base of the stem is observed. Generally harvesting is done by pulling or lifting the plants form the soil with pods intact. It soil moisture is adequate, then hand pulling. If soil is dry, tractor or bullock drawn 'Swastik' implement is use. Harvesting before maturity reduces yield and oil percentage and seed are highly susceptible to aflatoxin. If delayed, results in increased incidence of stem rot, weakening

of gynophore/peduncle and some of the pods may remain in soil itself at the time of harvesting.

The most common method is stripping pods with hand. At the time of harvest, pods usually have moisture content around 40–50% and hence need to be dried to 10% moisture content for safe storage. Drying should be done rapidly to prevent fungal infection. Sun drying is the usual method of drying. Summer groundnut should be dried in shade to prevent loss of viability, if it is for seed purpose.

Storage at farmer level is invariably in the form of pods. Farmers usually dispose of groundnut pods within a month from drying yard itself. A few store it for 6 months (till kharif seeding) in anticipation of high price. Pods for seed purpose are stored for 7–8 months. Pods for seed purpose are stored in earthern pots, mud bins or bamboo baskets or Gunny bags having polythene lining.

If the seed moisture content is above the critical level of 9-10%, then aflatoxin production due to *Aspergillusflavus* just before the post–harvest drying and mould growth at later stage takes place.

Yield :

a. Rainfed- 1000-1250 Kg/ha

b. Irrigated (Rabi/Summer) – 2000 -3500 Kg/ha

Pest and disease management:

- White grub, aphids, thrips, caterpillars, tikka leaf spot, collar rot and bud necrosis are the major insect pest and diseases in groundnut.
- Growing of resistant varieties like, BR 2, ICGV 87160, ICGV 86031, ICGV 86699 against leaf mine;r ICGV 86590 against *Spodoptera*; BG 2, Girnar 1 against aphids;
- Girnar 1, Co-1, Dh-3-30, ICGS 11, MH 1, POL 2, S 206 against leafhoppers and
- Girnar 1 against thrips.
- Spray neem oil @5ml/lt water alongwith suitable surfactant like soap powder @ 1g/lt or NSKE 5% as it acts as oviposition deterrent.

- Release of *Trichogramma chilonis* @ 50000/ha, two times at 7-10 days interval followed by release of *Bracon hebetor* @ 5000/ha two times at 7-10 days against Leaf Miner and Defoliators.
- Install pheromone traps @ 10 traps/ha for *Spodoptera* and *Helicoverpa* and 25 traps/ha for leaf miner.
- Erect bird perches @ 10-12/ha.
- Soil application of neem cake or castor cake @ 500kg/ha or neem seed kernel powder @ 3-5%.
- Seed treatment with commercial formulation of *Trichoderma harzianum* or *T. viride* or *Pseudomonas fluorescens* @ 10g/kg seed or Thiram or Carbendazim or Captan or Mancozeb @ 3-4g/kg seed or Tebuconazole (Raxil 2 % DS) @ 1.25g/kg.
- Foliar application of Carbendazim (0.025%) + Mancozeb (0.2%) at 2-3 weeks interval, 2 or 3 alternate spray of Mancozeb (0.2 %), Carbendazim (0.02 %) and Mancozeb (0.2 %) or three sprays of Chlorothalonil (0.2 %) or Hexaconazole (0.005 %) or Difenoconazole 25% EC @ 2ml/L at 30, 50 and 70 DAS effectively reduces the early leaf spot and late leaf spot severity.
- Spray Mancozeb (0.2 %) or Copper Oxychloride (0.2 %) and destroy the collateral weeds and self-sown plants.

SUNFLOWER (*Helianthus annus* L.)

- (2n=14) **Family :** Compositae

ECONOMIC IMPORTANCE :

- Sunflower content 21 to 27 per cent hull, 48 to 53 per cent oil, 14 to 19 per cent protein and 16 to 17 per cent crude fibre.
- Oil is rated as one of the best edible oil and good substitute for cooking oil. It is premium oil, pale yellow in colour and used as salad oil and in cooking and margarine.
- Sunflower yields poly unsaturated oil with high proportion of linoleic acid (40 to 70%) and oleic acid (22 to 50%). It is good for heart patients as it prevents deposition of cholesterol in coronary arteries.
- It is also used in industrial field for making cosmetic and pharmaceuticals.
- Sunflower protein has higher levels of essential amino acid *viz*., lysine and methionine. The essential amino acid index of sunflower protein is 68 as against 79 for soybean and 100 for egg. The protein is highly digestative (90%) with a biological value of 60 per cent.
- The cake is obtained after oil extraction. Partially dehulled cake has about 37 per cent protein, 10 per cent oil and 16 per cent crude fibre. Sunflower cake is extensively used as feed for ruminant animals, swine's and poultry.
- The roasted kernels of sunflower are eaten. Fried sunflower seeds mixed with pepper and a delicacy in East European countries. Seeds are also used as diuretic and in treating certain disorder of respiratory tracts.
- Flower is nutritive and used in bakeries.
- The pericarp or hull is used as bed material for animals. Hulls can be used to generate stem/electricity or production of furfurol/ethyl alcohol.

ORIGIN & DISTRIBUTION :

- All species of Helianthus are native to Americas and Mexico.

- In India, sunflower is grown in 2.70 million hectares with production of 1.40 million tonnes and productivity of 521 kg/ha. In India the crop cultivated states like Karnataka, Maharashtra, Andhra Pradesh, Tamil Nadu, Punjab, Haryana and Uttar Pradesh.

1. FIELD PREPARATION

Plough once with tractor or twice with iron-plough or three to four times with country-plough till all the clods are broken and a fine tilth is obtained.

2. APPLICATION OF FERTILIZERS

- Spread 12.5 t/ha of FYM or compost or composted coir pith evenly on the field before the last ploughing and incorporate in the soil by working a country plough.
- Apply NPK fertilizers basally as per soil test recommendations. If soil test recommendations are not available, follow the blanket NPK/ha for both irrigated and rainfed crops.

Biofertilizer : Soil application - Mix 10 packets (2000 g/ha) of Azospirillum and 10 packets(2000 g/ha) of Phosphobacteria or 20 packets of Azophos(4000 g/ha) with 25 kg FYM and 25 kg soil and apply before sowing.

3. APPLICATION OF MICRONUTRIENTS

1. Mix 12.5 kg/ha of micronutrient mixture formulated by the Department of Agriculture, Tamil Nadu with enough sand to make total quantity of 50 kg/ha.
2. (or) For ***rainfed sunflower*** apply TNAU MN mixture @ 7.5 kg ha -1 as enriched FYM for variety and 10 kg ha-1 as enriched FYM for hybrid and for ***Irrigated sunflower*** apply TNAU MN mixture @ 12.5 kg ha-1 as enriched FYM for variety and 15 kg ha-1 as enriched FYM for hybrid (Prepare enriched FYM at 1:10 ratio

of MN mixture & FYM ; mix at friable moisture &incubate for one month in shade).

3. Apply the mixture over the furrows and top two thirds of the ridges before sowing.
4. Do not incorporate the mixture in the soil.
    1. To overcome manganese deficiency, foliar spray of 0.5% MnSO4 on 30, 40 and 50th day / after sowing.
    2. For zinc deficiency, apply 25 kg/ha ZnSO4 as basal, or 0.5% ZnSO4 spray on 30, 40 and 50th day after sowing.

4. FORMING RIDGES AND FURROWS

1. Form ridges and furrows 6 m long.
2. Use bund-former or ridge plough to economise and
3. Form irrigation channels across and ridges according to the topography of the field.

5. Seed rate

Varieties: Rainfed- 7 kg/ha Irrigated- 6 kg/ha

Hybrid: Rainfed- 5 kg/ha Irrigated- 4 kg/ha

6. SEED TREATMENT

- Soaking seeds in 2% ZnSO4 for 12 hrs and shade drying is recommended for rainfed sowing.
- Treat the seed with *Trichoderma* @4g/kg. This can be done just before sowing. It is compatible with biofertilizers. Such seeds should not be treated with fungicides.
- Treat the seeds with Carbendazim or Thiram at 2 g/kg of seed.

- Treat the seeds 24 hours prior to sowing.
- Azospirillum : Use 3 packets of Azospirillum (600 g/ha) and 3 packets (600 g/ha) of Phosphobacteria or 6 packets of Azophos (1200 g/ha) for treating seeds using rice kanji as binder. Dry the treated seeds in shade for 15 minutes and sow immediately.
- Moist hydration for 24 hours in moist gunny bags followed by drying and seed dressing with Thiram @ 2g/kg to enhance field emergence.
- Seeds dried to 8 - 9% moisture content, treated with Thiram @ 2g/kg and packed in polylined (300 guage) cloth bag can store upto 9 months with 70% germination.

7. SOWING

Spacing:

Hybrids: 60 cm x 30cm

Varieties: 45 cm x 30cm

- Place the seeds at a depth of 3 cm along the furrows in which the fertilizer mixture is placed and cover with soil. Put two seeds per hole.
- Irrigate the crop according to the different growth stages. Regulate irrigation according to the following growth phase.
  Pre-sowing irrigation; Life irrigation; 20th day after sowing; Early bud development; Flowering-2 irrigations and Seed development-2 irrigations; Flowering period is critical.

8. THINNING

Thin out seedlings leaving only one healthy and vigorous seedling in each hole on the 10th day of sowing.

9. WEED MANAGEMENT

- Apply Fluchloralin at 2.0 l/ha before sowing and incorporate or apply as pre-emergence spray on 5 day after sowing followed by irrigation or apply Pendimethalin as pre-emergence spray 3 days after sowing. The spray of these herbicides has to be accomplished with Back Pack/Knapsack/Rocker sprayer fitted with flat fan nozzle using 900 l water/ha as spray fluid.
- All the herbicide application is to be followed by one late hand weeding 30 - 35 days after sowing.
- Hoe and hand weed on the 15th and 30th day of sowing and remove the weeds. Allow the weeds to dry for 2 - 3 days in the case of irrigated and then give irrigation.

10. WATER MANAGEMENT

Irrigate immediately after sowing followed by an irrigation on 4 - 5th day and later at intervals of 7 to 8 days according to soil and climatic conditions, seeding, flowering and seed development stage (ie) two weeks before and after flowering.

11. SPRAYING NAA

1. Spray the hormone Napthalene Acetic Acid (NAA) at 20 ppm concentration (280 g NAA in 625 litres of water per ha) on the 30th and 60th day of sowing.
2. Use a high volume sprayer and give a thorough coverage of the entire plant.
3. Do not use brackish water.

12. Sulphur fertilization

Apply sulphur @ 20 kg/ha through ammonium sulphate or single super phosphate Or apply gypsum@ 200kg/ha as basal

13. Boron application

Spray borax @ 0.2 % (2g/l of water) to capitulum at ray floret opening stage to improve seed set and seed filling.

14. IMPROVING SEED SET BY MECHANICAL MEANS

- During the mid flowering phase, improve pollination by :
  i. Mild rubbing of the capitulum with the hand covered with soft cloth or
  ii. Rubbing two flowers face to face gently.
- The mid-flowering phase are: 58 to 60 days of planting for long duration varieties, 45 to 48 days of planting for short duration varieties.
- Do this operation in the morning hours between 9.0 and 11.00 am when pollen shedding is high.
- Keeping bee hives at the rate of 5/ha improves seed setting.

15. JUDGE WHEN TO HARVEST

Observe the bracts on the backside of the capitula. When they turn lemon yellow, the heads harden and the crop is ready for harvest.
Bird damage: Use of reflective ribbons scares the birds effectively and thus prevents loss of grain.

16. HARVESTING

i. Cut the capitula (flower heads) only
ii. Thresh and clean
a. Immediately after harvest, dry the heads in the sun for 3 days.
b. Spread the heads in thin layer and give turning once in 3 hours.

NOTE: Do not heap or store the heads before drying properly as mould fungi will develop and spoil the grain quality.

c. Thresh using a mechanical thresher, or beat with a stick and separate the grains.

d. Winnow and clean the seeds

e. Dry the seeds again in the sun for another two days

f. Store in gunny bags

15. Crop Protection

- **Pests of Sun flower**

Capitulum borer (Head borer): *Helicoverpa armigera*

Symptoms of damage:

- The larva feeds on the developing seeds and bore the head
- Fungal developed and head starts rotting

The larva consumes leaf in early stage of growth and move towards the capitulum and tunnel the head

Identification of the pest:

- **Egg:** Spherical in shape and creamy white in colour, laid singly
- **Larva:** Shows colour variation from greenish to brown. It has dark brown grey lines on the body with lateral white lines and also has dark and pale bands
- **Pupa:** Brown in colour, occurs in soil, leaf, pod and crop debris
- **Adult:** Light pale brownish yellow stout moth. Forewings are olive green to pale brown with a dark brown circular spot in the centre. Hind wings are pale smoky white with a broad blackish outer margin

Management:

- Grow inter crops like, green gram, black gram, groundnut, soybean
- Sow 3-4 lines of maize (or) jowar around the sunflower crop to monitor the moth
- Sow trap crops like marigold at 50 plants/acre
- Use of pheromone traps (4 traps/acre) for pest intensity identification as well as to trap the male moths

- Setting of light traps (1 light trap/5 acre) to know the range of pest incidence as well as to kill moth population
- Release predators like coccinellids, *Chrysoperla carnea* @1larva/ head
- Release parasitoides like *Trichogramma* spp.@ 20,000/acre, (*Bracon* spp., *Campoletis* spp)
- Spray HaNPV 250 LE + Bt @0.5kg/ha for effective control
- Spray HaNPV 250 LE/ha +1 kg Jaggery + 200ml Sandovit (or) Teepal; mixing and spray in the evening hours only
- Spraying of 5% Neem oil or 5% Neem Seed Kernal extract before egg laying

Bihar hairy caterpillar: *Spilosoma obliqua*

Symptoms of damage:

- Young larvae feed gregariously mostly on the under surface of the leaves
- Caterpillars feed on leaves and in severe infestation the whole crop is defoliated
- Drying up of infected leaves is the main symptom

Identification of the pest:

- **Egg**: Laid in cluster on the underside of leaves
- **Larva:** Covered with long yellowish to black hairs
- **Adult:** Medium sized brown moth with a red abdomen. Wings pinkish with numerous black spots

Management:

- Deep summer ploughing
- Use of well rotten manures
- Intercropping with pigeon pea at a row ratio of 2:1 is effective in reducing the insect attack
- Collection and destruction of larvae
- Spray phosalone 35 EC at 1000ml/ha

Tobacco caterpillar : *Spodoptera litura*

Symptoms of damage:

- The larvae feed on the tender leaves, shoots, bracts and petals
- Later, the larvae spread in the field causing defoliation
- The larvae also feeds on the developing seeds in capitulum

Identification of the pest:

- **Egg:** Egg masses appear golden brown
- **Larva:** Pale greenish with dark markings, gregarious in the early stages
- **Adult:** Forewings are brown colour with wavy white marking. Hind wings are white in colour with a brown patch along the margin

Management:

- Hand pick the *Helicoverpa* larvae and destroy
- Spray any of the following insecticides
  - Dichlorvos 76 EC 500 ml/ha
  - Phosalone 35 EC 1000 ml/ha
  - Phosalone 4 D 25 kg/ha
- Insecticidal application at the time of bee visit is toxic to honey bees. So, apply the insecticides after 4 pm when the bee activity is minimum.

Do not spray insecticides on the same day when NAA is sprayed

Leaf hopper (jassids): *Amrasca biguttula biguttula*

Symptoms of damage:

- The adult and nymphs suck the plant sap
- The infected leaves show pale yellow colouration
- In case of heavy infestation the leaves turn inwards
- The leaf edges may turn light pinkish brown

Identification of the pest:

- **Nymphs:** Pale greenish almost translucent and walk diagonally
- **Adults:** Greenish yellow, wedge shaped with a pair of black spots

on vertex and a black spot on each of the forewings

Management:

- Treat seed with imidacloprid 70 WS at 7 g/kg protected the sunflower plants from leaf hopper up to 7 weeks
- Spray Imidacloprid 70% WS 490 ml/ha or Imidacloprid 17.8% SL 100 ml/ha
- **Diseases of Sun flower**

Symptom

- The disease is a destructive one, widely distributed wherever the crop is grown.
- Severe reduction in seed and oil yield reported.
- The most affected components are number of seeds per head and the seed yield per plant.
- The disease also affects the quality of sunflower seeds by affecting germination and initial vigour of the seedlings.
- The disease is characterised by the development of dark brown to black, circular to oval spots varying from 0.2 to 5 in diameter.
- The spots are surrounded by necrotic chlorotic zone with grey white necrotic centre marked with concentric rings.
- Spots first appear on lower leaves, later spread to middle and upper leaves.
- At later stages, spots may be formed on petioles, stem and ray florets.

Management

- Occurrence and severity of the disease depends on the season and planting dates.
- Mid-September planting of sunflower remains free from the disease.
- Foliar spray with 0.3 per cent Mancozeb four times at an interval of 10 days controls the disease.

Rust: *Puccinia helianthi*

Symptom

- It is more prominent in the *rabi* season and in the *kharif* season the appearance is usually late.
- This disease in conjunction with *Alternaria* blight of leaves may cause yield loss up to 40 per cent.
- Uredo pustules appear first on the lower leaves. Uredo pustules appear on the younger leaves and later spread over the entire vegetative surface covering stems, petioles, floral bracts and petals.
- Uredia often coalesce to cover large areas on the affected plant parts.

Management

Spray Mancozeb 1000 g/ha

Charcoal Rot : *Macrophomina phaseolina*

Symptom

- Charcoal rot is of economic importance particularly in the arid areas.
- The most common symptom of the disease, under field conditions is the sudden wilting of plants, usually after pollination.
- Early symptoms are not visible on infected plants, but they become weak, mature early and when dry, show a presence of black ashy discolouration of the stem.
- Black microsclerotia are formed in huge number on the affected portion.
- Sometimes the disease causes seedling blight, damping off, root rot or basal stem rot.

Management

- Soil application of *P. fluorescens* or *T. viride* – 2.5 Kg / ha + 50 Kg of well decomposed FYM or sand at 30 days after sowing.
- Spot drenching with Carbendazim @ 1 g/ litre

***Rhizopus* Head Rot : *Rhizopus* sp**

Symptom

- Initial symptom appears as brown irregular water soaked spots on the back of ripening head usually adjacent to flower stalk.
- Spots gradually enlarge and become soft and pulpy and get covered with superficial white mycelium which later becomes black.
- Some seeds of the rotted heads shed and those which remain in the head taste bitter.
- Injury before flowering or during the early stage of head development is unlikely to favour infection even though the inoculum may be present.
- Maximum rotting is noticed at the soft dough stage.
- Seed development is severely impaired depending on the stage of maturation at the time of *Rhizopus* infection and rot development.

Management

- To have effective control of the disease, simultaneous application of compatible insecticide and fungicide beginning with the completion of flowering stage is suggested.
- Injury to the head should be avoided as far as practicable.
- Spray Mancozeb @ 2g/lit in case of intermittent rainfall at the head stage.

Sclerotium* wilt or rot : *Sclerotium rolfsii

Symptom

- Initial symptoms of the disease are noticed 40 days after sowing. Sickly appearance of plants can be noticed from a distance and a row effect can be observed in heavily infested soil. Later the entire plant withers and dies.
- White cottony mycelium and mustard-seed-type sclerotial bodies are conspicuous on the affected stem near soil level.
- **Management**
- Collection and destruction of plant debris.

- Seed treatment with Captan or Carboxin 3g/kg and drenching the base of the plant with Carbendazim 1g/lit.

Downy Mildew: *Plasmopara halstedii*

Symptom

- The disease spreads rapidly through seeds.
- Symptoms of the disease are evident as seedling damping off, systemic infection, local foliar lesions and basal root or stem galls.
- First symptoms are yellowing of the first pair of true leaves.
- Sunflower plants carrying systemic infection are severely stunted and leaves are entirely chlorotic.
- Affected plants bear abnormally thick, downward curled leaves showing prominent yellow and green mottling.
- The stem becomes brittle. Small angular greenish yellow lesions may appear on leaves as a result of secondary infection.
- Fungal growth is visible at lower surface.

Management

- Seed treatment with Metalaxyl at the rate of 3 g per kg of seed has been found to give effective control.
- Choice of planting sites and disposal of infected crop residues also give a fairly good control.

Sesame (*Sesamum indicum* L.)

Sesame is the oldest indigenous oilseed crop, with longest history of cultivation in India. Sesame or gingelly is commonly known as til (Hindi, Punjabi, Assamese, Bengali, Marathi), tal (Gujarati), nuvvulu, manchi nuvvulu (Telugu), ellu (Tamil, Malayalam, Kannada), tila/pitratarpana (Sanskrit) and rasi (Odia) in different parts of India.

India ranks first in world with 19.47 Lakh ha area and 8.66 Lakh tonnes production. The average yield of sesame (413 kg/ha) in India is low as compared with other countries in the world (535 kg / ha). The main reasons for low productivity of sesame are its rainfed cultivation in marginal and submarginal lands under poor management and input starved conditions. However, improved varieties and agro production technologies capable of increasing the productivity levels of sesame are now developed for different agro ecological situations in the country. A well managed crop of sesame can yield 1200 - 1500 kg/ha under irrigated and 800 - 1000 kg/ha under rainfed conditions.

The crop is grown in almost all parts of the country. More than 85% production of sesame comes from West Bengal, Madhya Pradesh, Rajasthan, Uttar Pradesh, Gujarat, Andhra Pradesh and Telangana.

Season and climate :

Semi arid climate of Western India, Central, Eastern and Southern part of India including lower Himalayas.

Sesame is grown in almost all the states in large or small areas. It can be cultivated up to the latitude of 1600 m (India 1200 m). Sesame plant needs fairly high temperature during its life cycle. Normally the optimum temperature required during its life cycle is between 25 - 35 degree C. If the temperature is more than 40 degree C with hot winds the oil content reduces. If the temperature goes beyond 45 degree C or less than 15 degree C there is a severe reduction in yield.

Season : Kharif in arid and semi-arid tropics and rabi/summer in cooler areas

Cropping systems :

State	Crop Sequence
Andhra Pradesh	Rice-Groundnut-Sesame, Sesame - Horsegram, Finger millet/Sorghum/Horsegram - Sesame, Sesame - Upland Rice
Bihar	Early Rice - Potato-Summer Sesame/Green gram, Kharif Sesame-Maize/Pigeonpea/Chickpea, Wheat-Summer Sesame/Green gram
Gujarat	Sesame-Wheat/Mustard
Karnataka	Sesame-Horsegram/Chickpea
Madhya Pradesh	Cotton-Sesame-Wheat, Rice -Summer Sesame, Sesame-Wheat
Maharashtra	Sesame (Early)-Rabi Sorghum/Safflower, Cotton-Sesame-Wheat
Odisha	Rice/Potato-Sesame, kharif Sesame-Maize/Pigeonpea/Chickpea
Rajasthan	Sesame-Wheat/Green gram/Barley
Tamil Nadu	Rice/Groundnut-Sesame, Sesame-Black gram, Sesame-Rabi Sorghum, Sesame-Green gram, Cowpea-Sesame
Uttar Pradesh	Sesame (Early)-Chickpea/Rapeseed & Mustard/Lentil/Pea
West Bengal	Potato-Sesame (Late Jan./Early Feb), Rice – Sesame

Varieties :

For upland cultivation use varieties with long duration of 100-110 days and for low land, use varieties with duration of 80-99 days.

State	Variety	Seed Colour
Gujarat	Guj. Til-1, 2, 3 Guj. Til-10	White seed Black seed
Madhya Pradesh	TKG-21, 22, 55, 306, 308 and JTS – 8 PKDS-11, 12 PKDS-8	White seed Dark brown seed Bold black seeded
Rajasthan	RT-46, 103, 125, 127, 346, 351 RT-54	White seed Light brown seed
Maharashtra	Phule Til-1, Tapi, Padma, AKT-64 , AKT-101, JLT-408, PKVNT-11	White seed
Uttar Pradesh	T-78, Sekhar	White seed
Tamil Nadu	TSS-6 Co-1, Paiyur-1, VRI-1, VRI-2, TMV-7	White seed Black and Brown seed
West Bengal	Rama, Savitri	Brown seed
Odisha	Nirmala, Shubhra Prachi, Amrit Smarak	White seed Brown / Black seed Golden yellow and bold seed

Andhra Pradesh	Varaha, Gautama, Chandana Swetha Til, Hima	Brown seed White seed
Karnataka	DS-1 DSS-9	Dark brown seed White bold seed

Soil :

Sesame can be grown on a wide range of soils but well drained light to medium textured soils are preferred. The optimum pH range is 5.5 to 8.0, acidic or alkaline soils are not suitable.

Seed rate

A seed rate of 5 kg/ha is adequate to achieve the required plant population.

Sowing

For prevention of seed borne diseases, use seed treated with Bavistin 2.0 g/kg seed. Wherever bacterial leaf spot disease is a problem, soak the seed for 30 minutes in 0.025% solution of Agrimycin-100 prior to seeding.

Preparation of land :

Prepare the soil into a fine tilth by ploughing 2-4 times and breaking the clods. Broadcast seeds evenly. To facilitate easy seeding and even distribution seed is mixed with either sand or dry soil or well sieved farm yard manure in 1:20 ratio. Work with harrow, followed by pressing with wooden plank so as to cover the seed in the soil.

Sowing Time and Spacing

State	Season	Sowing time	Spacing (cm)
Andhra Pradesh/ Coastal Telangana	Kharif Summer Kharif	Second fortnight of May Second fortnight of January Second fortnight of July	30 x 15 30 x 15 30 x 10-15
Assam	Kharif	July-August	30 x 10-15
Bihar/ Jharkhand	Kharif	July	30 x 15
Gujarat	Kharif Semi-rabi Summer	Last week of June to second fortnight of July Mid September January-February	45 x 10 45 x 10 45 x 15
Karnataka North	Kharif	June-July	30 x 15

South	Early Kharif	April-May	30 x 15
Kerala	Kharif Summer	August December	30 x 10-15 30 x 15
Madhya Pradesh /Chhattisgarh	Kharif Semi-rabi Summer	First week of July Late August-Early September Second to last week of February	30 x 10-15 30 x 15 30 x 15
State	**Season**	**Sowing time**	**Spacing (cm)**
Maharashtra	Kharif Semi-rabi Summer	Second fortnight of June to July Early September February	30 x 15 30 x 15 45 x 15
Odisha	Kharif Rabi Summer	June-July September-October February	30 x 15 30 x 15 30 x 15
Punjab/ Haryana	Kharif	Second fortnight of July	30 x 10-15
Rajasthan	Kharif	Late June-Early July	30 x 15
Tamil Nadu	Kharif Rabi Summer	Second fortnight of May to Second fortnight of June November-December Second fortnight of January to March	22.5 x 22.5 22.5 x 22.5 30 x 10
Uttar Pradesh & Uttarakhand	Kharif	Second fortnight of July	30-45 x 15
West Bengal	Summer	February-March	30 x 15

Manuring :

Apply cattle manure/compost as basal dressing @ 7.5 to 10 t/ha and incorporate into the soil along with last ploughing. Apply fertilizers as basal dose when there is enough moisture in the soil. Urea is preferable to ammonium sulphate. Nitrogen may be applied in split doses, 75 per cent as basal and the balance as foliar spray at 3 per cent concentration, 20-35 days after sowing keeping the discharge rate at 500 1 ha-1.

State/ Situation	Recommended dose of N:P:K (kg/ha)	Specific recommendation
Andhra Pradesh - Coastal region	40-40-20	
Telangana	30-30-20	-
Gujarat		
Kharif	30-25-0 25-25-0	Apply sulphur @ 20-40 kg/ha.

Semi-rabi	37.5-25-25	Half N + full P_2O_5 and K_2O as basal, remaining half N at 30-35 DAS.
Madhya Pradesh /Chhattisgarh		
Rainfed		
Summer	40-30-20 60-40-20	Apply 25 kg/ha zinc sulphate once in three years in zinc deficient soils.
Maharashtra	50-0-0	Half N at 3 weeks after sowing and remaining half 6 weeks thereafter
Odisha	30-20-30	-

State/ Situation	Recommended dose of N:P:K (kg/ha)	Specific recommendation
Rajasthan		
Heavy soils	20-20-0	For areas with less than 350 mm rainfall
Light soils	40-25-0	For areas with more than 350mm rainfall
Tamil Nadu		
Irrigated	35-23-23	Apply full dose of N, P2O5, K2O as basal.
Rainfed	25-15-15	Seed may be treated with Azospirillum.
Uttar Pradesh /Uttarakhand	20-10-0	-
West Bengal		
Irrigated	50-25-25	No fertilizer if sown after potato.
Rainfed	25-13-13	

Interculture

The crop is very sensitive to weed competition during the first 20-25 days. Two weeding, one after 15-20 days of sowing and other at 30-35 days after sowing are required to keep the field weed free and to make moisture and nutrients available to the crop.

When the plants are about 15 cm in height, thin the crop so as to give a spacing of 15-25 cm between plants.

State-wise intercropping

State	Intercropping System
Gujarat	Sesame+Groundnut / Urd bean (3:3) Sesame+Pearlmillet / Cotton (3:1)

Karnataka	Sesame+Groundnut (1:4)
Madhya Pradesh	Sesame+Green gram / Black gram (2:2 or 3:3) Sesame+Soybean (2:1 or 2:2)
Maharastra	Sesame+Pearlmillet / Black gram (3:1)
Odisha	Sesame+ Summer Groundnut (2:3) Sesame+Green gram/Black gram (2:2)
Rajasthan	Sesame+Pearlmillet / Mothbean (1:1)
Tamil Nadu	Sesame+Green gram / Black gram (3:3) Sesame+Pigeonpea (3:1), Sesame+Groundnut (2:4)
Uttar Pradesh	Sesame+Green gram (1:1), Sesame+ Pigeonpea (3:1)
West Bengal	Sesame+ Groundnut (1:3 or 2:2)

Irrigation :

- Usually the crop is grown under rainfed conditions. When facilities are available, the crop may be irrigated to field capacity after thinning operation and thereafter at 15-20 days interval.
- Stop irrigation just before the pods begin to mature. Surface irrigation at 3 cm depth during the critical stages, viz., 4-5 leaves, branching, flowering and pod formation will increase the yield by 35-52 per cent.
- Two irrigations of 3 cm depth each in the vegetative phase (4-5 leaf stage or branching) and in reproductive phase (at flowering or pod formation) are the best, registering maximum yield and water use efficiency.
- In the case of single irrigation, it can be best given in the reproductive phase.
- In the tail end fields in command area, best use of the sparingly available water can be made for augmenting sesame production.

Plant protection :

- For control of leaf and pod caterpillar, remove affected leaves and shoots and dust with carbaryl 10 per cent.

- Azadirachtin 0.03 per cent at 5 ml per litre spray at 7th and 20th DAS and thereafter need based application can manage the incidence of leaf and pod caterpillar, pod borer infestation and phyllody incidence.
- For control of gall fly, give preventive spray with 0.2 per cent carbaryl.
- For control of leaf curl disease, remove and destroy disease affected sesame plants as well as the diseased collateral hosts like chilli, tomato and zinnia.
- Remove plants affected with phyllody and destroy them. Do not use seeds from affected plants for sowing.

Harvesting :

- Harvest the crop, when the leaves turn yellow and start drooping and the bottom capsules are lemon yellow by pulling out the plants. Harvest during the morning hours.
- Cut the root portion and stack the plants in bundles for 3-4 days when the leaves will fall off. Spread in the sun and beat with sticks to break open the capsules.
- Repeat this for 3 days. Preserve seeds collected during the first day for seed purposes. Clean and dry in sun for about 7 days before storing.

Storage of seeds

- By keeping sesame seeds in polybags, tin bins, wooden receptacles or in earthen pots, the viability can be maintained for about one year.
- Admixture of seeds with ash will drastically reduce germination.

Yield :

- Kharif – 375-500 kg/ha
- Rabi – 500-750 kg/ha
- Rainfed condition – 500-600 kg/ha
- Irrigated (Rabi/summer) – 900-1000 kg/ha

SOYBEAN (EDIBLE)(*Glycine max-Linn)*

Family: Fabaceae (Leguminoceae)

Chromosome number: 2n=40

Soybean with 40% protein and 20% oil in its seed is one of the important and cheapest sources of vegetable proteins and oils. Owing to its multiplicity of uses as food and industrial products, it is called a 'wonder crop'. It is the number one oilseed crop of the world. Soybean protein is rich in the valuable amino acid lysines (5%) in which most of the cereals are deficient.

In addition, it contains a good amount of minerals, salts and vitamins (thiamine and riboflavin). A large number of Indian and western dishes such as bread, kachori, pastries, high-protein food for children, food for diabetic, milk, biscuits, sweets, fermented food, chhbole, khoa, paneer rabdi, powdered food material, chocolate, ice cream, protisnacks, nutrinugget, green pods as vegetable, canned seed vegetable, salad, dry seed-roasted, boiled, cooked, soya sauce, soya soup etc. can be prepared from its seed/flour.

It is widely used for manufacturing of edible oil, vanaspati ghee, salad oil, butter, glycerine, oil for light, explosive, varnish paints, linolium, soap, lubricating oil, printing ink, celluloid, plywood material, tape joint, typewriter ribbon, rice cream, vitamins, antibodies, medicine and cosmetic material etc. It is widely used in different antibodies. It can be used as forage, hay, silage etc. Its forage and cake are excellent nutritive foods for livestock and poultry.

Soybean builds up the soil fertility by fixing atmospheric nitrogen through the root nodules, and also through leaf fall on the ground on maturity. Soybean is a food that is as nearly perfect as cow milk. Its fortification (5%) with wheat flour is done for alleviating protein malnutrion in the country.

Origin and History :

Soybean originated in China around 2800 B.C. The wild form, a slender twinning vine, Glycine soja is considered to be the predecessor of Glycine max (cultivated form)

occurring in China, Manchuria and Korea. It was domesticated in eastern half of the North China around the 11th century B.C. It was introduced into Korea from North China and then into Japan sometimes between 200 BC and 3rd century A.D. It is introduced into northern India in 1000 AD from Central China through silk route and is an important source of food in Kumaon hills and Naga hills. Black seeded soybean was also grown in Kumaon and Garhwal hills region and some places of Madhya Pradesh.

Geographic distribution :

Soybean is globally cultivated over an area of 91.2 million ha with a production of 206.5 million tonnes (2004). The important soybean growing counties are USA, China, Brazil, Mexico and Russia. In India, Madhya Pradesh and Maharashtra states are major producers of soybean accounting for 87% of acreage and 82% of the production.

Classification :

- **Genus Glycine** consists of two subgenera Glycine Willd. and Soja (Moench) F.J. Herm.
- The **sub-genus Soja** comprises of the cultivated soybean Glycine max. and its wild annual progenitor, Glycine soja Sieb and Zucc.
- The **subgenus Glycine** consists of 16 wild perennial species [of which 2 species *G. tabicina* (2n = 40, 80) and *G. tornentosa* (2n = 38, 40, 78, 80) have polyploid forms] and the rest are diploids (2n=40).

Soybean is classified on the basis of various criteria used as below:

Manchurian classification As per this classification based on colour of seed, soybean has been classified into 3 groups:

Yellow group: They fetch higher price.

- Yellow seeds with light hilum
- Yellow seeds with golden hilum
- Yellow seeds with brown hilum

Black group: They fetch higher price.

- Large black seed

- Flat black seed
- Small black seed

Green group

- Epidermis of seed green but embryo yellow
- Epidermis as well as embryo green

Martin's classification

This classification is based on shape and size of soybean seed

- Soja elliptica : Egg shaped seed
- Soja spherical : Round seed
- Soja compressa : Pressed seed

Hertz Classification

This classification is based on the shape of pods

- Soja platycarpa : Flat seed
- Soja tumida : Thick seed American classification

This classification is based on maturity duration. The varieties available in USA have been divided into 10 groups.

Group	Maturity (in days)	Varieties (Hilum colour)
(00)	117	Flambeau (b), Portage (y)
(0)	126	Traverse (y), Merit (bf), Grant (b)
(i)	126	Chippewa (b), Hark (y)
(ii)	130	Amsoy (y), Harosoy 63 (y)
(iii)	131	Ford, Kim, Sheby, Adams, Wayne (b), Adelphia (bf)
(iv)	136	Delmar (y), Scott, Kent (b), Clark 63 (b)
(v)	139	Dare Hill (br), Dorman, York (bf)
(vi)	148	Hood (bf), Pickett (b), Lee (b), Davis (bf)
(vii)	156	Bragg (b), Jackson, Semmes (b)
(viii)	158	Hardee (bf), Bienville, Improved Pelican b = black; y = yellow; br = brown; bf = buff colour hilum

Climate :

Soybean grows well in warm and moist climates from sea level to an elevation of 3,000 m. Temperature of 15-32 ^{0}C is optimum for germination. For growth and development, the optimum temperature is 30 ^{0}C. Lower temperatures tend to delay the flowering. It has been observed that low temperatures reduce the oil content, whereas higher temperatures during seed formation increase the oil content in seed. At temperatures >42 ^{0}C, nodulation is hampered severely. A relative humidity of 70-75% is optimum for pod formation. The crop 40 cannot tolerate frost and waterlogging. It is grown in areas of 40-75 cm annual rainfall. Drought at flowering or just before flowering results in flower and pod drop. Rains during maturity impair the quality of grain. It is a short day plant and requires a photoperiod of less the 14 hours provided that temperatures are also favourable.

Soils :

The crop performs best in well drained medium textured soils with moderate to deep soils. Sandy loam to clay loams is preferred for its cultivation. Soils with neutral pH are ideal. The soils with an electrical conductivity >4dS/m and exchangeable sodium percentage >15% are not suitable for soybean.

Land preparation :

Soybean requires well pulverized seed bed with no clods for proper germination and crop establishment. The required seed bed can be prepared by a deep ploughing followed by cross harrowing twice and planking.

Seeds and Sowing:

Seed rate :

- Soybean crop needs about 70-80 kg/ha seed during kharif season and 100-120 kg/ha seed during spring and summer seasons.
- A spacing of 45 cm x 5 cm in kharif crop and 30 cm x 3 cm in spring and summer crops is optimum. Intercropping with other crops either in alternate rows or 2 rows of soybean between two rows of main crop would require 60% of the seed rate.

Time of sowing :

- Time of sowing of kharif crop is dependent on onset of monsoon or availability of irrigation water. The sowing starts from last week of June and continue up to first fortnight of July.
- In northern and central India, last week of June is the optimum time of sowing under irrigated conditions. However, it not only takes long duration to maturity but is also highly susceptible to yellow mosaic virus disease. The optimum time of sowing is, however, earliest in northern hills zone i.e. last week of May to mid June.
- Under irrigated conditions, it is sown in spring season between mid February to mid March.

Method of Sowing :

It is conventionally sown by broadcast. However, it involves several problems; *viz*. plants are not properly spaced, resulting in inconvenience in hoeing, weeding etc. Broadcast method is still ideal for fodder and green manure crop.

For seed purposes, the crop is sown in rows with the help of seed drill or behind the plough. The depth of sowing should not be more than 2-3 cm in heavy soils to 3-4 cm in light to medium-textured soils under optimum conditions. Rains immediately after sowing results in crust formation inhibiting seedling emergence. Crust breaking by light racking is desirable under these situations.

Varieties :

The important varieties of soybean released/ introduced in India and their areas of recommended are given below :

Region	Varieties
Northern Hills Zone (Himachal Pradesh and Hills of Uttar Pradesh, Uttarakhand)	PK-416, Bragg, PK-262, VL2, PSS-64, PK 327, VLS-47, VLS-1, Alankar (PK-74-21), Shilajeet (UPSM-19), Hara Soya, Pusa-16
North Plains Zone (Punjab, Haryana, North eastern plains of Uttar Pradesh and western Bihar)	PK 262, PK 327, PK 416, PK 308, PS 564, PS 1024, Pusa 16, Bragg, Ankur (UPSM-38), Alankar, Shilajeet, DS-73-16, DS-7522-4, PK-472, VL Soya-21, SL-95, SL-295, PK-1042, PK 564-Y, PK-1024

Central Zone (Madhya Pradesh, Bundelkhand regions of Uttar Pradesh, Rajasthan, Gujarat, western Maharashtra and Orissa)	JS-2, JS-335, Ankur, Gaurav (JS-72-74), Durga, MACS-13, PK-472, MACS 58, JS-80-21, MACS-57, JS-80-21, MAUS81, PK-472, Prasad (MAUS-32), Ahilya-4 (NRC-37), Parbhani sona (MAUS-47), NRC-2 (Ahilya-1), NRC-7 (Ahilya-3), NRC-12 (Ahilya-2), JS-90-41, Indira Soya-9, JS71-05, JS-9041
Southern Zone (Karnataka, Andhra Pradesh, Tamil Nadu, Kerala and Southern Maharashtra)	KHsb-2, Co-1, Monetta, Hardee, Pratiksha (MAUS-61-2), MAUS-32, MACS-450, PK-1029, KP-79 (Sneha), JS-93-05, LSb-1, Co Soya-2, MAUS-2 (Puja), MACS-124, Partikar (MAUS-61)
North-East Zone (Assam, West Bengal, Eastern Bihar, Meghalaya etc.)	JS-80-21, RAUS-5, Samrudhi (MAUS-71)

Manuring and Fertilization :

Soybean removes substantial amount of nutrients from the soil. The nutrient requirement in India with low to moderate yield levels (~ 1.1 t/ha) are entirely different from countries with 4-8 tonnes/ha productivity. In these countries, removal of P and K far exceeds their application. Soybean has rapid uptake of nutrients at pod filling period.

For raising a good crop, application of 15-20 t/ha of FYM is recommended. Being a legume, it fixes atmospheric nitrogen in association with *Bradyrhizobium japonicum* to meet most of its requirement.

To meet the N requirement of crop before fixation starts, 40 kg N/ha is applied at the time of sowing. At flowering stage, the nitrogen supply from soil and symbiotic N fixation often lags behind the requirement. Hence top dressing of 20 kg N/ha would be required.

Soybean requires liberal P fertilization for proper nodulation. In acidic soils, P gets fixed owing to predominance of aluminium and iron oxides. Hence, liming of such soils is desirable for raising a good crop. In general, 60-80 kg P2O5/ha is recommended as basal application.

Potassium need of soybean is the highest amongst 3 primary nutrients, For proper nodulation, 600-800 mg K/kg biomass is required. Indian soils are rich in

potassium, and therefore the response is rare. In K deficient soils, basal application of 40 kg K2O/ha is recommended. To correct K deficiency in a standing crop, 0.5% foliar spray of KCl is recommended.

Soybean requires S for oil synthesis. In areas with low S availability, 20 kg S/ha is necessary. In sodic soils and high rainfall zones, soybean usually encounters Zn deficiency. Further, liberal P fertilization also aggravates Zn deficiency due to their antagonism. Hence, application of 5 kg Zn /ha recommendation is made for all soybean growing zones.

Weed control :

Uncontrolled weeds in the field can cause reduction in yield up to 65%. The initial 40 days have been found as critical period of crop weed competion. *Cyperus rotundus, Echinochloa colonum, Sorghum halepense, Setaria glauca, Cynodon dactylon, Celossia argentia and Trianthema monogyna* etc. are the most common weeds of soybean. Two manual weedings or hoeings at 20 and 40 days after sowing may effectively control the weeds in soybean. However, continuous rains may limit the utility of manual weeding/hoeing. Under such cases, use of herbicides is inevitable. Pre-plant incorporation of fluchloralin @ 0.75-1.00 kg/ha or pre-emergence application of alachlor @ 1.5-2.0 kg/ha or metolochlor or chlomazone or pendimethalin or linuron @ 1 kg/ha or metribuzin @ 0.75 kg/ha have been found effective to control annual grasses and broad leaved weeds.

In recent times, some post-emergence herbicides are also used for control of grasses. They include quizalofop-ethyl @ 50 g/ha 25 days after sowing (DAS) or imazethapyr @ 75 g/ha 15-20 DAS.

Water management :

In *kharif* soybean, drainage is more important than irrigation. In soybean, sprouting, flowering, pod initiation and grain filling are critical stages of irrigation. Moisture stress at flowering and pod initiation results in flower and pod abortion, while stress at grain filling reduces seed size. Waterlogging is detrimental to nodulation,

hence ridge and furrow planting is recommended, where irrigation is provided in furrows.

Spring and summer season soybean is grown with assured irrigation facilities, and requires 3 and 5 irrigations, respectively. Under prolonged dry spells, kharif crop also requires protective irrigation at the end of flowering to pod initiation stages.

Cropping Systems :

Mixed cropping of soybean with maize, sesame has been found feasible and remunerative. In mixed stand of maize and soybean, the yield of maize is not affected, and an additional 1.0-1.2 t/ha of soybean grain can be obtained. In this system maize is planted at 100 cm row spacing keeping plant-to-plant distance of 10 cm, and 3 rows of soybean are planted in between maize rows.

In north India, it has tremendous scope as an intercrop in pigeonpea, maize, cotton and upland rice. In southern part of the country, soybean has a good scope as intercrop in cotton, sorghum, pigeonpea, groundnut and sugarcane.

In central India, it has been found very remunerative on the fallow lands in kharif. In low rainfall areas of Madhya Pradesh, soybean-rabi cropping has been found more economical than kharif fallow.

Some common soybean based rotations followed in north India are given below.

Soybean-gram Soybean-potato

Soybean-wheat (most extensively followed in 2 m ha)

Soybean-tobacco Soybean-potato-wheat

Soybean-wheat-groundnut Soybean-mustard/toria

Soybean-maize

Harvesting and Threshing :

Early varieties usually take 90-120 days to mature, whereas late varieties mature in 140-150 days. There is a thumb rule for harvesting soybean crop i.e. the crop should be harvested after it has fully matured. The matured crop is harvested manually with the help of sickles. Shattering of grains from pods is not common in most of the

commercial varieties. The harvested crop is kept on threshing floor to dry for a few days. Thereafter, it is threshed by trampling with bullocks or tractor. Grains are separated by winnowing. It can also be threshed by wheat thresher after some adjustments. A moisture content of 13-14% is ideal for threshing with thresher.

Yield :

A well managed crop yields about 2.0-2.5 tonnes grain/ha.

Oil to soybean seed crushed is 18%, meal to soybean seed crushed is 73%, hull from soybean seed crushed is 8% and wastage from soybean seed crushed is 1%.

Castor

B.N. :- Ricinus communis L. Family :- Euphorbiaceae

Origin :- Tropical Africa and India

Geographical Distribution :- The world castor area and production are 1.16 mha and 1.14 mt, rerspectively. India, China, Brazil, Paraguay, Thailand, Ethiopia and Pakistan are the major castor producing countries. In India, it is grown on 7.3 lakh hectares with a production of 8.0 lakh tones. India accounts for nearly 61% of world's castor area and 73% of world production. In India the castor growing states are Gujarat, A.P, Rajasthan, Karnataka, Tamil Nadu and Orissa. Gujarat alone produces about 80% of the total castor of our country from 50% of the area.

Economic Importance :-

1. It is imp. industrial oilseed crop and gives foreign exchange.
2. Seed contain 50-55% oil (non-edible oil)
3. Castor oil contain very high percentage of hydroxyl fatty acid (ricinoleic acid 85%)
4. Dehydrated castor oil is in demand for paints and varnishes because of non-yellowing quality.
5. Castor oil is the chief material for the production of sebacic acid, which is the basic ingredient in production of synthetic fibre.
6. Castor oil is used as lubricant in machinery and for internal combustion engine in Aeroplane.
7. It is used as an illuminant, giving a bright and steady flame and burning much longer than any other vegetable oil.
8. Hydrogenated castor oil is used in polishes, ointments, waxes, printing inks, cosmetics, hair dressing, soaps and disinfectants.
9. Castor oil is used as purgative
10. In dyeing industries, it is used for the preparation of Turkey red.

11. Its oil is used in many veterinary uses.
12. The oil cake is a valuable manure, Owing to the presence of the poison 'ricin' it is unfit for cattle feed

Classification :- The classification is based on the eco-geographical groupings. The *Ricinus communis* is divided into following six sub-species.

1. persicus 2. chinensis 3. zanzibarinus 4. sanguineus 5. africanus 6. mexicanus

Botanical description :-

Root system :- The plants have a well developed tap root system, with thick horizontal roots.

Stem :- The stem is erect, partially hallow, smooth, either red or green or with shades of both, with well defined nodes.

Leaves :- Leaves are alternate, large, palmate with 5-11 lobes, acuminate, margins are notched, serrate or indented and glossy green.

Inflorescence :- Inflorescences are borne terminally on main and lateral branches. Flowers are large, in terminal sub-panicled racemes, monoecious, apetalous, upper portion of raceme being occupied by female flowers and lower by male flowers.

Fruit :- Fruit is a capsule with three projecting sides covered with tough spines and divided into three locul, each locul contain one seed. The seed coat is brittle and polished.

Climate :-

1. Castor can be grown throughout India up to an elevation of 2500 m.
2. Castor require moderately high temperature of 20-27^{0}C
3. It grows best in areas where there are clean warm sunny days.
4. Prolonged cloudy weather with high temp. at flowering results in poor seed setting.

5. Temp. above 41^{0}C at flowering for short period result into blasting of flowers.
6. 80-100 mm evenly distributed rainfall is optimum for growth. Heavy rainfall during flowering reduce yield.
7. Castor is susceptible to frost.

Soil :-

1. It can be grown on all types of soils
2. Well drained loam is better for growth
3. Crop is susceptible to water logged condition
4. It can not tolerate alkalinity of soil but can withstand slight to moderate acidity of soil.

Field Preparation :- Owing to its well-developed root system, it require deep ploughing. One deep ploughing followed by disk harrowing to break up clouds, level the seedbed and destroy weeds. The seedbed should be moist to a depth of 15-20 cm.

Seed and Sowing :-

1. Sowing Season	:	Kharif
2. Sowing time	:	20th June to 5th July, Late sowing reduces the yield
3. Spacing	:	i. Irrigated – 60 x 45 cm ii. Rainfed – 90 x 45 cm
4. Seed rate	:	18 – 20 kg/ha.
5. Sowing depth	:	8-10 cm
6. Method of sowing	:	Dibbling

Varieties :- Aruna, Bhagya, Saubhagya, Girija, , Rosy,Pujab castor, Tarai, J 44, Type- 3, HC 6, Dwarf Mutant.

Hybrids :- GCH 2, GCH 4, MCH 1, Western 6

Cropping System :-

Castor is grown in rotation with wheat, linseed etc. It is grown mixed with cotton, groundnut, pigeon pea, green gram, sorghum, pearl millet, cowpea and sesamum.

Manures and fertilizer :- 10-15 t/ha FYM is applied 15-20 days before sowing

Fertilizer dose :- Irrigated :- 60:40:40 NPK kg/ha

Rainfed :- 30 :20:20 NPK kg/ha

Under irrigated conditions half dose of nitrogen and full dose of P and K should be applied at the time of sowing and remaining half dose of N should be top dressed at 60 day of crop growth. For rainfed crop full dose of NPK are given as basal dose

Weed Management :- Conditions during rainy season are conductive to rapid and luxuriant growth of weeds. Weeds compete with the plants in the early stages of growth. To keep the weeds down, two hand weeding, one at 30 days of crop growth and the other after 60 days of crop growth should be given. Incorporation of Eptam @ 3-4 kg a.i./ha three weeks prior to planting will control all grasses and dicots.

Water Management :- Castor is usually grown under rainfed conditions. However for good yields, wherever possible 2-3 irrigations may be given. If there is soil moisture deficiency at flowering stage, then one irrigation may be given. In heavy rainfall areas proper drainage is essential.

Nipping of axillary buds :_If all axillary buds on the main shoot are nipped soon after the emergence of the primary spike and thus a single main spike is allowed to develop, not only duration of the crop is reduced but also yields are increased substantially.

Harvesting and Threshing :-

Crop mature between 145-180 days. Harvesting is done when capsules turn yellowish in colour. All the spikes do not matures at the same time. The central spikes on main rachis mature first and thereafter the spikes on the side branches start

maturing. Therefore, usually 2-3 pickings may be needed for harvesting the entire crop. The spike should be dried in the sun for 4-5 days and then threshed. Threshing is usually done by either beating capsules with sticks or alternatively by trampling with bullocks or tractor. Power operated mechanical threshers are also used. It is essential to dry the seeds completely before storage.

Yield :- 20-25 q seed /ha.

Insect pest :-

1. Castor semilooper :- The caterpillars feed voraciously on leaves and defoliate the crop.

Control measures :- i. Hand picking of larvae and destruction

ii. Sevin 50 WP (0.1%)

2. Castor Hairy caterpillar :- The caterpillars feed on the leaves by scraping

Control measures :- i. Collect and destroy the eggs and young larvae.

ii. Dust 2% Methyl parathion @ 25-30 kg/ha for control of young caterpillar.

3. Castor shoot and Capsule borer :- The larvae first feed on the leaves, flowers, young shoot and later on bore into the pods and seeds.

Control measures :- i. Destroy the infested shoots and pods.

ii. Spray the crop with Malathion 50 EC 800 mi) or Methyl parathion (metacid 50 EC) @ 1 litre in 400 litres of water per ha.

Other pest are Jassids, Aphids, Red-spider mite

Diseases :-

1. Seedling blight :- The first indication of the disease is the appearance of a roundish patch of an unhealthy dull green colour on both the surface of a cotyledonary leaves. In older plants, symptoms are localized on the lamina or leaf blade on spots.

Control measures :- i. Select well drained fields as poorly drained soil encourages the incidence of the disease. ii. Grow tolerant varieties like TMV -9, H.C. – 6, PC. 1 etc. iii. Spray Blitox @ 0.3%

2. Alternaria blight :- The fungus affects all the aerial parts of the plant including the inflorescence and capsules.

Control measures :- i. Follow clean cultivation and field sanitation ii. Treat the seed with thiram or captan @ of 5 g/kg of seed. iii. Spray Blitox @ 0.3%

Other diseases are Twig blight, Pod rot, Bacterial leaf spot.

NIGER/ Ram til (*Guizotica abyssinica* L.)

Niger is an annual dicotyledonous herb. with epigeal germination. The root system is well developed, with a central tap-root and its lateral branching. The stem of niger is usually round, smooth to slightly rough, hollow and moderately branched. It is cross pollinated crop. The fruit is an achene, small, 3-5 mm in length and 1.5mm in width, almost lanceolate in shape, without pappus. There are usually between 15 and 30 mature seeds/head; occasionally more, and a varying number of immature seeds or pops at the centre.

Niger is a minor oilseed crop that is grown predominantly under rainfed conditions. Niger seed is used as a human food. The seed contains 37- 47% oil, which is pale yellow with nutty taste and a pleasant odour. The oil is used for culinary purposes, anointing the body, manufacturing paints and soft soaps and for lighting and lubrication. The niger oil is good absorbent of fragrance of flowers due to which it is used as a base oil by perfume industry. Niger oil can be used for birth control and treatment of syphilis. Niger seed cake is a valuable cattle feed particularly for milch cattle. Niger meal with 30% protein and 17% crude fibre in India could replace linseed cake in calf ration. It can also be used as a manure. Niger is also used as a green manure for increasing soil organic carbon.

Season and climate :

Sown under rained situations in *kharif* and *rabi* as a sole crop or mixed crop with little millet, finger millet, pearl millet, groundnut or pulse crops in different States. A rainfall of 1000 - 1300 mm is considered as optimum.

Soil :

Niger requires moist soil to grow properly. Niger could be raised in wide range of soils from clay loam to sandy loam, sandy and gravel soil. It grows well under light black soils or brownish loam with sufficient depth and on well drained heavy soils or rocky laterite soils. It can withstand slight alkalinity and salinity also.

Varieties :

The state-wise preferred varieties of Niger are as follows.

State	Varieties
Madhya Pradesh/ Chhattisgarh	JNC-6, JNC-1, JNC-9
Maharashtra	IGP-76, IGPN-2004-1 (Phule Karala-1)
Karnataka	RCR-317, RCR-18, KBN-1
Odisha	GA-10, Utkal Niger-150
Jharkhand	Birsa Niger-1, Birsa Niger-2, BNS-10
Gujarat	Gujarat Niger-1, NRS-96-1
Tamil Nadu	Paitur-1

Seed rate and sowing :

- Generally 5 kg/ha seed is required for sowing of sole crop.
- Seed should be treated with Thiram or Captan @ 3.0 g/kg seed before sowing. Seed treatment with 10 g/kg Azatobactor, 8 g/kg Trichoderma and 10 g/kg PSB enhances the income by 20%.

Land should be prepared thoroughly by giving 3-4 ploughings followed by laddering to obtain a fine tilth. The crop is largely sown by broadcasting. Seeds are mixed with sand/ powdered FYM/ ash to increase the bulk, 20 times to ensure even distribution of seed. Line sowing has been found beneficial with spacing of 30cm x 10cm. Furrows of 5 cm depth are to be prepared at 25 cm apart. Seeds are to be placed in furrows preferably at 3-5 cm depth. Then laddering should be done along the furrows to cover the seeds with a soil layer of about 3-5 cm. This ensures compacting of soil resulting in quick and uniform germination.

Nutrient Management :

The crop is mostly grown on marginal and sub-marginal land without manure or fertilizer application. However, application of recommended N through urea + seed

treatment with PSB 10 g/kg seed enhances yield significantly. Application of sulphur (20-30 kg/ha) increases seed yield and oil content in niger.

Fertilizer application - Recommended dose

State	Recommended dose of fertilizer
Madhya Pradesh	10 kg N + 20 kg P_2O_5/ha at sowing and 10 kg N/ha 35 DAS
Maharashtra	4 tonnes of FYM and 20 kg N/ha at sowing.
Odisha	20 kg N + 40 kg P_2O_5 /ha at sowing and remaining 20 kg N/ha at 30 days after sowing
Bihar/ Jharkhand	20 kg N +20 kg P_2O_5 + 20 kg K_2O + 15 kg $ZnSO_4$ as basal doze
Andhra Pradesh	5 tonnes of FYM and 10 kg N/ha at sowing
Karnataka	20 kg N + 20-40 kg P_2O_5 + 10 kg K_2O /ha at sowing

Weed management :

- First weeding is needed 15-20 days after sowing. In Odisha, Cuscuta (*Cuscuta hyalina/ C. chinensis*) infestation has become a major problem. Seed should be obtained from Cuscuta free areas. Cuscuta seeds could be separated with a 1 mm sieve.
- Pre sowing soil application of Fluchloralin (1 kg a.i./ha). or Pre emergence application of Pendimethalin (1.5 kg a.i./ha).

Water management :

It is invariably grown in the rainy season and it is seldom irrigated. There are indications that niger yields can be doubled under irrigation, it the crop suffers from moisture stress. Irrigation may be given at the seedling stage.

Pest management

As no serious pests and diseases have been observed, plant protection measures are not required.

Bee pollination

For enhancing yield through increased pollination, 5 honey bee colonies/ha of niger is recommended.

Harvesting :

Niger usually matures in 95-105 days after sowing. The crop should be harvested when the leaves dry up and the capitula turns brownish / blackish in colour.

Average Yield :

- Pure crop – 400-500 kg/ha.
- Intercrop – 150-300 kg/ha.

CASTOR

Lecture No. 15

CULTIVATION OF FIBRE CROPS- COTTON, JUTE SUNNHEMP, DHAINCHA

Cotton (*Gossypium spp.*)

Family: Malvaceae

Chromosome number: 2n=13 (Deshi), 2n=26 (American)

Cotton (*Gossypium* spp.) is one of the most important commercial fiber crops of the world contributing 40% of raw material to textile industry, besides serving as raw material to over 25 industries. Hence it is called 'white gold'.

Cotton is chiefly grown for its seed fiber, which is used in the manufacture of cloth for the mankind. It is also used for several other purposes like making threads, for mixing in other fibers and extracting of oil from the cotton seed. The oil and protein content in the cotton seed is about 17% and 24% respectively. American varieties contain more percentage of oil. Deoiled cotton seed and cake are good organic manure with 6-3-2% of N-P_2O_5-K_2O. Cotton seed, and cotton meal forms concentrated feed for cattle.

Origin and Taxonomy :

The genus *Gossypium* comprises 49 species, of which 4 are commercially grown for lint and seed purposes. Among them, two each are diploids and allo tetraploids species. The 2 diploid species (2n = 26) are known as old world or Asiatic cottons (in India, they are called *deshi* cottons). *Gossypium arboreum* L. also called tree cotton is cultivated in India and *G. herbaceum* L. called Arabian/Syrian cotton is cultivated in central Asia. The other 2 species called new world cottons are *G. hirsutum* L. (American or upland cottons) and *G. barbadense* L. (Egyptian or sea island cottons)

G. arboreum has originated in the Indo-Gangetic alluvium of north India. The cultivated *G. herbaceum* derived from *G. herbaceum* var. *africanum* (distributed in South

Africa). *G. hirsutum* is native to Mexico and Central America, while *G. barbadense* has originated from South America (probably Peru).

Cotton has been used as a fabric in India since time immemorial. It has been cultivated in the Indus valley more than 5000 years. The excavation of Mohenjodaro indicates high degree of art in spinning and weaving with cotton at that time. India is considered as a center of an important cotton industry as early as 1500 BC. The cultivation of cotton spread from India to Egypt and then to Spain and Italy.

Geographic Distribution :

Cotton is the most important fiber crop of the world cultivated over an area of 35.2 million ha with a total production of 69.9 million tonnes of seed cotton. The important cotton growing countries are India, China, USA, Pakistan, and Brazil.

India ranks first in the world in respect of acreage and third in seed cotton production. In India, cotton is grown on a large scale in Maharashtra, Gujarat, Karnataka, Madhya Pradesh, Punjab, Rajasthan, Haryana, Tamil Nadu and Uttar Pradesh. Gujarat is the largest producer of cotton in India followed by Maharashtra and Punjab.

Classification :

Genus *Gossypium* includes 49 species of cotton including wild as well as cultivated species. The cultivated species have spinable lint, while wild species have only short seed fuzz or smooth seeds. Out of the total species, only 4 are cultivated, of which 2 are diploids (*deshi*) and two tetraploids (American cottons).

1. *Gossypium arboreum* (n = 13) – *Deshi*/ Asiatic cottons:

It is most widely grown deis cotton. The lint is short (staple length <25 mm) and coarse with micronaire value >60.

2. *Gossypium herbaceum* (n = 13) - *Deshi* / Asiatic cottons:

It is less widely grown. These two species accounts for ~2% of world cotton production. In India, they account for 28% of the cotton acreage.

3. *Gossypium hirsutum* (n = 26) – American or African upland cotton:

These are medium staple (staple lenth 25-30 mm) cottons with micronaire value ranging from 3.8-5.0. it accounts for over 90% of global cotton production.

4. *Gossypium barbadense* (n = 26) – Egyptian cottons:

The fibre length is long (staple length .32 mm) and fine with micronaire value of < 4.0. it accounts for about 8% of global cotton production.

Gossypium barbadense

India is divided into 3 cotton zones based on species grown as below.

1. **Northern *hirsutum, arboreum* and hybrid zone:** In this zone short (<20 mm) and medium staple (>20.5 -25.5 mm) cotton is cultivated under irrigation.
2. **Central *hirsutum, herbaceum, arboreum* and hybrid zone:** In this zone medium (26.0-27.5 mm) and long staple (28.0-33.5 mm) cotton is cultivated under rain fed situation.
3. **Southern *arboreum, hirsutum, herbaceum, barbadense* and hybrid zone**: In this zone long (28-33.5 mm) and extra long staple (>35 mm) cotton is cultivated under irrigated or rain fed situations.

Botanical Description :

In the wild state, cotton is a perennial plant, attaining height of 5-6 m. However, most of the cultivated cottons are annuals. Cultivated cotton is an herbaceous plant, which attains a height of 75-200 cm.

Root system: Cotton plant has a tap root with secondary roots that branch laterally from primary root.

Stem: The main stem is erect and profusely branched. The branches develop from buds located at the nodes of the main stem. There are 2 buds at the base of each leaf petiole. The true axillary buds develop into a vegetative branch, which only bear leaves and no flowers. The accessory bud generally develops into sympodial or fruiting branch. Vegetative branch may arise either from axillary or an accessory bud. There is tendency for the lower branches to be vegetative, while the upper ones as fruiting branches.

Leaves: The leaves are spirally arranged on the main stem and vegetative branches, except on fruiting branches, where they form 2 alternate rows. The leaves are

petiolate. The outline of leaf is more or less cordate with 3-9 lobes depending on variety. The leaves are green, but in some species such as *arboreum*¸ leaves contain some purplish colour.

Flowers: The flowers develop at the node of opposite to a leaf in fruiting branches only. The flowers are typical of the Malvaceae family. The flower buds appearing as small, and pyramidal shaped green structure are called 'square'. The flowers open about 18-24 days after the squares are formed. Flowers consist of pistil, the stamens arranged in a tube-like staminal column the revolves the style of the pistil, 5 petals and 5 green sepals, joined together to form a cup like calyx.

Fruit: The fruit is the enlarged ovary that develops into 3-5 loculed capsule or boll. The bolls vary in size and shape, but are usually more or less egg shaped. When the boll is ripe, the capsule cracks or splits along the lines or sutures where carpels meet, and the cotton within expands greatly in a white fluffy mass. The number of seed in the boll varies from 24 to 50. The cotton fiber is simply an elongation or outgrowth of an epidermal cell of the seed coat. The long outgrowth forms the 'staple' or 'lint', while shorter outgrowth forms 'fuzz'.

Climatic Requirements :

Cotton, a warm season (semi-xerophyte) woody indeterminate shrub, is grown under a wide range of climate. The minimum temperature for germination is 15.5^{o}C, while the optimum being 18-38^{o}C. For vegetative growth, 21-27^{o}C is suitable. For reproductive growth, a night and day temperature of 20 and 30^{o}C respectively is the optimum. It has the ability to withstand the various degrees of drought. The mean relative humidity in the growing season should be >50%. However, it can tolerate temperatures as high as 43^{o}C. During fruiting phase, cool nights are required. Abundant sunshine during the period of boll maturity and harvesting is essential to obtain a good quality produce.

A frostless season of 180-240 days is required in north India for successful cotton growing. High temperature of about 45°C during sowing and seedling stage and extremely low temperature with frequent frost during winter coinciding with picking, and moderate rainfall of 30-70 cm usually occur in the northern zone. In central and southern zones, the climate is more uniform. The maximum temperature during the season varies from 32 to 40°C, while minimum temperature ranges between 10 and 20°C. In Tamil Nadu and Andhra Pradesh, a part of the rainfall is received during September to December through the north-east monsoon.

Soils :

Cotton is grown on extremely diverse soil types. However, a deep (>60 cm), friable, well drained and fertile soil is most suitable. Silty clay to clay soils are the best. Soils with a pH >9.0 and <6.5 and $CaCO_3$ content > 10% in root zone are not suitable for cotton cultivation. It is raised mainly as a rainfed crop in the black cotton and medium soils and as an irrigated crop in the alluvial soils.

The predominant types of soil on which the crop is raised are:

Alluvial soils *(preponderant in the northern states of Punjab, Haryana, Rajasthan and Uttar Pradesh)*, Red sandy loams to loams *(preponderant in Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh, Karnataka and Tamil Nadu) and* Laterite soils *(found in parts of Assam, Tamil Nadu and Kerala).*

Varieties :

Since first five year plan, several promising cotton varieties have been released and recommended for different regions of the country. Region wise recommended Bt cotton hybrids, hybrids and varieties are given below.

Bt. Cotton hybrids suitable for cultivation in different agro-climatic zones of India

Agro-climatic zone	BG-I (Boll Gaurd I)	BG-II (Boll Guard II)
Northern Zone (Punjab, Haryana, Rajasthan)	MRC 6304, MRC 6301,MRC 6025, MRC 6029, Ankur-651, Ankur 2534, RCH 134, RCH 317, RCH 308, RCH 314, NCS 913,	

	NCS 138	
Central Zone **(Gujarat, Maharashtra, Madhya Pradesh)**	Mech 12, Mech 162, Mech 184, MRC 6301, RCH 2, RCH 118, RCH 138, RCH 144, RCH 377, Ankur 09, Ankur 651, NCS 145 Bunny Bt., NCS 207 Mallika Bt, GK 205, Tulasi 4,Brahma Bt, VCH-111, ACH 33-1, ACH 155-1, VICH 5, VICH 9, PRCH 02	ACH-11-2 KDCHH-444, MRC 7301 MRC 7326 MRC 7347
South Zone **(Tamil Nadu, Karnataka, Andhra Pradesh)**	Mech 162, Mech 184, MRC 6322, MRC 6918,RCH 2, RCH 20, RCH 368, RCH 111, RCH 371, RCHB 708, NCS 145-Bunny Bt, NCS 207, Mallika Bt, GK 209, Brahma Bt, NCS 913, PRCH-02, PRCH-02, PRCH-103, GK 207, ACH 33-1, PCH 2270, KDCHH-9632, VICH 5	MRC 7351 MRC 7201

Cotton hybrids recommended for different zones

Zone	Desi hybrids *herbaceum* x *arboreum* (diploid hybrids)	Intra-*hirsutum* hybrids	*hirsutum* x *barabadense* hybrids
North Zone	LDH-11*	Fateh, LHH 144, Dhanalaxmi, Maruvikas, Omshankar	
Central Zone	GDH 7, GDH 9, Pha 46	CICRHH-1, Hybrid 4, Hybrid 6, Hybrid 8, Hybrid 10, PKV Hy2, PKVHy3**, PKV Hy 4**, NHH 144, JKHY-1,JKHY-2, Godavari, NHH-302	NHB-12, NHB 302, JKHy-11
South	DDH-2	DHH-11, Suguna**, Surya, Savita	Varalaxmi, DCH 32, DHB 105, CBS 156,TCHB 213, HB 224, Sruthi, KCH-1, Savitri

Cotton varieties recommended for different zones

Zone	*arboreum*	*herbaceum*	*hirsutum*	*barbadense*
North Zone	G 27, Lohit, Shyamali, RG 1, LD 133, LD 230, LD 327, DS 1, HD 11,	Digvijay	Ganganagar Ageti, SH 131, Vikas, F 414, H 777, Pramukh, H 14, LH 900, F 505, F 848, H 794, PST 9, F 1054, HS 45, Pusa 31, Pusa 8-	

	RG 8		3, F 286, LH 372, BC 761, F 1861, RS 310, H 1117, RS 20113	
Central Zone	Sanjay, Maljari, AK 235, G 22, AKH 4, AKA 1, AKA 5, Sujay, Eknath	F 46, V 797, Digvijay, G.Cot. 11, G.Cot. 13, G.Cot. 18, G.Cot. 19, G.Cot. 23, CNH 36	Laxmi, Khandwa 1, Khandwa 2, Khandwa 3,Vikram, LRA 5166, PKV 081, L 174, Devitej, Gujarat 67, DHy 286, Purnima (NH 239), Badnawar 1, Nimbakar 1, Buri 1007, Narbada, AKA 8401, Deviraj, Arogya, Rajat	Suvin
South Zone	Nardium, Srisailam, Mahanandi, Pandaripur, Coconada red, K 7, K 9, K 10, Gorani 6	Jayadhar, Westerns 1, Raichur 51, Ajanta (DB 3-12)	Laxmi, Hy 14, Bhagya, Sharada, MCU 6, MCU 7, MCU 8, MCU 9, MCU 10, MCU 12, LRA 5166, Kanchana, LK 861, L 389, L 603, L 604, Mysore Vijay, Hampi, Krishna, Mahalaxmi, Suman, Sowbhagya, Sumangala, Supriya, Pratima	Suvin, Sujata, TNB 1

Recently released varieties and Hybrids:

RHy 253, LAHH 4, LAHH 5, Lam Hybrid 1, Vagad Kalyan (RB 423), HHH 223, Arvinda (NDL 2708), ICMF 20, Shana, RAMPBS 155, Parbhani 316, GBhv 179, GSGDH 2, ADCH 1, HD 123, CDHB 1, NFHB 109, WHH 9, AAH 1

Jawahar Kapas 4 (Madhya Pradesh); RHH 492, RHB 388 (Maharashtra); Narasimha, Veena (Andhra Pradesh)

Land Preparation :

Cotton requires thorough land preparation for germination and growth of the crop. In cotton-wheat cropping system of north, cotton is sown immediately after harvest of wheat leaving little scope for proper land preparation. The field is irrigated immediately after *rabi* crop followed by ploughing with MB plough and planking.

Under rainfed conditions, land preparation starts with the onset of monsoon. However, a deep summer ploughing is desirable once in 3 years to ward off perennial weeds and also to kill pests and disease propagules hibernating in the soil. After the start of monsoon, the field is harrowed 3-4 times followed by planking in vertisols of central and southern India. However, in red soils of southern India, 2-3 light ploughings

are given before planking. Land preparation costs can be minimized by adopting minimum or zero tillage coupled with use of suitable herbicides.

Seed and Sowing :

Seed rate and spacing :

The seed rate varies with species, growing zone and availability of irrigation. A highly branching monopodial variety/hybrid requires more spacing than non-branching sympodial types. With the evolution of compact varieties, the concept of wider row planting has been changed to closer planting systems which can accommodate more plant population.

Species	Growing condition	Cotton zone	Seed rate (kg/ha)	Spacing (cm)
G. hirsutum	Irrigated	North	20-25	75 x 15
	Irrigated	South	10-15	75 x 30/45
	Rainfed	North/Central/Southern	18-20	60 x 30
	Rainfed	Southern	10-12	90 x 30
G.arboreum/ herbaceum	Irrigated/ Rainfed	North	10-12	60 x 30
	Rainfed	Central/Southern	12-15	45 x 25/ 60 x 30
G. barbadence	Irrigated	Southern	8-10/12-15	90 x 30/ 75 x 30
Hybrids	Irrigated	Southern	2-3	90 x 30/ 45/60
	Rainfed	Central	3-4	150 x 60
	Rainfed	Southern	2-3	120 x 60

Method of sowing :

In case of *desi* cottons, line sowing behind the seed drill is common. However, in case of hybrids and Bt cottons dibbling the seeds is preferred owing to higher seed costs. Square planting are beneficial than rectangular planting methods. The optimum depth of sowing is 4-5 cm.

Gap filling and thinning :

As the crop is grown at wider spacing, the gaps arising due to failure of seed germination or seedling mortality or incidence of pests / disease must be filled by sowing water soaked seeds. To ensure full stand, 2-3 seeds/hill are dibbled. After

germination, the weak/diseased/damaged seedlings are removed by keeping a healthy seedling/hill.

Seed treatment :

The seed is covered by short fiber called 'fuzz' in most of the American cottons that makes sowing difficult owing to clinging of seeds. Its separation is essential for ease of sowing and is achieved by the following ways.

- **Non-chemical method:** The seeds are soaked in water overnight, and then rubbed with cowdung and wood ash or saw dust to separate fuzz from seeds. The seeds are dried in shade before sowing. The rubbing also helps in crushing the pink boll worm affected seeds.
- **Chemical method:** Seeds placed in an earthen pot are soaked for 2-3 minutes in concentrated sulphuric acid. The seeds are immediately washed in water 3-4 times to remove acid residues left on the seed and dried in shade before sowing.

For chemical seed treatment, wood or metal container should not be used. The operator should wear the plastic gloves. The water containing acid and alkali residue should be properly disposed off in the waste land. Inadequate washing or delayed washing of the seed after seed treatment and residual acid on the seed if not neutralized may impair the germination of seed.

Add 10 g of ceresan wet and 0.5 g of streptomycin or 15 g of agrimycin 100 in 10 litres of water and soak the seed in it for 6-8 hours to prevent primary infection of seed-borne pathogens. In case of acid delinted seeds, soaking for 2-4 hours is sufficient. If ceresan wet is not available, use of 10 g agallol or 5 g of tafasan / aretan may serve the purpose. One g of succinic acid in 10 litres of water may also help to promote good establishment of plant stand, and better early growth.

Time of sowing :

The optimum time of sowing is 1st week of May in north. However, this may be extended up to 3rd week of May to the first week of June with selection of new compact varieties. Under rainfed conditions of central and south zone, the sowing starts with

onset of monsoon in June and may be extended up to first week of July. Under irrigated conditions, the optimum time of sowing varies from first fortnight of March (western Maharashtra) to 2nd to 3rd week of May (Vidarbha region of Maharashtra and Khandesh tracts of Madhya Pradesh). In Tamil Nadu cotton is planted during September-October under both irrigated and rainfed conditions. The time of sowing in rice fallows depends on the harvest of rice crop from October-November. For spring cotton, February is the optimum time of sowing.

Nutrient management :

Cotton is a heavy feeder of nutrients. It requires adequate supply of nutrients through manures or fertilizers. Cotton soils are universally deficient in N, but are moderate to adequate in respect to phosphorus and potassium. This shows the importance of N nutrition.

For moisture conservation and better response to applied nutrients, FYM application @ 5-10 and 10-20 t/ha under rainfed and irrigated conditions is recommended. It is applied at the last ploughing for proper incorporation into the soil.

The N dose varies from 40-60 kg/ha (rainfed) to 100-150 kg/ha (irrigated conditions). Similarly *desi* cotton requires less N than hybrids. The N demand of crop is spread over from sowing to boll development. Therefore, split application is desirable. The number of splits may vary from 2-3. In case of 3 splits, 50%, 25% and 25% of total N is applied at sowing, square formation and flowering. In hybrids, spot application of top-dressed N is more efficient than broadcast. Inoculation of cotton seed with *Azotobacter* and *Azospirillum* has been found effective in meeting N requirement of cotton to the extent of 30 kg/ha.

Application of phosphate and potash fertilizers should be based on soil test values. The P_2O_5 dose varies from 30-40 and 40-60 kg/ha under rainfed and irrigated conditions respectively. It should be applied as basal at sowing and placed at 7-10 cm below soil for efficient utilization. The response to K fertilization is rare in India.

However, hybrids under irrigated conditions with high N and P fertilization usually respond to K fertilizer. It is applied similar to P fertilization.

Use of phosphate solubilizing microbes (*Bacillus, Pseudomonas, Aspergillus*) along with rock phosphates are more effective than rock phosphates alone. Responses to S and Zn fertilizers have also been reported. Zn deficiency is accentuated with alkalinity of soils.

Water Management :

Cotton, a predominantly rainfed crop, has only 34.3% of the total area under irrigation (2003-04). Hence, both moisture conservation and water management are equally important.

Rainfed crops have low yields owing to erratic and uneven rainfall. Moisture stress during reproductive phase is most harmful to the crop performance. Tied ridging at 6 m interval, broad-bed and furrows and ridge planting are effective in rain water conservation. Use of farm yard manure and effective weed management are conducive for moisture conservation.

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). Depending on rainfall and soil types, the number of irrigations (each of 7.5 cm) may vary from 2 (sandy loam of Delhi and clay soils of Akola) to 13 in red sandy loam of Bhavanisagar. Thus, the quantity of irrigation water varies from 140-840 mm. The mean consumptive use is about 700 mm in the country. In heavy soils, cotton withstands up to 75% depletion of available soil moisture (DASM), while in sandy loams, it is 50% DASM only. For timely sowing of succeeding crops, irrigation should be withheld from 50% boll bursting stage onwards. Under limited water resources, irrigation in alternate furrows is recommended.

The drip irrigation is being increasingly adopted, and irrigation at 0.6 irrigation water (IW) / cumulative pan evaporation (CPE) ratio has been found promising. This ratio also holds good for flood irrigation.

Weed control :

In wide spaced crops like cotton, weeds pose serious threat to realizing the optimum yields. A weed free period of 50-60 days from sowing is required. The profuse vegetative growth beyond this period may suppress the weed growth. Uncontrolled weeds may cause 60-80% reduction in yields.

Manual, mechanical and chemical methods of weed control either alone or in combination are followed for effective weed management. The first manual hoeing 5-6 weeks after sowing or before first irrigation is essential for removal of weeds at an early stage. Later hoeings either by hand or bullock drawn implements should be done after each irrigation or rain. The interculture operations not only aid in weed control, but also help in creation of mulch, aeration of soil and better intake of water.

Among the herbicides, pendimethalin (pre-emergence) or fluchloralin (pre-plant incorporation) @ 1 kg/ha are found effective in controlling grassy weeds for the initial 2 months. For broad leaved weeds, post-emergence herbicides like diuron + paraquat (0.5 + 0.3 kg/ha) for directed spray against weeds was recommended. In developed countries, bromoxynil and glyphosate resistance has been introduced into cotton for spray for effective post-emergence weed control. Of the total cotton acreage of the world in 2002, 4.4 m ha (2.2 m ha is exclusively herbicide resistant cotton and 2.2 m ha is herbicide + Bt resistant cottons) is under herbicide resistant cottons.

Use of Plant Hormones :

It has been observed that the cotton plant sheds the greater proportion of the buds at any stage between bud formation and boll maturity under normal growth conditions. Application of plant hormones such as *planofix* (α-NAA) and *cycocel* (CCC) at 10 ppm 80-90 days after sowing coinciding with square formation helps in more bud-retention besides helping in more sympodial branching in plants, and also inducing drought resistance.

Topping plant at a height of 1 to 1.2 m or between 80-90 days of crop growth. This practice arrests further terminal growth and encourages sympodial branching and boll development. It also facilitates spraying operations and picking of cotton.

Harvesting :

Cotton is harvested in 3 or 4 pickings by hand as the bolls mature. The number of picking may vary with the maturity habit of the variety. The season of harvesting also varies with time of sowing and the duration of variety. Generally, crop sown in April-June is harvested in October-December, while those sown in June-September and September-October are harvested from November to March and March to June respectively. Generally, the crop in northern and central parts of India is harvested from October to December, whereas in Gujarat, from January to March/April. In the states of Tamil Nadu, Andhra Pradesh and Karnataka, the harvesting season is November to June.

Yield :

By adopting improved package of practices, it is possible to harvest about 1.5-2.0 tonnes of seed cotton (kapas)/ha. However, much higher yields may be obtained from hybrid cottons.

Cooton lint production is $^{1}/_{3}$ of *kapas* production, while cotton to seed production is $^{2}/_{3\text{ of}}$ *kapas* production. Oil to seeds crushed is 14-18% and cake to seeds crushed is 82-86%.

Ginning (%) :

Ginning is the process of separating the fibers from seed cotton. Ginning % is the ratio of the weight of fibers to seed cotton (*kapas*) expressed as %.

$$\text{Ginning (\%)} = \frac{\text{Weight of fibers}}{\text{Weight of seed cotton}} \times 100$$

It varies from 28-30% in *G. arboreum,* 34-38% in *G. hirsutum,* and 36-42% in *G. herbaceum and G. barbadense.*

Fiber (staple) length:

It is the most important quality parameter of fibers deciding their value. It is taken as arithmetic mean of the length of all fibers present in the sample. Cottons are classified based on staple length into the following classes.

Class	Staple length (mm)	Cotton zone
Short and medium staple	< 20 and 20.5 to 25.5	Northern zone
Medium long staple	26-27.5	Central and southern zone
Long staple	28-33.5	
Extra long	>35	Southern zone

Spinning potential :

It is measured as number of counts [i.e. number of hanks (1 hank= 840 yards) that weigh to a pound (lb). it varies from as low as 6 S (*G. arboreum*) to the highest of 120 S (*G. barbadense).*

Micronaire value :

Micronaire value is used for judging the fiber strength. It is a measure of the air permeability of a unit mass of cotton under specified conditions, expressed in terms of an arbitrary scale (micronaire scale). In immature and dead fibers it is ≤ 2. The metric equivalent of it is Tex. The units of tex are micrograms/mm of fiber length.

Major insects and pests of cotton and their management

Insect pests	Scientific name	Symptoms of damage	Insecticide	Qty. of insecticide / ha
Sucking pests				
Jassids	Amrasca biguttula biguttula	Affected leaves curl downwards, turn yellowish, then to brownish before drying and shedding, “hopper burn” stunts young plants	Methyl demeton 25EC Dimethoate 30EC Phosphamidon 100EC	500-750 ml 500-750 ml 100-250 ml

Thrips	Thrips tabaci	Leaves of seedlings become wrinkled and distorted with white shiny patches, older crop presents rusty appearance from a distance.	Methyl demeton 25EC Dimethoate 30EC Phosphamidon 100EC	500-750 ml 500-750 ml 100-250 ml
Whiteflies	Bemisia tabaci	Upward curling of leaves, reduced plant vigour, lint contamination with honey dew and associated fungi, transmission of leaf curl virus disease	Methyl demeton 25EC Neem oil + Teepol Fish oil resin soap Phosalone 35EC	500-750 ml 3.0-3.51+500 ml 14-15 kg 2.5-3.0 litres
Bollworms				
Spotted & spiny bollworms	Earias vittella & E.insulana	Boremark in main shoot, dried and withered away shoot, twining of main stem due to auxillary monopodia, feeding holes in flower buds and bolls blocked by excrement.	Endosulfan 35EC Chlorpyriphos 20EC Quinalphos 25EC Monocrotophos 40EC Carbaryl 50WP Fenvalerate 20EC Cypermethrin 10EC Decamethrin 2.8EC	2.5-3.0 litres 2.5-3.0 litres 2.5-3.0 litres 2.5-3.0 litres 1.5-2.5 kg 400-500 ml 800-1000 ml 600-700 ml
American bollworm	Helicoverpa armigera	Small amount of webbing on small squares injured by young larvae, quares have a round hole near the base, larval frass and flaring of bracts on larger squares, clean feeding of internal contents of bolls, excessive shedding of buds and bolls.	Endosulfan 35EC Chlorpyriphos 20EC Quinalphos 25EC Monocrotophos 40EC Carbaryl 50WP Fenvalerate 20EC Cypermethrin 10EC Decamethrin 2.8EC	2.5-3.0 litres 2.5-3.0 litres 2.5-3.0 litres 2.5-3.0 litres 1.5-2.5 kg 400-500 ml 800-1000 ml 600-700 ml
Pink bollworm	Pectinophora gossypiella “	Rosetted” bloom pink larvae inside developing bolls with interloculi movement	Endosulfan 35EC Chlorpyriphos 20EC Quinalphos 25EC Monocrotophos 40EC Carbaryl 50WP Fenvalerate 20EC Cypermethrin 10EC Decamethrin 2.8EC	2.5-3.0 litres 2.5-3.0 litres 2.5-3.0 litres 2.5-3.0 litres 1.5-2.5 kg 400-500 ml 800-1000 ml 600-700 ml

Red cotton bug	Dysdercus cingulatus	Feed on developing and mature seeds, stain the lint to typical yellow colour, reddish nymphs seen in aggregations around developing and open bolls.		
Dusky cotton bug	Oxycarenus hyalipennis	Associated with ripe seeds, all stages characterized by a powerful smell, discolour the lint if crushed.		

JUTE (*Corchorus* sp.)

Family: Tiliaceae

Chromosome number: 2n=14

Jute is cultivated for its bast (stem) fiber obtained from 2 cultivated species of *Corchorus capsularis* and *C. olitorius*. The fiber has great utility in both domestic and industrial uses. It is used for making various types of ropes, rugs, carpets, mats, coarse woolen fabric (druggist), cloth (hessians) and sacks to store food grains. It is also used in making coarse canvas for wrappings, wall covers; its blend gives good blanket and clothing. Of the various trade goods, sacking constitutes the major utility followed by hessians. *C. olitorius* and *C. capsularis* contribute to 78 and 10% of the total fiber sources of the country.

The sticks are used as fuel and lighting material, and for making gun powder and charcoal. In paper industry, these are used as raw material for coarse paper and resin cloth. Resin bonded and pressed jute sticks make durable hard boards.

Origin :

The genus *Corchorus* has 2 cultivated species. *C. olitorius* L. is widely cultivated, and has originated from Africa (primary center of origin) with India or Indo-Myanmar region as its secondary center of origin. This species has been reported from Africa, Asia and Northern Australia. The other cultivated species *C. capsularis* is found in Indo-Myanmar and South China region, but not in Africa and Australia. It has originated from Indo-Myanmar region including South China. In India, nine species of *Corchorus* (7 wild and 2 cultivated) have been reported so far. *C. capsularis* is commonly distributed in north-eastern parts of India, and gradually becomes scarce towards west, whereas *C. olitorius* is more common in western and north-western India.

Geographic distribution :

Jute is mainly cultivated in India and Bangladesh, besides, these two countries it is also grown to some extent in China, Myanmar, and Nepal. In India, the most

important jute producing state is West Bengal, contributing more than 75% of India's total production, other states are Assam, Andhra Pradesh and Bihar.

Classification :

Genus *Corchorus* has 2 species viz. *olitorius* (It is raised on well drained high lands only), and *capsularis* (It is more popular and widely grown). The plant has tap root system with numerous lateral branches. It is hardy in nature and can grow well both on high and low lands and is able to tolerate waterlogging conditions to some extent).Jute growing areas in India may be divided into the following 8 agro-climatic zones.

1. ***Lower Bengal* (The Ganga Riverine Tract):** This is primarily *C.olitorius* raising tract with JRO 632 as a standard variety. This tract includes 24 Pargana, Hoogly, Nadia and Murshidabad districts.
2. ***Malda, Dinajpur*:** Both species of jute (*C. olitorius* and *C. capsularis*) are raised in this tract comprising Malda and West Dinajpur districts.
3. ***North Bengal and Brahamputra Valley New Alluvium*:** This tract is spread into Cooch-Behar and Jalpaiguri districts of West Bengal, and Golpara, Kamrup, Nowgoan districts of Assam. This is mainly *C. capsularis* raising tract with JRC 321 in low lying areas, and JRC 212 in rest of the areas. On uplands, *C. olitorius* variety JRO 632 is also raised.
4. ***Tripura, Cachora Area of Old Alluvium*:** This tract is very small, but productivity is very high. *C. capsularis* is mainly grown in this tract.
5. ***Kosi area – Purnea and Saharsa*:** Purnea and Saharsa are important jute raising districts of Bihar. This is a *C. capsularis* raising tract but *C. olitorius* is also raised on a very small area.
6. ***Muzaffarpur, Darbhanga area:*** This is a *C. capsularis* growing tract.
7. ***West Bihar and eastern Uttar Pradesh*:** This tract includes Champaran district of Bihar, and Bahraich, Sitapur and Lakhimpur Kheri districts of Uttar Pradesh. This is *C. capsularis* raising tract.

8. ***Cuttack-Balasore area*:** This tract includes Cuttack, Balasore, Sambalpur and Puri districts of Orissa. This is mainly *C. capsularis* raising tract, but *C. olitorius* is also cultivated under upland conditions.

Botanical Description :

Jute is a herbaceous annual plant. Although both the species of jute (*C. capsularis* and *olitorius*) are alike in general appearance, there are considerable differences between them as given hereunder.

Character	*C. capsularis*	*C. olitorius*
Stem	Conical, base diameter tapering sharply towards apex. Pigmentation varies from green to dark red with various intermediate shades. Periderm develops prominently at base. Technical height is more. Stem is branched or unbranched.	Cylindrical, base diameter tapering gradually towards apex. Pigmentation is green or light red or deep red. Shades of colour are fewer. Periderm is absent. Technical height is less than *capsularis*. Stem is branched usually.
Leaves	Leaves are dull. Tastes bitter owing to presence of glucoside corchorin, hence called *tita pat*. Leaves are lanceolate, oblong with coarsely toothed margin. Lower most pair of serrations enlarged and end in filiform appendages.	Leaves with shining upper surface and rough under surface. Taste less or slightly sweet, hence called *mitha pat*. Leaves are elliptic to ovate with smoothly serrated margin. Lower most pair of serrations enlarged and end in filiform appendages that are long and prominent.
Flowers	Small with 5 yellow-pale yellow sepals. Ovary is round, anthers have 20-30 stamens.	Larger (2-5 times that of capsular is) with 5-6 coloured or green sepals, ovary is elongated; anthers have 30-60 stamens.
Pods	Rounded, 1-5 cm diameter with flat tops, wrinkled with green, yellowish to copper coloured and 5 locular. The fruits are internally divided by 5 septa and dehisce into 5 segments	Cylindrical-long (6-10 cm long 0.3-0.8 cm diameter) green capsule with 5-6 locales.

Seeds	Copper coloured, 2-3 mm long with 7-10 seeds in 2 rows in each locule with transverse partition between seeds. Contains 35-50 seeds/pod with a test weight of about 2 g.	Bluish green to steel grey coloured with 25-40 small seeds/row with transverse partition between each seed. It contains 125-200 seeds/pod with a test weight of about 3.33 g.

Character	*C. capsularis*	*C. olitorius*
Fiber	Ordinarily whitish, hence called white jute for trade purposes. The fiber layers are more (10-24) with more fiber bundle/cross section (2573)	Frequently finer, stronger and more lustrous than capsularis with yellowish or greyish fiber (tossa jute). The fiber layers are less (8-19) with less fiber bundles/cross section (2181).
Roots	Less deeper, having more lateral roots and is tolerant to water logging. Root: shoot ratio is less (1:7)	Deeper with less number of lateral roots and less tolerant to water logging. Root: shoot ratio is more (1:12).

Climate :

Jute is a crop of humid tropical climates. It thrives well in areas with well distributed rainfall of 2,500 mm spread over vegetative growth period of the crop with no cloudiness. Locations with a mean rainfall of <1,000 mm, incessant rainfall and waterlogging are not suitable for its cultivation. For better growth, a mean maximum and minimum temperature of 34^{o}C and 15^{o}C and a mean relative humidity of 65% is required. Temperatures below 15^{o}C and above 43^{o}C during growth are not suitable for jute crop. *C. olitorius* cannot withstand waterlogging, however, *C. capsularis* can withstand water logging, but its fiber quality is impaired with prolonged water stagnation. At a temperature below 10^{o}C no germination occurs in both the species. *C. capsularis* can withstand higher temperature at germination (up to 32^{o}C), while *C. olitorius* is sensitive to such high temperatures.

Soil and its preparation :

Jute can be raised on all kinds of soils from clay to sandy loam, but loamy alluvial are best suited. Laterite and gravel soils are not suitable for this crop. The new grey alluvial soils of good depth, receiving silt from the annual floods are the best for jute cultivation. A soil pH of 5.0-7.4 is within the tolerable limit of soil reaction. Soils with acidic pH (<4.5), effective soil depth <50 cm, electrical conductivity >2 dS/m and exchangeable sodium percentage >15 are not suitable for the crop. The crop is raised successfully on old alluvial soils of Bihar, mild acidic soils of Assam, Orissa, and light alkaline soils of *tarai* districts of Uttarakhand. It has been observed that clay loam for *C. capsularis* and sandy loam for *C. olitorius* are most suitable soil types.

Jute seeds being small require very fine tilth. The land can be prepared by ploughing and cross-harrowing 3-5 times followed by planking. In acidic soils (pH <6.0), incorporation of 1-1.5 t/ha of lime, 30-40 days before sowing is necessary for better crop performance. Soil moisture between 21-45% is considered ideal for proper germination.

Sowing :

Time of sowing

C. capsularis sowing starts from late February, whereas that of *C. olitorius* in early April and continues up to mid June. In Bihar and Uttar Pradesh, sowing is done up to mid July as per the onset of monsoon. In lowlands, February sowing is ideal, as it helps in avoiding waterlogging in early crop growth phases. In mid-lands and uplands, March-April sowing is preferred. For *capsularis*, March-April and for *olitorius* April-May is the optimum sowing time.

Method of sowing

Broadcast sowing is the most common method. Owing to the small size of seeds, small quantity of seed is required. To ensure even distribution of seed, they are mixed with 3-4 times well powdered soil and broadcast cross-wise. Immediately after sowing, the soil is harrowed and planked for covering the seeds. In broadcast crop, weeding is difficult and cumbersome owing to uneven distribution of plants. Hence line sowing behind a plough or using seed drill are preferred for ease of interculture.

Seed rate and spacing

Seed rate varies with method of sowing and species to be grown. For broadcast sowing, 6 and 10 kg seed/ha of *olitorius* and *capsularis* are required. Line sowing needs 4 and 6 kg seed/ha only.

The seeds are sown in row 20 cm (*olitorius*) and 30 cm (*capsularis*) apart. The plants within the row should be thinned manually at 2 stages. First thinning is done 20 days after sowing (DAS), when the plants are of 5-10 cm. At this stage, plants are thinned to a distance of 5 cm. In second and final thinning 35 DAS, when plants are 12-15 cm height, and are thinned to a distance of 10 cm. Thus the optimum population varies from 3.33 (*capsularis*) to 5.0 lakh/ha (*olitorius*).

Varieties

The important varieties of jute for different states are given below.

Important varieties of jute recommended for different states for cultivation

State	Recommended varieties	
	Corchorus olitorius	***Corchorus capsularis***
Assam	JRO 524 (Navin), JRO 632 (Baisakhi tossa), JRO 7835 (Vasudev), JRO 66, JRO 8432, JRO 128 (Surya), JRO 878, JRO 36E, S 19, Subala	JRC 212 (Sabuj sona), JRC 321 (Sonali), JRC 7447 (Shyamali), UPC 94 (Reshma), Hybrid C (Padma), JRC 1108, Bidhan Pat 3 (D-110), Bidhan Pat 1, Bidhan Pat 2, Fanduk, D-154, UPC 7716, C-80, CIN 178, CO 234
Bihar	JRO 524, JRO 7835, JRO 66, JRO 8432, JRO 128 (Surya), JRO 632, JRO 878, JRO 36E, S 19, Subala	JRC 212, JRC 321, JRC 7447, KTC 1 (Rajendra Sada Pat), UPC 94, JRC 698, Bidhan Pat 3 (D-110), Bidhan Pat 1, Bidhan Pat 2, Fanduk, D-154, C 80, CIN 178, CO 234
Orissa	JRO 524, JRO 632, JRO 878 (Chaitali tossa), JRO 7835, TJ 40 (Mahadev), KOM 62 (Rebati), JRO 878, KOM 9	JRC 212, JRC 7447, UPC 94, JRC 4444 (Baldev), KC 1 (Jaydev), JRC 1108, Bidhan Pat 1, Fanduk, JRC 321
Uttar Pradesh	JRO 524, JRO 3690 (Sabitri), JRO 66, JRO 8432, JRO 128 (Surya), JRO 632, JRO 878, JRO 7835, JRO 36E, S 19, Subala, Co 234	JRC 212, JRC 321, JRC 7447, UPC 94, JRC 1108, Bidhan Pat 3 (D-110), Bidhan Pat 1, Bidhan Pat 2, Fanduk, D-154, C 80, CIN 178, Co 234

West Bengal	JRO 632, JRO 3690, JRO 524, JRO 7835, JRO 878, JRO 66, JRO 8432, JRO 128 (Surya), S 19, Subala	JRC 212, JRC 321, JRC 7447, UPC 94, JRC 1108, Padma (Hybrid C), JRC 698, Bidhan Pat 3 (D-110), Bidhan Pat 1, Bidhan Pat 2, Fanduk, D-154, C-80, CIN 178, Co 234

Manures and Fertilizers :

In general, the nutrient requirement of *capsularis* is more than that of *olitorius*. In soils with low organic carbon content, FYM application @ 5-10 t/ha, a month prior to crop sowing is recommended. The leaf fall from the standing crop and also root stubbles left in the soil after harvest results in recycling of handsome amount of nutrients besides organic matter in intensive cropping systems. The recommended doses of fertilizers are 20 to 60 – 20 to 30 – 20 to 50 (*olitorius*) and 40 to 80 – 40 to 50 – 60 to 80 (*capsularis*) kg/ha of N-P_2O_5-K_2O respectively.

In heavy soils with low to moderate rainfall, all nutrients are applied as basal. In light soils and high rainfall situations, N is applied in 2 equal splits, ½ basal and ½ top dressing, i.e. preferably after weeding and thinning operations. Seed inoculation with *Azotobacter chroococum* and *Azospirillum brasilense* has been found promising to supplement part of N fertilizer. Foliar application of 20 kg N through urea solution with teepol as sticker at pre-flowering stage is promising. In acidic soils, P gets fixed; hence, their placement is better. K is usually applied as basal, but in leaching prone soils, split application is ideal.

In acid soils and regions with high rainfall, calcium and magnesium deficiency is common. Liming of soil @ 2-5 t/ha, once in 4 years or Dolomite application (40 kg MgO) is found promising as it supplies both calcium and magnesium.

Water management :

Jute is sensitive to both drought and waterlogging. The crop sown during the months of February-April requires irrigation till the onset of monsoon. At germination and knee-high stages, adequate soil moisture must be ensured by irrigation. In general, after pre-sowing irrigation, monthly irrigation till onset of monsoon may be necessary.

During rainy season, the crop experiences waterlogging that adversely affect fibre quality. Provision of quick drainage in uplands will be beneficial to the crop. However, in lowlands, it may not be feasible.

Weed management :

The crop suffers from heavy weed infestation in the initial 6-8 weeks after sowing. Two-three hand weedings or mechanical hoeings are required to arrest weed menace. The first 2 manual weedings are combined with thinning operations at 20 and 35 DAS. The third weeding should be done 55-60 DAS. Due to continuous rains, sometimes manual weeding may not be possible. In such a situation, herbicide integrated with manual weeding is promising. Fluchloralin (pre-plant incorporation, 3-7 days before sowing) or pendimethalin (pre-emergence, 1-2 days after sowing) @ 0.75-1.0 kg/ha combined with one hand weeding at 35DAS may effectively control the weeds. Recommended post-emergence herbicides for weed control include MSMA (mono sodium methane arsenate) @ 4-5 kg/ha and dalapon @ 6 kg/ha. They should be applied 20 days after sowing.

Cropping Systems :

Jute can be intercropped with green gram and groundnut. Green gram is sown in lines 40 cm apart. After 1 month 2 rows jute variety JRO 878 or JRO 7835 are sown in between green gram rows. Groundnut is sown in 60 cm rows in mid-January (in eastern India only) and 2 rows of jute 'JRO 878' or 'JRO 7835' are sown in between groundnut rows in the end of March. In seed crop of jute, intercropping of blackgram is promising. The following crop rotations are adopted in jute-growing areas.

Irrigated areas

- Jute + green gram-paddy-potato Jute-paddy-potato
- Jute-paddy-gram Jute-paddy-wheat
- Jute-paddy-mustard Jute-paddy-barley
- Cowpea-jute-potato Jute-paddy-berseem
- Rainfed areas

- Jute-paddy-pulses Jute-gram
- Jute-paddy-mustard Jute-mustard
- Jute-paddy Jute-wheat

Harvesting :

Harvesting of the crop at pre-bud or bud stage gives best quality fiber; however, the yields are low. Hence, as a compromise between quality and quantity, early pod formation stage has been found best for harvesting. Harvesting is done by cutting the plants at or close to the ground level with sharp sickles. In flooded lands, the plants are uprooted. The harvested plants are left in the field for 2-3 days for the leaves to shed. Next, the plants are tied into bundles 20-25 cm of diameter and the branching tops are lipped off to rot in the field.

Retting of jute :

Retting is an aerobic and anaerobic microbiological process by which the fibers in the bark get loosened and separated from the woody stalk. There are 2 processes of retting of jute. The bundles are kept in 30 cm deep water, and later placed side by side in retting water, usually in 2-3 layers and tied together. They are covered with water-hyacinth or any other weed that does not release tannin and iron. The float is then weighed down with seasoned logs or with concrete blocks or are kept emerged (at least 10 cm below the surface of water) with bamboo-crating. Clods of earth used as a covering material or as weighing agent produce dark (Shyamla) fiber of low value. Retting is best done in shallow canal with slow running clean water. The optimum temperature is around 34^{o}C. If fiber comes out easily from the wood on pressure from the thumb and fingers, retting is considered complete

Extraction of fiber :

The fiber, extracted separately from each reed (stem) with fingers is sleek, clean and free from entanglement. By the beat-break-jerk method, 10-12 reeds are taken at a time, their stiffer root-ends are beaten with a mallet to loosen the fiber. The bundle is then broken in the middle and the fiber is loosened. By gripping this loosened fiber in

the middle, the broken bundle is jerked in water so that the sticks slip off. The fiber is then washed in clean water, rung and eventually spread to dry, preferably in shade or mild sun. The second method often leaves the broken sticks and make fiber somewhat entangled resulting in sticky fiber. The extraction of fiber from the green stem with a machine followed by a short period retting has also proved to be successful.

Yield :

The national average is 1.3 tonnes of fiber/ha. However, with improved package of practices, it is possible to get 2.0-2.5 tonnes of fiber yield/ha from improved varieties. If the seed is produced, it may yield about 0.4-0.5 tonnes in case of white jute and 0.25-0.30 tonnes/ha in case of *tossa* jute.

- 100 yards of hessian = 54 lbs of raw jute
- 4148 yards of hessian = 1 tonne raw jute (5.55 bales raw jute)
- 1 tonne of sacking = 1.11 tonne of raw jute (6.17 bales of raw jute)
- 1 tonne of hessian, sacking etc.=1.05 tonnes raw jute (5.85 bales of raw jute)

Sunnhemp

B.N. :- ***Crotalaria juncea*** **L.** **Family :- Leguminoceae**

Origin :- India

Economic Importance :-

Sunnhemp is known as Bombay hemp or Banaras hemp. It is grown for fibre as well as green manuring purpose. Fibre is used for making ropes twines, nets and gunny bags. It is also used for making rugs. Due to high cellulose and low lignin it is used for manufacturing tissue paper and paper currency.

Geographical distribution :-

The imp. Sunnhemp growing countries of the world are Russian federation, Romania, India, China, Hungary, Poland, Turkey, Brazil, Chili and Bangladesh. In India it is cultivated on about 1.4 lakh ha. with a total production of about 50,000 tonnes of fibre. It is grown mainly in U.P., M.P., Maharashtra, Rajasthan and Orissa.

Botanical description :-

Root system :- The plant is deep rooted with well developed lateral roots all covered with numerous nodules.

Stem :- The stem is straight and thin. The stem has a very thin outer skin which contains the long bast fibre.

Leaves :- The are almost sessile, small and narrow, shining and covered with short silky hairs.

Inflorescence :- The inflorescence is raceme usually of 12 to 20 bright yellow flowers typically papillinaceous in in structure. Flower are cross fertilized.

Pods :- The pods are small, rattle with the pods when shaken, from which the name Crotolaria has been derived. The seeds are kidney shaped.

Climatic requirement :- Sunnhemp is a warm season crop and hence grows best in tropical and subtropical region. In Northern India, it is grown in the kharif season, while in Southern parts of the country, where winter is not severe, it is grown in rabi season also. It require a minimum of 40 cm well distributed rainfall during the growing season.

Soil :- It requires well drained loamy soils for successful cultivation. If there is proper management of drainage it can also be grown on heavy soils. Acid soils are not at all suitable for this crop. When grown for fibre purpose it is not sown on heavy or waterlogged soils but for green manuring purpose it can be sown on heavy soils too.

Land Preparation :- The soil should be made friable and weed free for sowing of sunnhemp. One ploughing followed by 2-3 cross harrowings are sufficient. In case summer ploughing is done, only two harrowings or ploughing with local plough is needed. After harrowing, the field should be leveled by giving a gentler slope for easy drainage. There should be proper moisture in the soil at the time of sowing for proper germination of seeds.

Seed and sowing :-

Sunnhemp seed losses its viability quickly, therefore the seed older than one year should not be used for sowing.

Seed treatment	:	Seeds are treated with thirum @ of 3g/kg of seed
Seed rate	:	20-25 kg/ha When the crop is sown for green manuring purpose, the seed requirement is 55-60 kg/ha.
Season	:	Kharif and Rabi
Sowing time	:	Kharf – June –July Rabi - Sept. – Oct.
Spacing	:	30 cm in between rows and 7-10 cm plant to plant
Sowing method	:	Fibre purpose :- Drilling Green manuring :- Broadcasting
Depth of sowing	:	3-4 cm

Manures and fertilizer :- Sunnhemp being leguminous crop fulfils its nitrogen requirement through the process of symbiotic nitrogen fixation in nodules on roots. However, it requires about 50 kg P_2O_5 per ha for proper development of roots and nodules and also to stimulate the crop growth. No response to application of potash is observed. The fertilizer should be given at the time of sowing.

Water management :- Generally the crop does not requires any irrigation during kharif season. But in case the crop is sown early in the month of May-June, it may require 1-2 irrigations before rains start. When there is long dry spell one irrigation must be given. The crop at the same time cannot tolerate too much water standing in the field, therefore excess water should be removed from the field after heavy and continuous rains.

Weed management :- There is not much weed problem in sunnhemp crop, because seedling grow very fast and smother all weeds. In problem areas one weeding in the early stage of crop growth is sufficient. Sometimes there is a problem of Ipomoea plants that grow with crop plants and flower and fruit at the same time as sunnhemp. Therefore, they should be removed manually before flowering.

Varieties :- D-IX, M-19, M-35, K-12, ST –55

Cropping system :- It is grown in rotation with wheat, potato, Rabi oilseeds etc. It is grown as mixed crop with ragi, cotton, sesamum etc. By tradition fartmers sow a few lines of sunnhemp on the border of pearl millet, ragi, and sorghum.

Harvesting :- The harvesting of sunnhemp for fibre purpose is done at the pod formation stage for good quality fibre. Such fibre have a good colour and luster. If the plants are allowed to remain in the field until they are dead ripe, the fibre obtained from such plants is of very poor quality. Too early as well as too late harvesting spoils the fibre quality.

When the crop is grown for green manuring purpose it should be incorporated in the soil within 2 moths of sowing. At this time stalks are tender with very little fibre formation and will take less time for decomposition.

Harvesting of fibre crop is done by cutting the plants close to the ground level with a sickle. The leafy top portion of the plants may be chopped off and used either as fodder or may be ploughed down to add organic matted to the soil. After 2-3 days when most of the leaves get dried up these plants are shaken to shed the leaves. The plants are then tried into bundles.

Steeping, retting and extraction :- The bundles are brought to the nearest ponds, ditches, pools or streams and arranged side by side to form platform in water for steeping. In some states, the bundles are covered with hyacinth, grass etc. and the ‘jak’ is weighted down 10-15 cm below the surface of water by stone blocks, concrete slabs or seasoned logs. Substance rich in tannin

like freshly cut logs or clods should not be used as weighing material, because it will turn the colour of the fibre dark. Care should also be taken to see that while weighing down 'jak', the bundles do not touch the bottom of the retting tank. Retting in slow running water is better than retting in stagnant water. This process is complete when the fibre is loose enough for extraction and is easily separated from the sticks. This can be determined by examining 1-2 plants from the bundles after 2-3 days of retting. The period of retting may vary from 3-15 days depending upon the temp. of retting water and the month of harvesting. The optimum temp. for retting is 21-27^{0}C.

The extraction of the fibre of sunnhemp is more difficult than jute. The beat and jerk method is unsuitable in the case of sunnhemp as the tendency of fibre to stick to the wood is more and the fibre gets entangled with broken twings. There fore fibre is extracted single plant wise by breaking the lower ends of the plants and then stripped upwards from the bottom. After extraction, the peeled fibre should be washed thoroughly in clear water to remove the dirt and other adhering plant materials. The fibre needs to be squeezed to remove excess water and spread on bamboo rafts to dry in mild sun for 2-3 days, After drying the fibre is graded and bundled into small 'moras' for marketing

Yield :- 8-10 q of fibre/ha.

Sunnhemp has a fibre content of 2-4% on the basis of the weight of green stem or 8-10% in terms of dry weight

Insect pests :-

1. Stem borer :- They bore into stem near the nodes causing characteristics swelling and affect fibre quality

Control Measures :- i. Grow resistant varieties ii. Spray 0.4 % Diazinon (20 ml in 10 litres of water)

2. Green bug :- Nymphs and adults suck the sap from the leaves.

Control Measures :- Spray the crop with Oxydemeton methyl (Metasystox)25 EC @ 1ml/litre of water

Diseases :-

1. Anthracnose :- Seedling are mostly infected , where spots are developed on the cotyledons. The infected leaves drops out from the seedling and plants.

Control Measures :- i. Seed treatment with thirum @ of 3g/kg of seed ii. Spraying with 0.2% Blitox

2. Rust :- All the above ground plant parts are affected, scattered yellowish brown pistules appear on all the aerial parts . The affected plant tissue dry up.

Control Measures :- i. Grow resistant varieties

ii. Spray Mancozeb 75 WP @ of 2kg in 800-1000 litres of water per ha.

3. Wilt :- The affected plants dry up

Control Measures :- i. Grow resistant varieties like K-12.

ii. Seed treatment with thiram @ of 3g/kg of seed

Dhaincha

B.N. :- *Sesbania aculeate*

Economic Importance :- It is excellent green manuring crop. It adds 200-250 q organic matter per hectare.

Climate :- It can be grown in wide range of climatic condition

Soil :- It can be grown in all types of soil including light to heavy soil.

Land Preparation :- One ploughing and one harrowing is sufficient to obtain good seedbed.

Seed and Sowing :-

Season :- Grown in all season. As rainfed crop it is sown in July –August. But if irrigation is available it can be sown in may also.

Seed rate :-

For green manuring :- 50-60 kg/ha.

For seed purpose :- 20-25 kg/ha. Seed treatment :-

Seed treatment :- Seeds are treated with suitable Rhizobium culture

Spacing :- 40-45 cm in between rows.

Method of sowing :- Broadcasting and Drilling

Manures and fertilizer :- 25 kg N and 50 kg P_2O_5 per ha.

Water management :-

Kharif crops does not require irrigation unless there is dry spell. But when it is grown in summer 5-7 irrigation are required.

Green Manuring :-

It become ready for turning into soil in 45-50 days after sowing. The land is ploughed for incorporation into the soil.

Yield :- Green biomass 200-250 q/ha

Seed yield :- 10 q/ha.

Lecture 16

CULTIVATION OF FORAGE CROPS- SORGHUM, MAIZE, PEARL MILLET,COWPEA, NAPIER, RAINFED AND IRRIGATED GRASSES

Fodder Sorgum (*Sorghum bicolor*)

Sorghum as a green foliage is very popular in most parts of north India and nearly 2.5 million ha area is planted during *kharif*. In summer, under irrigated conditions, multicut sorghum is very popular. Forage sorghum is characterized by quick growth, high biomass accumulation, and dry matter content and wide adaptability beside drought withstanding ability. It is also suitable for silage and hay making.

Varieties:

There are improved varieties and hybrids capable of yielding on an average 50 tonnes/ha in single cut varieties and up to 70 tonnes/ha in multi cut varieties. The dual-purpose varieties and hybrids, CSV 15 and CSH 13 are suitable for both forage and grain production. A promising dual-purpose *kharif* variety SPV 1616 was released as CSV 20 for the states of Andhra Pradesh, Tamil Nadu, Maharashtra, Karnataka, Madhya Pradesh and parts of Gujarat. It has distinct superiority in fodder yield. An early high-yielding hybrid SPH 1290 has been released as CSH 23 for *kharif* season for the Zones 2 and 3 during 2005. This hybrid matures early (103 days) and is superior to the early checks, CSH 14 and CSH 17 for grain and fodder yields. It is also relatively less susceptible to shoot fly, stem-borer and grain mold compared to the checks. A forage sorghum hybrid CSH 20 MF was released in 2005 by GBPUA&T, Pantnagar, for tan, dark green heavy foliage with green midrib. This has medium thick juicy stem and resistant to foliar diseases.

Single cut :

- **Pusa Chari-1 :** Green fodder yield is 28 t/ha and dry matter yield is 8.9 t/ha.
- **Haryana Chari (J5-73/53):** The green fodder yield is 30 t/ha and dry matter yield is 9 t/ha.

- **SL-44:**
- **MP Chari:** The variety matures in 110 days and produces 30 t/ha green fodder and 10 t/ha dry matter yield. **Pusa Chari –6:** It produces 34 t/ha green fodder and 12.5 t/ha dry matter.
- **HC-136:** The variety is tall growing with long and broad leaves and matures in 140 days. It is tolerant
- to foliar diseases. Seeds are creamy and bold. It has low HCN and tannin contents. The fodder yield is 39 t/ha green and 10.8 t/ha dry.
- **Jawahar Chari-6:** It produces 70.2 t/ha green fodder and 20.4 t/ha dry fodder.
- **UP Chari-1 (IS 4776):** The green fodder yield is 33 t/ha and dry matter yield is 8 t/ha
- **Pusa Chari-23:** The variety produces 44.5 t/ha green fodder and 16 t/ha dry matter.
- **Haryana Chari-171 (HC-171):** HC-171 is suitable for *kharif* and summer seasons. It matures in 110 days. It has tall plants having long and broad leaves and is resistant to foliar diseases. The green fodder yield is 35 t/ha and dry matter yield is 9.5 t/ha.
- **Rajasthan Chari- 1:** Green fodder yield is 45 t/ha and dry matter yield is 12.3 t/ha.
- **Rajasthan Chari - 2 (SU- 45):** Green fodder yield is 33 t/ha and dry matter yield is 8.3 t/ha.
- **UP Chari-2:** The green fodder yield is 38 t/ha.
- **Pusa Chari – 9:** The variety produces 42 t/ha green fodder and 10 t/ha dry matter.
- **Haryana Chari-260 (HC-260) :** The variety produces 32 t/ha green fodder and 9.5 t/ha dry matter.
- **MFSH-3:** It produces 65 t/ha green fodder and 14.1/ha dry matter.
- **Pant Chari- 3:** The variety produces 37 t/ha green fodder and 20 q/ha seed.

Double Cut :

- **CO-27:** It provides 40 t/ha green fodder with 9.8% crude protein.
- **Gujarat Forage Sorghum (AS-16):**
- **Gujarat Forage Sorghum Hybrid-1 (GFSH-1):** Its plants are succulent, moderately salt tolerant and is suitable for two cuttings providing 65 t/ha green and 25 t/ha dry fodder.

Multi Cut :

- **SSG 59-3 (Meethi Sudan):** The variety is tall and profuse tillering with quick growth. It is tolerant to drought and water logging. The stems are sweet and thin. The variety produces 75 t/ha green fodder and 22 t/ha dry fodder.
- **Ruchira Maldandi:** The variety was developed by MPKV, Rahuri It is recommended for cultivation in Maharashtra state in 1982. It has multi-cut ability and yields 40–50 t/ha green fodder and 8.2 t/ha dry matter.
- **Jawahar Chari-69:** It becomes ready for 1st cut in 55–60 days and subsequent cuttings at an interval of 40–45 days. It gives 4–5 cuts under irrigated conditions and 2 cuttings under rainfed situation. The total green fodder and dry fodder yield is 53 and 15 t/ha respectively.
- **Proagro Chari (SSG-988):** It is high tillering, thin stem, leafy, dark green in colour producing 40–45 t/ha green fodder. The variety produces 40 t/ha green fodder and 10 t/ha dry matter.
- **PCH-106 (Hybrid):** It has profuse tillering and quick regeneration capacity and provides 3–4 cuts. It yields up to 65 t/ha of green fodder and is recommended for sorghum growing areas in north zone of the country.

Field preparation and sowing:

Normally 2-3 harrowing are required before taking up planting as rainfed crop and sown with the onset of monsoon. Seed rate of 12-15 kg/ha for singlecut and 20-25 kg/ha for multicut sorghum is required. Optimum spacing is 45 cm between rows for multicut sorghum and 30 cm for single cut sorghum. As regards fertilizer application 100 kg N and 60 kg P2O5/ha for multicut sorghum and 80 kg N and 40 kg P2O5 /ha for

single cut sorghum is recommended. In forage sorghum, the mixed cropping is also practiced with fodder legumes, viz. cowpea and clusterbean, in 2:1 ratio to improve fodder yield and quality.

Harvesting:

Since HCN is present in sorghum especially in early stages up to 40- 50 days, proper care has to be exercised during harvesting for avoiding HCN poisoning.

Single cut varieties are harvested at 50% flowering to full bloom stage and in multicut varieties the first harvest is taken at 55 days after sowing and subsequent cuts at 40 days interval.

Pearl millet (*Pennisetum glaucum*)

Pearl millet is the fourth most important grain crop next to rice, wheat and sorghum. The crop is cultivated for grain as well as fodder in the semi arid tropical regions of Africa and Asia including India. In India, annual planting area is around 10 million ha producing nearly 7.5 million tonnes of grains. It is grown mainly in Rajasthan, Maharastra, Gujarat, Uttar Pradesh, Haryana, Karnataka, Tamil Nadu and Andhra Pradesh.

Pearl millet traditionally is an indispensable component of dry farming system. With the advent of pearl millet hybrids in mid sixties, its cultivation doubled. The crop is mainly confined to low fertile water deficit soils. Because of its remarkable ability to withstand and grow in harsh environment, reasonable and assured harvests are obtained. The crop responds to nitrogen, cultural management, and water harvesting.

Soil and climate:

The crop is mostly grown in *kharif* season from June to October. Crop grows on a wide range of soils from very light soils from sand dunes in Rajasthan to red loams of Karnataka and Maharatsrta.

Seed rate and sowing:

The recommended spacing is 45 cm between rows and 10-12 cm between plants within row. The seed rate of 8-10 kg/ha for single cut and 12-15 kg/ha for multicut is required to obtain desired yields.

Manures and fertilizers:

It responds well to applied nutrients. Besides recommended dose of fertilizers, application of 8-10 tonnes of FYM is also helpful as it conserves moisture. An application of 20-40 kg N/ha in 2 split doses is recommended in Rajasthan, while in Gujarat, Haryana and Maharatstra, 60-80 kg N/ha is recommended as optimum. Application of 20 kg ZnSO4/ha enhanced grain and fodder yields. Also foliar application of ZnSO4/ha at tillering and pre-flowering stage increased grain and fodder

yield. Maximum grain yield was recorded in plots of dust mulching when trial was conducted to mitigate the adverse effect of drought stress under rainfed condition.

Spray of 0.1% thiouorea at tillering and flowering stages also helped to mitigate drought stress.

VARIETIES

- **Giant Bajra:** The variety was developed by MPKV, Rahuri by intervarietal hybridization between Australian and local bajra from Dhule district followed by selections. The variety has been recommended for cultivation in entire bajra growing area. Plants are leafy with profuse tillering and have 9-10% protein at boot stage. The variety is good for hay and silage making. It is moderately resistant to downy mildew and ergot diseases. The green fodder yield is 50–75 t/ha.
- **Raj Bajra Chari-2:** The variety was developed by RAU, Jobner. The green fodder yield is 30–45 t/ha and is resistant to foliar diseases and insect-pests.
- **CO-8:** The variety was bred by TNAU, Coimbatore by hybridization (732 A × Sweet Giant Bajra) followed by pedigree selection. It was released for entire bajra growing areas of the country. It is ready for fodder harvest in 50–55 days and produces green fodder to the tune of 30 t/ha.
- **TNSC-1:** The variety was bred by TNAU, Coimbatore and recommended for cultivation in the entire bajra growing area of the country in 1995. The variety provides 27–40 t/ha green fodder and is resistant to foliar diseases and insect-pests.
- **APFB-2:** The variety was developed by recurrent selection in the randomly mated population at ANGRAU, Hyderabad in 1997. It was recommended for cultivation in Andhra Pradesh. It belongs to early maturity group, non-lodging, fertilizer responsive, best suited to summer and early *Kharif* sowings. The plant height is 160–180 cm providing green fodder yield 25 t/ha and dry fodder yield 5.5 t/ha in a single cut. The variety is useful for multi-cut also in the summer season.

- **Proagro No. 1 (FMH-3):** This variety was developed by Proagro Seed Company, Hyderabad through hybridization of PSP-21 × PP-23. The variety is recommended for cultivation throughout the pearl millet growing areas of the country. The plants require 50-55 days for flowering and matures in 90-95 days. The variety is highly resistant to downy mildew and provides 75 t/ha green fodder in multi cut system and 36 t/ha in single cut system.
- **GFB-1:** The variety has been bred by GAU, Anand and released in 2005.
- **PCB-164:** The variety has been developed by PAU, Ludhiana from five late maturing lines. It was released and notified for cultivation in North West India.
- **FBC-16:** The variety has been bred by PAU, Ludhiana and notified for cultivation in the entire north-west India. This is a multi-cut variety, resistant to major diseases. The green fodder yield potential is 70–80 t/ha.
- **Avika Bajra Chari (AVKB-19):** The variety has been bred by IGFRI- RRS, Avikanagar by selection from material collected from Nagore, Rajasthan in 2006. The variety is recommended for cultivation in the state of western Uttar Pradesh, Rajasthan, Haryana, Punjab and Tarai region of Uttarakhand. The variety is a dual purpose with green fodder yield potential of 36.7 t/ha, dry fodder 8.8 t/ha and 10.2 q/ha seed yield.
- **Narendra Chara Bajra-2 (NDFB- 2):** The variety has been developed by NDUA&T, Faizabad and is recommended for cultivation in pearl millet growing areas in north-east zone under salt-affected soils.

Inter-cultivation and weed management:

The fields should be maintained free from weeds for the first 30 days as it is very important to ensure good crop growth. Two inter-cultivation and one hand weeding is necessary to minimize weed competition. Chemical weed control with Atrazine @ 0.5 kg ai/ha given as pre-emergence spray is also useful.

Diseases and pest management:

Crop is comparatively less prone to pests and diseases. However, downy mildew among diseases, shoot fly and root grub among pests are prevalent in many

states. Choice of diseases resistant variety is an important step in effectively managing the diseases. A seed treatment with Apron 35 SD @ 2 g ai /kg seeds followed by Ridomil 25 WP (1,000 ppm) spray 20-25 days later will effectively check the disease. Rotation of different varieties and hybrids in alternate years is also effective in arresting spread of downy mildew. Seed treatment with *neem* oil 5 ml/kg seed + spray of 5% (*neem*-seed-kernel extract (N.S.K..E.) at 50% flowering was found effective in controlling pests. Plant-protection measures are essential for white-grub and shoot fly. White-grub infestation is managed by mixing of Phorate 10G or Quinalophos 5G @ 12 kg /ha with seed and applying in furrows at sowing. Four varieties, MH 1336, MH 1364, MH 1392, and Pusa 383, were found to be resistant to smut ergot and blast**.**

Pearl millet-based cropping systems:

In Rajasthan, intercropping of pearl millet with clusterbean or *moth* bean or cowpea or greengram in 2: 1 proportion is followed. This not only covers the risk due to failures of monsoon but also provides the grain legumes which help in better nutritional security and as source of additional income. In most parts of north India, Andhra Pradesh, Maharatsrtra, Tamil Nadu, and Karnataka, intercropping of pearlmillet with pulses is followed, viz. red gram/ green gram/ cowpea/horsegram/ clusterbean.

Harvesting and yield :

Boot leaf stage to 50% flowering is best time for harvesting bajra for fodder as well as silage making.

Harvesting should be done after 50 days of sowing. After first cutting, when crop height becomes one meter, take second cutting. Do not allow to grow crop for more than 2 meter as it will leads in decreased in nutritional value of fodder. Such fodder is heavy for digestion.

Yield :

- **Rainfed crop :** 15-20t/ha - Dryland crop.
- **Irrigated crop :** 35-50 t/ha.

Maize (*Zea mays*)

Maize in India ranks fifth in total area and third in total production and productivity. The level of production has to be raised because of substantial demand as food, feed and poultry feed. Maize can successfully be grown as *kharif, rabi* and *zaid* crop. Presently, the maize crop is grown in 20-30% irrigated conditions only.

Varieties:

Mostly maize is grown during rainy season. Some cultivars require 60-70 days to mature; others require 100-110 days to mature. Grain colour also varies from yellow to orange to white. Mainly flint types are preferred.

- **African Tall Composite:** The variety was bred at MPKV, Kolhapur and is a composite of seven genotypes (H-611 C, H-611, H-611 (R)C3, K-III × EC-573 (R12) C3, Ukiri Comp A (F) C5 × Ukiri Comp A, (F) C3, Chitedge Comp A and Ilonga Comp) developed through modified mass selection technique. It has more dry matter and crude protein content, more number of leaves/plant, more leaf area, good grain and seed yield potential than other grain varieties. The variety is resistant to foliar diseases and stem borer. The average plant height is 260 cm and provide 60–70 t/ha green fodder and 30 q/ha grain. It is released for cultivation throughout the country.
- **APFM-8:** This variety was developed at ANGRAU, Hyderabad in 1997 and is suitable for cultivation in south zone of the country. This is a synthetic variety derived from Varun (V- 41) and Palampur local varietal cross advanced by mass selection. It is leafy, non-lodging, orange grain variety, plant height 180– 200 cm, sturdy plants type with dark green leaves. The seed to seed maturity is 90–95 days during *kharif* and 105–110 days in winter. It provides 35 t/ha green and 7.5 t/ha dry fodder.
- **J-1006:** The variety was developed at PAU, Ludhiana by crossing 'Makki safed 1-DR' × 'Turpeno PB' and released in 1992 for cultivation in Punjab. It is resistant to Maydis blight, brown striped downy mildew and stem borer.

- **Pratap Makka Chari 6:** The variety was developed by MPUA&T, Udaipur by compositing 11 early to medium white seeded entries. The variety was released in 2008 for north-west zone of the country covering Punjab, Haryana, western UP, Rajasthan and Uttarakhand. Average green forage yield is 35 t/ha. It matures in 90–95 days. Its green fodder yield potential is 45–50 t/ha. It is released for cultivation in Punjab.

Soil:

Very sandy soils rapidly respond to management practices than those that are fine textured. Intermediate texture of loam to silt loam in surface horizon and little higher content of clay as silt loam to silty clay loam in subsoil is the most ideal. Soil pH of 7.5-8.5 supports good crop growth, as the crop is grown under rainfed conditions it is important that soil must have good water holding capacity, with proper drainage system to avoid waterlogging conditions.

Seed rate and sowing time:

About 50-60 kg seed would be needed to sow one hectare. Seed should be grown 5 cm deep into soil for good germination, seedling growth and vigour. Transplanting should be avoided as the plant cannot cope up with main crop stand. It is preferred to sow 10-15 days before start of rain which will give 15% higher yield.

- Spacing : 30 cm x 10 cm plant population is 3,33,333

Manures and fertilizers:

A balanced application of 60-120 kg N, 40-60 kg P and 40kg K/ha is recommended. Early maturing varieties require less quantity than full season maturity crops. It is also advisable to apply 20 kg zinc sulphate /ha along with basal dose of fertilizer. One-fourth of nitrogen and entire quantity of phosphorus, potassium and zinc should be applied 5-7 cm deep before sowing. The rest of the doses are applied at knee-high stage and after emergence of flag leaf but before tassel emergence.

Irrigation:

To ensure high and stable yield, it is desirable to give 1 or 2 irrigations at critical stages. Flowering and grain-filling stages are most critical; the crop should be irrigated at these stages, if rain fails.

Intercropping:

Short-duration varieties of pulse crop, oilseed crop and vegetable can successfully be grown as intercrop. A ratio of 2 rows of maize with 1 row of other desired crop can be adopted.

Harvesting:

In absence of irrigation, crop can be harvested at any stage, at preflowering it can be used as fodder and at dough stage green ear and stover may be used for cattle. For fodder purpose, the milk to early dough stage is preferred for higher yield and protein content. For silage, late dough stage is preferred.

Yield : 350 to 450 q/ha

Cowpea (*Vigna unguiculata*)

Cowpea is native to Africa and Asia and is now cultivated throughout the tropics and sub tropics. It is used as pulse, vegetable fodder and green manure. It is of considerable importance in dryland farming.

Nutritive value :

Cowpea is used as fodder crop for green feeding, hay making, grazing and also for ensiling in mixtures with sorghum or maize. The grains are used as human food as well as animal feed. Cowpea is also used as green manure crop and as cover crop in plantations. The feeding value of cowpea forage is high. It is superior to other legumes like soybean because of its low fibre content and minimum wastage in feeding livestock.

The crop can support a 6-7 kg milk yield/ cow/ day without any concentrate supplement. It can be used as a dual purpose crop; that is the green mature pods are removed for human consumption and the residual fodder is used as a cattle feed. When so used, the residual crop forms an excellent fodder which is comparable with any legumes and can support growth and milk production up to 5 kg daily, without any concentrate supplement.

The early fresh leaves and stalks contained 18.0% crude protein, 3.0% ether extract and 26.7% crude fibre. The total digestible nutrient is 59.0% in early and 58.0% in mature cowpea fodder. The calcium and phosphorus content is 1.40 and 0.35%, respectively.

Soil and climate:

It is adapted to variety of soil types, viz. red loam, black clay loam, coarse gravel, sandy loam, light sandy soils. It is also grown in sloppy land in hilly tracts and heavy loam soils. It is more tolerant to heavy rainfall than any other pulse crop. It suffers from water stagnation and heavy drought. It thrives well under the temperature range of 21-35°C.

Cropping system:

The crop is usually grown as dryland *kharif* crop and can also be grown as pre-monsoon and late monsoon crop. It is also grown as second crop during *rabi* after rice in southern parts of country.

VARIETIES :

- **Cowpea-74:** The variety was developed by PAU, Ludhiana by hybridization (FS 68 ×strain No. 102) followed by selection.
- **Kohinoor:** This variety was developed by IGFRI, Jhansi The plant height is 55-70 cm, stem green in colour, pods are green with a smooth surface and horizontally dispositioned with tendency to droop. The seeds are bold and red. Average green fodder yield is 40-45 t /ha and average dry fodder yield 50-60 t/ha.
- **HFC-42-1 (Hara Lobia):** This is an erect variety with dark green foliage and is suitable for mixed cropping. The variety has been developed by CCS HAU, Hisar and is suitable for cultivation in Haryana and Punjab. It gives green fodder yield of 26.2 t/ha.
- **Cowpea-74:** This is a variety from PAU, Ludhiana developed from irradiation of F1 of cowpea-74 × H2 for Punjab State.
- **EC 4216:** The variety was developed by IARI, New Delhi through selection from exotic material. The plants are erect to semi-erect, 140-150 cm long and climbing type. The green fodder yield is 30 t/ha and dry matter yield is 5.5 t/ha.
- **Type-21:** The variety was developed by IGFRI, Jhansi through single plant selection. The plants have dark green leaves and provides 33 t/ha green fodder and 5 t/ha dry fodder.
- **GFC-1 (Gujarat Forage Cowpea-1):** The variety was developed by selection from local collection from Chharodi area of Gujrat by GAU Banaskantha. The plant has a trailing habit with a height of 125 cm. It takes 65–70 days for 50% flowering and has dark green pods. It is recommended for *kharif* sowing in Gujrat and provides 25–30 t/ha green fodder.

- **GFC-2 (Gujarat Forage Cowpea-2):** This is a variety developed by GAU, Banaskantha through selection of local material. The variety gives 20 t/ha green fodder and 3–4 t/ha dry fodder. The protein content is 14–19%.
- **GFC-3 (Gujarat Forage Cowpea-3):** The variety is developed by GAU, Banaskantha, Gujrat through selection of local material. The plants are trailing type and are 196 cm long. It provides 20 t/ha green fodder and 3–4 t/ha dry fodder. The protein content is 17.5–19.5%.
- **GFC-4 (Gujarat Forage Cowpea-4):** This is a variety developed by GAU, Banaskantha through selection from Chharodi area of Gujrat and it performs well during summer season. The variety gives 20 t/ha green fodder and 3.0–3.5 t/ha dry fodder.
- **UPC-5286:** The variety was developed by GBPUA&T, Pantnagar through single plant selection. The variety matures in 140–150 days with green fodder yield of 35 t/ha.
- **CO-5:** This variety was developed by TNAU, Coimbatore and is a gamma irradiated mutant of CO- 1. It has been recommended for cultivation in south zone of the country. It produces 30 t/ha of green fodder.
- **UPC-5287:** The variety has been developed by GBPUA&T, Pantnagar from single plant selection from CK-74-5287 followed by selection on single pod basis and bulking on plant basis. The variety matures in 155–170 days with green fodder yield of 26 t/ha.
- **UPC – 287:** The variety has been developed by GBPUA&T, Pantnagar using single plant selection from germplasm line CK-72-287. It provides green fodder yield of 17 t/ha. The variety takes 135–140 days for 50% flowering and 135–145 days for maturity. The green fodder yield is 30–35 t/ha.
- **Sweta (No. 998):** This is a variety developed by MPKV, Rahuri.
- **Charodi:** This variety has been developed at GAU, Anand and has been notified for cultivation in Gujrat state.

- **Cowpea-88:** This variety was developed by PAU, Ludhiana from irradiation of F1 of intervarietal cross (cowpea-74 × H2) and has been notified for cultivation in Punjab state.
- **UPC-4200:** This variety was developed by GBPUA&T, Pantnagar by pure line selection from CK-76-4200. The variety has been recommended for cultivation in north east zone of the country. The variety yields 30.0–32.5 t/ha green forage and is resistant to collar rot, wilt and pod borer.
- **Bundel Lobia-1 (IFC - 8401):** The variety was developed by IGFRI, Jhansi through single plant selection from IL-515. It is ready for green fodder harvest in 60–65 days. The green fodder yield, dry-matter yield and crude protein are 30–35, 4–5 and 0.60 t/ha respectively.
- **Bundel Lobia-2 (IFC - 8503):** The variety was developed by IGFRI, Jhansi through single plant selection from IL-978. The fodder yield (t/ha) is 30–35 green and 3.5–4.0 dry with 63.8% IVDMD and 17% crude protein.
- **UPC- 8705**: The variety was developed by GBPUA&T, Pantnagar and is a derivative of the cross (N-425 × H-288). It provides green fodder yield of 35–40 t/ha and dry fodder yield of 5.3 t/ha. The variety takes 80–90 days for 50% flowering and 140–145 days for seed maturity.
- **CS – 88 (Haryana Lobia - 88):** The variety has been developed by CCSHAU, Hisar by hybridization of C-28 and HFC- 42-1 followed by pedigree selection. This is suited for cultivation in summer and rainy season providing 31 t/ha green fodder with erect growth nature, good early vigour, having long and broad leaves, it is suitable for mixed cropping.
- **Konkan Fodder Cowpea-1: (DFC-1):** The variety has been developed by KKV, Dapoli through selection from local germplasm material of Ratnagiri district. It comes to 50% flowering in 60–65 days. It takes 100 days for seed to seed maturity. It provides 23–25 t/ha green fodder during *kharif* and 20–22 t/ha during *rabi*. The dry matter yield is 5 t/ha. The seed yield is 7–8 q/ha.

- **UPC- 9202:** The variety has been developed by GBPUA&T, Pantnagar by pedigree selection from intervarietal cross (V-260 × UPC 9805-7-2-4). The variety has been notified for cultivation in sub-tropical to tropical regions of central zone of the country comprising of MP, Gujrat and Maharashtra. It is a medium late variety which matures in 80–85 days. It provides 35–40 t/ha green fodder.
- **UPC 607:** The variety has been developed by GBPUA&T, Pantnagar by selection from intervarietal cross (L-212 × Singapore) - 48-2-9. The variety matures in 140–150 days. The variety has been notified for cultivation in subtropical to tropical plains of north-west zone comprising Uttaranchal, northern Uttar Pradesh, tarai belt, Punjab, Haryana and Rajasthan. It provides 35–40 t/ha green fodder and 4.5–5.0 t/ha dry matter.
- **CL-367:** The variety has been developed by PAU, Ludhiana (Cowpea 74 × Strain No. 90) and bulked in F6 generation. It has been recommended for irrigated areas of Punjab. This is an early short duration variety which provides 27 t/ha green fodder and 12.3 q/ha seed yield.
- **UPC – 618:** The variety has been developed by GBPUA&T, Pantnagar from cross (UPC-8703 × IT-84 E-124 -2-5-1). The variety has been notified for cultivation in Uttranchal, UP, Punjab, Haryana, Rajasthan, Jharkhand, West Bengal, Orissa, Assam, MP, Gujrat and Maharashtra. It is medium late variety which matures in 140–150 days. It provides 30 t/ha green fodder and 4.5–5.0 t/ha dry matter
- **UPC-622:** The variety has been developed by GBPUA&T, Pantnagar through single plant selection. The variety is recommended for cultivation in north-west, north–east and hill zone of the country.
- **UPC- 621:** The variety is developed by GBPUA&T, Pantnagar. This variety is released for cultivation in the lower hills and plains of Uttrakhand. The green fodder yield is 32.5–35.0 t/ha and dry fodder yield is 50–55 q/ha at 50% flowering stage in 85–90 days. The seed yield is 6-8 q/ha in uncut crop. DM digestibility is 60–65% with 16-17% CP besides lower ADF and NDF. Slight

twining tendency character is suitable for mixed/intercropping with sorghum, maize, bajra and other cereal forages during summer and *kharif* season.

Cultivation:

Fields should be prepared well for sowing. The crop is sown in the first week of July in the hills and in the second fortnight of March in lower hills and in October in plains. One hand weeding or hoeing 30-35 days after sowing or application of weedicide Pendimethalin @ 1.0-1.5 kg a.i /ha immediately after sowing helps in control of weeds. The crop requires adequate moisture. In plains, 3-4 irrigations are required. About 120 kg N and 80 kg P/ha are recommended. Half the nitrogen is applied as basal dose and half for top dressing. The crop matures in 120-125 days. The row to row spacing is 30-45 cm. The recommended seed rate is 20-25 kg/ha. Seed yield up to 1.0 tonnes/ha is obtained.

Napier grass-cumber napier (P. glaucum)

It is a tall growing (200–300 cm) erect, stout, deep-rooted perennial hybrid grass derived from *P. glaucum* × *P. purpureum.* The crude protein content is 10.1%.

Origin: Native of Rhodessia and South Africa.

Distribution:

It is widely distributed in tropical and subtropical regions of Asia, Africa, Southern Europe and America. In India, it is grown in Punjab, Uttar Pradesh, Haryana, Gujarat, Madhya Pradesh, Bihar, Orissa and West Bengal.

Climate: It grows well under warm tropical conditions.

Soil: Loamy soil with good drainage is good. It can withstand in saline soils to some extent.

Season: It is cultivated throughout the year under irrigation.

Varieties:

- BN 2 – Green fodder yield of 250 t/ha/year
- NB21 – 225 t/ha/year
- CO1 – 250–300 t/ha/year
- CO2 – 350–385 t/ha/year
- CO3 – 380–400 t/ha; higher foliage, low oxalic acid content
- (2.8–2.9%) Non-lodging, profuse tillering, more leafy.

Field preparation:

The field is ploughed with Iron plough 2–3 times to obtain good tilth. Ridges and furrows are formed using ridge plough (Ridger), 6 m long and 50 cm apart.

Seeds:

It is multiplied by vegetative propagation by two nodded stem cutting or by root slips. For sole crop: 40,000 slips or stem cuttings/ha. For inter cropping with one row of Desmanthus: 30,000 slips/ha.

Transplanting:

Irrigate through furrows and plant one rooted slip per hole at a depth of 3–5 cm on the side of the ridges. A spacing of 50 × 50 cm with 40,000 slips/ha is maintained. As

a mixed crop, 3 rows of cumber napier hybrid and one row of desmanthus can be raised to increase the nutrient value.

The following inter cropping systems are suggested:

- CNH + desmanthus at 3:1 ratio
- CNH + lucerne + oat
- CNH + velvet beans
- CNH + cowpea + berseem

Fertilizer application:

FYM: 25 t/ha of FYM/compost is applied and incorporated.

It is applied as per soil test recommendation. If it is not possible, blanket recommendation of 50:50:40 of NPK kg/ha is followed. Full dose of NPK is applied before planting by opening furrow 5 cm deep on the side of the ridges and cover.

Water Management:

Life irrigation on 3rd day is given and thereafter once in 10 days. Sewage or wastewater can also be used for irrigation.

After cultivation:

Hand weeding and hoeing is done on 30 DAP (days after planting). Thinning and gap filling is done to maintain plant population. Earthing up is done once after 3 cuts and remove dried leaves once a year.

Harvest: First harvest is on 60 DAP and subsequent harvests at interval of 45 days.

Green fodder yield: 380 t/ha/year.

RAINFED AND IRRIGATED GRASSES

Forage Grasses

Package of practices	Name of the crop		
	Dinanath Grass	**Rhodes Grass**	**Marvel Grass**
Botanical Name	*Pennisetum pedicellatum*	*Chloris gayana*	*Dicantium annulatum*
Rainfall (mm)	800-2000	1250-1500	300-2000
Soil	Clay loam to Sandy loam	Loam to Sandy loam	Medium to heavy
Sowing time	June. – July (N) Feb. – Nov. (S)	Mar. – Aug (N) Feb. – Nov. (S)	June-July (N) Feb. Nov. (S)
Seed rate (kg/ha.)	8-9	5-8 Root cutting 27,780	4-5
Row spacing (cm)	50 x 30 60 x 40	60x60	50x30 40x40
Manuring/ha.	FYM 10 tonnes N – 90 kg P_2O_5 – 30 kg K_2O – 20 kg	FYM 20 tonnes N – 20 kg after each cut P_2O_5 – 30 kg	FYM 5 tonnes N – 60 kg P_2O_5 – 20 kg K_2O – 20 kg
Weeding	Two	Two	1-2
Irrigation	-	1-2	-
Harvesting	1st cut at 90 days and 2nd cut 60 days interval	1st cut 80 days, Subsequent cuts 30-35 days interval	In establishment year one in mid Oct. In subsequent years 1st cutting after 60 days and 2nd 30-45 days interval
No. of cuts	Two	5-6 (N) 10-12 (S)	1st year 1 cut 2nd year 2-3 cuts
Fodder yield	750-800 q/ha	700-800 q/ha (N) 1500-1750 q/ha. (S)	200-250 q/ha

Forage Grasses

Package of practices	Name of the crop		
	Sain grass	**Blue panic**	**Anjan Grass**
Botanical Name	*Sehima nervosum*	*Panicum antidotale*	*Cenchrus ciliaris*
Rainfall (mm)	300-2000	500-700	125-1250
Soil	Red, dark, grey, gravelly	Fertile Sandy loam	Sandy to sandy loam
Sowing time	June. – July	June. – July	June-July (N) Feb. Nov. (S)
Seed rate (kg/ha.)	7-8	2.5 - 4	5-6
Row spacing (cm)	50 x 40 50x 0 (Transplanting)	50 -75 in rows	50x30 75x50
Manuring/ha.	FYM 10 tonnes N – 60 kg P_2O_5 – 20 kg	FYM 12-15 tonnes N – 30 kg P_2O_5 – 25 kg K_2O – 25 kg	FYM 5 tonnes N – 45 kg P_2O_5 – 20 kg K_2O – 20 kg
Weeding	1 - 2	Two	1-2
Harvesting	In establishment year one in mid Oct. In subsequent years 1st cutting after 60 days and 2nd 30-45 days interval	1st cut 3-3½ months from sowing, 2nd cut after 2 months. In following years clipping done every 2 months.	
No. of cuts	1st year 1 cut 2nd year 2-3 cuts	4-5 (N) 6-7 (S)	1st year 1 cut 2nd year 2-3 cuts
Fodder yield	250-300 q/ha	50-70 q/ha (Dry)	300-350 q/ha
Varieties			CAZRI 358, Marwar Anjan, Biloela, IGFRI 3108.

Forage grasses

Package of practices	Name of the crop		
	Napier Grass or elephant grass	**Guinea grass**	**Para grass**
Botanical Name	*Pennisetum purpureum*	*Panicum maximum*	*Brachiaria mutica*
Rainfall (mm)	Warm tropical climate,	1200-1500	1000 to 1500
Soil	Variety of soil especially soil having good moisture retention capacity	Loam to clay loam	Loam to clay loam, moist soil
Varieties	Pusa Giant, NB 21,Pusa Napier 1, Pusa Napier 2 , NB 5,	Hamil Panic, Coloniao, Sabi,	
Sowing time	June-July	Mar.- Aug. (N) Feb.-Nov. (S)	Mar.- Aug. (N) Feb.-Nov. (S)
Seed rate (kg/ha.)	27,800 root slips or stem cuttings	3-4 kg or 20,000 rooted slips	27780 sets
Spacing (cm)	90 x 60	100 x 50	60 x 60
Manuring/ha.	FYM 20 tonnes N – 40 kg after each cut P_2O_5 – 30 kg K_2O – 20 kg	FYM 20-25 tonnes N – 30-40 kg after each cut P_2O_5 – 30 kg	FYM 25-30 tonnes N – 40 kg after each cut P_2O_5 – 30 kg
Harvesting	1st cut 75 days subsequent cut at 45 days interval	1st cut 70-75 days subsequent cut at 40-45 days intervals	1st cut 80-85 days subsequent cut at 30-35 days
No. of cuts	8	5-6 (N) 10-11 (S)	4-5 (N) 10-11 (S)
Fodder yield	1200-1500 q/ha.	750-850 q/ha (N) 1500-1600 q/ha (S)	1500-1750 q/ha (N) 2000-2500 q/ha (S)

Forage grasses

Package of practices	Name of the crop	
	Hybrid Napier	**Napier Grass or elephant grass**
Botanical Name	*Pennisetum purpureum x P. americannum*	*Pennisetum purpureum*
Climate	Rainfall - 800-1000 mm	Warm tropical climate,
Soil	Sandy loam to clay loam	Variety of soil especially soil having good moisture retention capacity
Varieties	Pusa Giant, NB 21,Pusa Napier 1, Pusa Napier 2 , NB 5,	Pusa Giant, NB 21,Pusa Napier 1, Pusa Napier 2 , NB 5,
Sowing time	Mar.- Aug. (N) Feb.-Nov. (S)	June-July
Seed rate (kg/ha.)	i. 27,780 ii. 33,346 iii. 10,000 rooted slips	27,800 root slips or stem cuttings
Spacing (cm)	i. 60 x 60 ii. 100 x 30 iii. 100 x 100	90 x 60
Manuring/ha.	FYM 25 tonnes N – 40 kg after each cut P_2O_5 – 30 kg K_2O – 20 kg	FYM 20 tonnes N – 40 kg after each cut P_2O_5 – 30 kg K_2O – 20 kg
Harvesting	1st cut 75 days subsequent cut at 45 days interval	1st cut 75 days subsequent cut at 45 days interval
No. of cuts	6-8 (N) 8-10 (S)	8
Fodder yield	150 -200 t/ha (Green)	120-150 t/ha. (Green)