Introduction to major field crops

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CLASSIFICATION OF FIELD CROPS

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CLASSIFICATION OF FIELD CROPS

Introduction

"A man without food for three days will quarrel, for a week will fight and for a month or so will die". Agriculture is a branch of applied science. Agriculture is the science and art of farming including cultivating the soil, producing crops and raising livestock. It is the most important enterprise in the world.

Among all the branches of agriculture, agronomy occupies a pivotal position and is regarded as the 'mother' or 'primary' branch. The word Agronomy has been derived from two Greek words i.e., '*agros'* meaning field and '*nomos'* meaning to manage. Literally it means the art of managing fields and technically it means the science and economics of crop production. In other words it is the art and underlying science in production and improvement of field crops with the efficient use of soil fertility, water, labour and other factors related to crop production. Agronomy is the field of study and practice of ways and means of production of food, feed and fibre crops. Thus, agronomy as a branch of agricultural sciences deals with principles and practices of field management for the production of field crops.

Classification

Classification of field crops is necessary to know the adaptation, habitat, life cycle, nutrient requirement, insect-pest and disease reaction of crops, so that an appropriate production technology could be developed and adopted for maximum productivity at minimum cost.

Crop plants are grouped into three main classes according to the range of cultivation. They are as follows.

1. Garden Crops: Crop plants that are grown on a small scale in gardens such as kitchen gardens, flower gardens and backyard gardens.

2. Plantation Crops: Crop plants that are grown on a larger scale on estates. They are perennial or permanent in nature.

3. Field Crops: Crop plants that are grown on a vast scale. They are mostly seasonal.

Among these three classes agronomy deals with field crops only. Field crops are classified in many ways. According to economic or agrarian or agricultural classification or classification according to use of crop plants and their products, field crops are classified as follows.

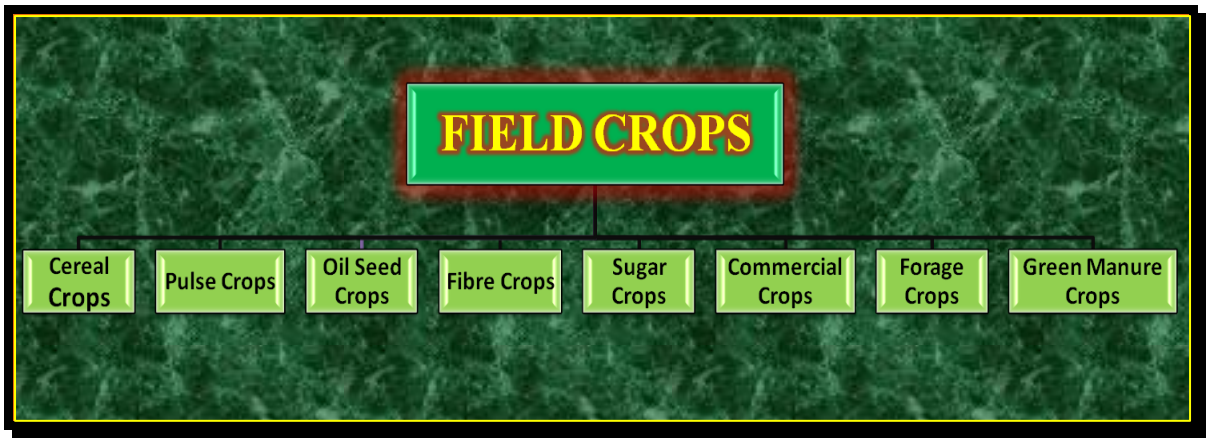

Fig: Classification of Field Crops.

I. Cereal Crops

A cereal is generally defined as a cultivated grass grown for their edible starchy grains. Bulk of staple food crops all over the world comes from this group.

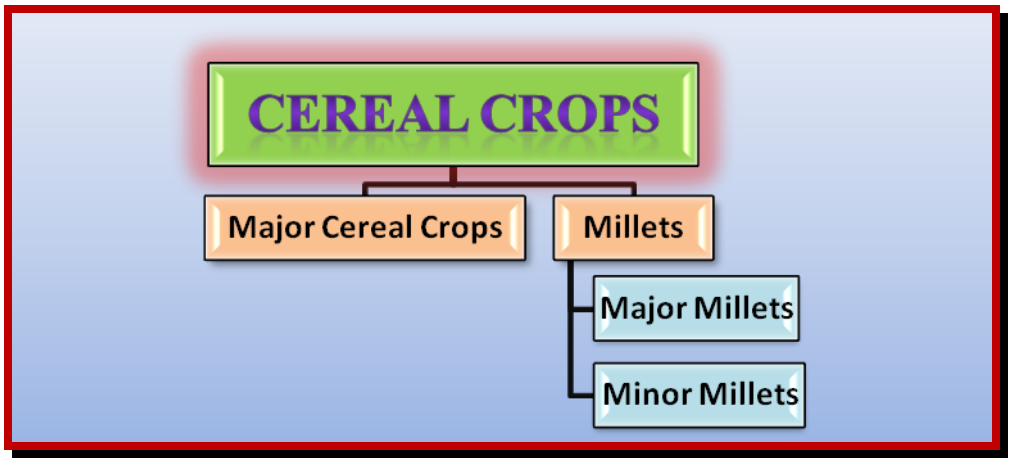

Fig: Classification of Cereal Crops.

A. Major Cereal Crops

In general, the larger grains are used as staple food is considered as major cereals.

1. Paddy/Rice : *Oryza sativa*
2. Wheat : *Triticum aestivum*
3. Maize/Corn : *Zea mays*
4. Barley : *Hordium vulgare*

B. Millets

Millets are a group of small grained cereals which are of minor importance as food and they have a single cover. Millets are further classified into two groups.

a) Major Millets

1. Sorghum/Jowar/ Great millet : *Sorghum bicolor*
2. Bajra/Pearl millet : *Pennisetum typhoides*
3. Ragi/Finger millet : *Eleusine corcana*

b) Minor Millets

1. Foxtail millet/Navane : *Setaria italica*
2. Little millet/Saame : *Panicum milliare*
3. Kodo millet/Haraka : *Paspalum scrobiculatum*
4. Proso millet/Baragu : *Panicum millaceum*
5. Barnyard millet/Udlu : *Echinochloa frumentaceae*

II. Pulse Crops

Pulses are grain legumes used as food. On splitting they produce dal which is rich in protein. They are regarded as building blocks of living organisms for high protein content. These crops have the unique built in ability of fixing atmospheric nitrogen in their root system.

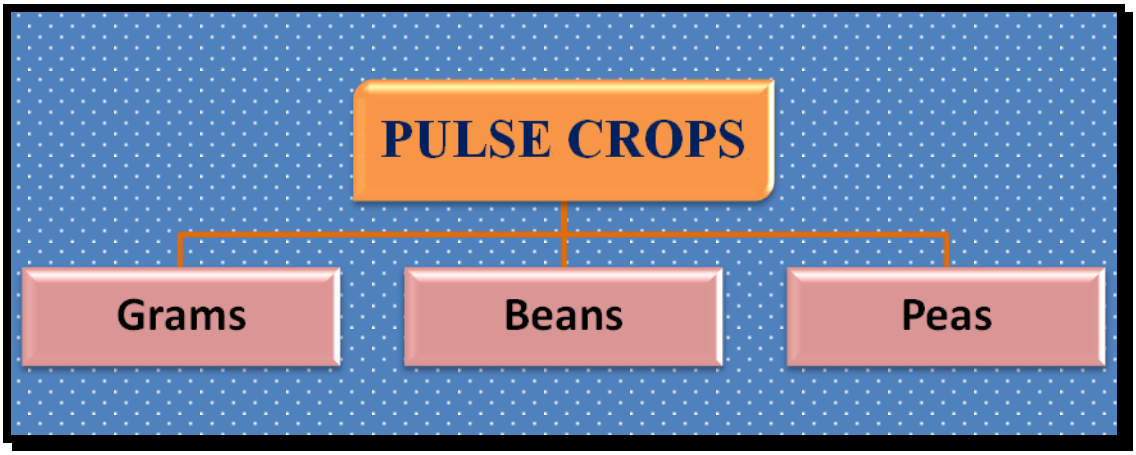

Fig: Classification of Pulse Crops.

a) Grams

1. Red gram/Pigeon pea : *Cajanus cajan*
2. Bengal gram/ Chick pea : *Cicer arietinum*
3. Black gram/Urd : *Phaseolus mungo/Vigna mungo*
4. Green gram/Mung : *Phaseolus aureus/Vigna radiata*
5. Horse gram : *Macrotyloma uniflorum*

b) Beans

1. Soybean : *Glysine max*
2. Field bean/Avare : *Dolichos lablab*
3. French bean : *Phaseolus vulgare*
4. Lima bean/ Double bean : *Phseolus lunatus*

5. Winged bean : *Psophocorpus tetragonolobus*
6. Cluster bean : *Cyamopsis tetragonoloba*
7. Moth bean : *Vigna aconitifolia*

c) Peas

1. Pea : *Pisum sativum*
2. Cow pea : *Vigna unguiculata/V. sinensis*

III. Oil Seed Crops

Oil seed crops are grown for the purpose of oil. The seeds of these crops are rich in fatty acids and are used to extract vegetable oil to meet edible oil, industrial and plant protection requirements.

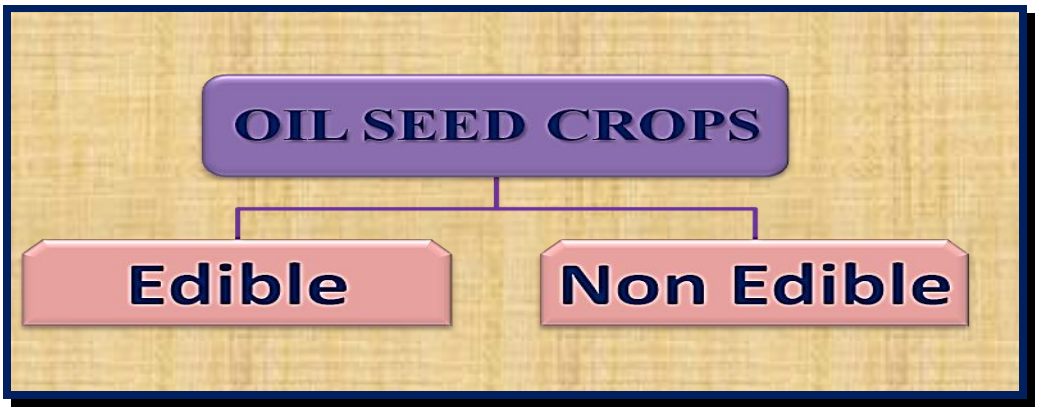

Fig: Classification of Oil Seed Crops.

a) Edible Oil Seed Crops

1. Ground nut/Pea nut : *Arachis hypogaea*
2. Soybean : *Glysine max*
3. Sunflower : *Helianthus annus*
4. Safflower : *Carthamus tinctorius*
5. Sesamum : *Sesamum orientale*
6. Niger : *Guizotia abyssinica*
7. Mustard : *Brassica juncea*
8. Rape : *Brassica campestris*

b) Non Edible Oil Seed Crops

1. Linseed/Flax : *Linum usitatisium*
2. Castor : *Recinus comunis*
3. Cotton : *Gossypium hirsutum*

IV. Fibre Crops

These plants are grown for extraction of fibres which are mainly used for clothing, rope making, carpet making and other purposes.

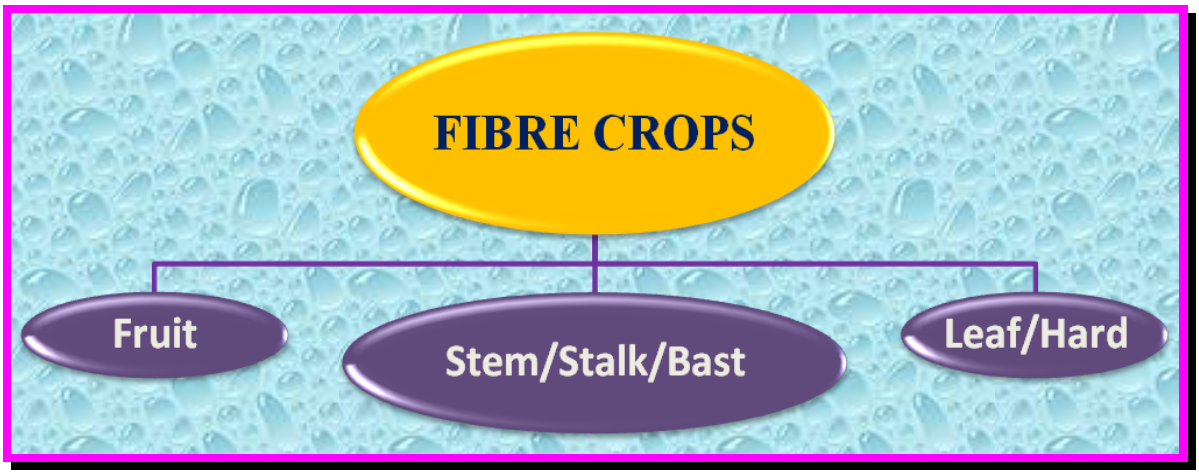

Fig: Classification of Fibre Crops.

a) Fruit Fibres

1. Cotton : *Gossypium hirsutum*
2. Kaps/Silk cotton : *Ceiba pentandra*

b) Stem/Stalk/Bast Fibres

1. Jute : *Corchorus capsularis*
2. Mesta : *Hibiscus cannabinus*
3. Ramei : *Boemeria nivea*
4. Roselle : *Hibiscus sabdariffa*
5. Linseed /flax : *Linum usitatisamum*

c) Leaf Fibres/ Hard Fibres

1. Sisal : *Agave sisalana*
2. Henequan : *Agava fourcroydes*
3. Manila hemp : *Musa textiles*

V. Sugar Crops

Crops are grown for the production of sugars and starch.

1. Sugarcane : *Sacharum officinarum*
2. Sugarbeet : *Beta vulgaris*

VI. Commercial Crops

In these crops, more than 75 per cent of the product is for trade but not for home consumption.

1. Sugarcane : *Saccharum officinarum*
2. Cotton : *Gossypium hirsututm*
3. Tobacco : *Nicotiana tabacum*
4. Jute : *Carchorus capsularis*
5. Potato : *Solanum tubersosum*

6. Chilli : *Capsicum annum*
7. Betelvine : *Piper betel*
8. Mulberry : *Morus alba*

VII. Forage Crops

Forage crops refer to vegetative matter, fresh or preserved, utilized as feed for animals. It includes fodder, hay, silage and pastures.

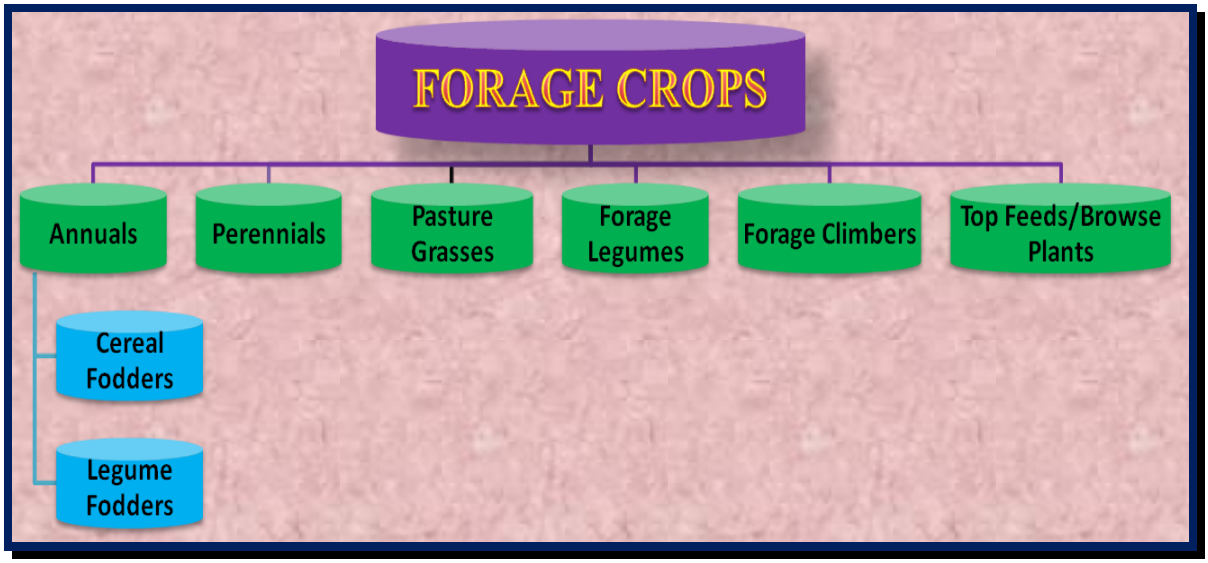

Fig: Classification of Forage Crops.

a) Annuals

i) Cereal Fodders

1. Maize : *Zea mays*
2. Jowar : *Sorghum bicolar*
3. Bajra : *Pennisetum typhoides*
4. Barley : *Hardium vulgare*
5. Oats : *Avena sativa*
6. Mustard : *Brassica oleracea*
7. Deenabandhu : *Pennisetum pedicillatum*

ii) Legume Fodders

1. Cowpea : *Vigna unguiculata/V. sinensis*
2. Horse gram : *Dolichos biflorus*
3. Lucerne/Alfa alfa : *Medicago sativa*
4. Cluster bean/Guar : *Cyamopsis tetragonaloba*
5. Berseem : *Trifolium alexandrium*
6. Rice bean : *Phaseolus calcaratus*
7. Lupins : *Lupinus lupins*

b) Perennials

1. Rhodes : *Chloris gayana*

2. Green panic : *Panicum maximum cv trichoglume*
3. Guinea : *Panicum maximum*
4. Setaria : *Setaria anceps*
5. Para : *Bracharia mutica*
6. Napier : *Pennisetum purpureum*
7. Signal : *Bracharia brizantha*
8. Sudan : *Sorghum sudanensis*

c) Pasture Grasses

1. Anjan : *Cenchrus ciliaris*
2. Dawalu : *Chrysopogon fulvis*
3. Marvel : *Dicantheum annulatum*
4. Pavan : *Sehima nervosum*
5. Spear : *Heteropogon contentus*
6. Dhallis : *Paspalum notatum*

d) Forage Legumes

1. Stylo : *Stylosanthes hamata*
2. Glysine : *Glysine weightii*
3. Centro : *Centrosema pubescence*
4. Calapo : *Calapogonium muconoides*
5. Glysine : *Glysine weightii*
6. Green leaf : *Desmodium intortum*
7. Silver leaf : *Desmodium unicatum*

e) Forage Climbers

1. Winged bean : *Psorocarpus tetragonoloba*
2. Velvet bean : *Styzolobium deerengianum*
3. Dolichos : *Dolichos lablab*

f) Top Feeds/Browse Plants

1. Agase : *Sesbania grandiflora*
2. Sesbania/Shevri : *S. aegyptica*
3. Subabul : *Leucana leucocephala*
4. Mulberry : *Morus alba*
5. Erythrina/Harivana : *Erythrina indica*

VIII. Green Manure Crops

Green manure crops are those crops which are used for incorporating their plant tissues into the soil for improving the soil productivity.

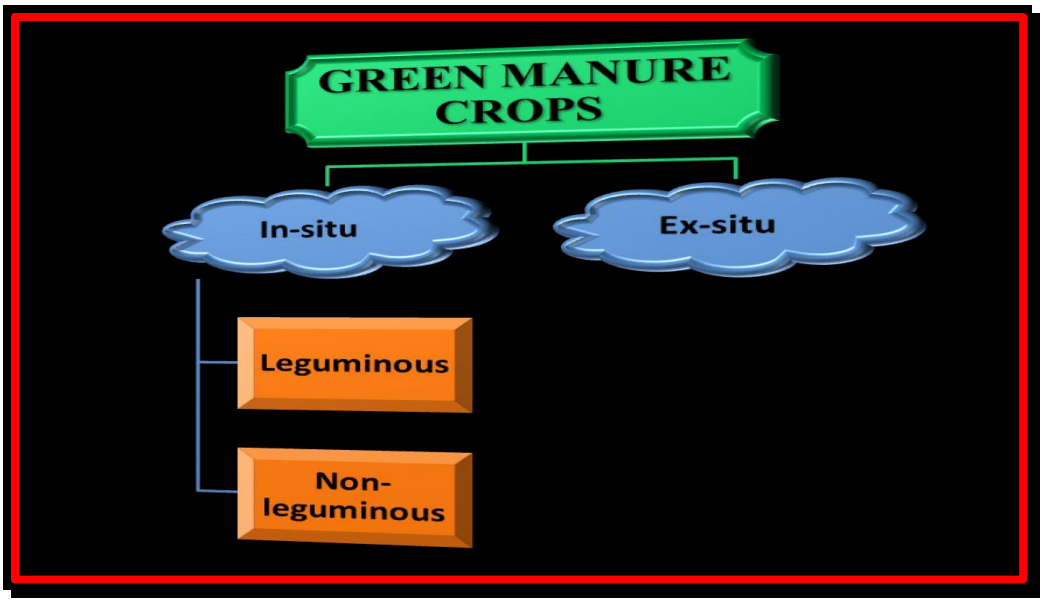

Fig: Classification of Green Manure Crops.

a) In-Situ Green Manure Crops

Green manure crops are grown and incorporated in to the soil of the same field in which it is grown.

i) Leguminous green manure crops

1. Sunnhemp : *Crotalaria juncea*
2. Daincha : *Sesbania aculeata*
3. Sesbania : *Sesbania speciosa*
4. Indigo : *Indigofera tinctoria*
5. Wild Indigo : *Tephrosia purpurea*
6. Cow pea : *Vigna unguiculata/V. sinensis*
7. Green gram/Mung : *Phaseolus aureus/Vigna radiata*
8. Black gram/Urd : *Phaseolus mungo/Vigna mungo*
9. Horse gram : *Macrotyloma uniflorum*
10. Cluster bean/Guar : *Cyamopsis tetragonaloba*
11. Berseem : *Trifolium alexandrium*

ii) Non-leguminous green manure crops

Crops like maize, jowar, barley and oats can be used as green manure crops.

b) Ex-situ Green Manure Crops /Green Leaf Manure Crops

Green leaves are collected from all the available sources and incorporating them in the soil.

1. Glyrcidia : *Glyrcidia maculata*
2. Subabul : *Leucaena leucocephala*
3. Agase : *Sesbania grandiflora*
4. Pongamia : *Pongamia glabra*
5. Eupatorium : *Chromolaena odorata*
6. Neem : *Melia azadiracta*
7. Cassia : *Cassia siamea*

8. Ipomea : *Ipomoea carnea*
9. Yekka : *Calotropis gigantia*

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CROPPING SYSTEM

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CROPPING SYSTEM

Cropping system is a pattern of crops for a given piece of land or the order in which the crops are cultivated on a piece of land over a fixed period of time.

Methods of Cropping

I. **Monocropping/Sole Cropping**: One crop or variety is grown alone in pure stands at normal density season after season or year after year in the same field.

Fig: Mono Cropping.

II. **Multiple Cropping**: Cultivation of two or more crops on the same piece of land in a year. The intensification of cropping is in terms of time and space dimensions. Multiple cropping systems can be classified as follows.

A. Sequential cropping
B. Intercropping
C. Mixed cropping

A. Sequential Cropping: Growing of two or more crops in sequence on the same piece of land in the same year. The succeeding crop is planted or sown only after harvest of the preceding crop. The crop intensification is only in terms of time dimension. Farmers will manage only one crop at a time.

Types of Sequential Cropping

1. Double Cropping: Cultivation of two crops in succession on a piece of land in a year.
2. Triple Cropping: Cultivation of three crops in succession on a piece of land in a year.
3. Quadruple Cropping: Cultivation of four crops in succession on a piece of land in a year.
4. Ratoon Cropping/Ratooning: Cultivation of crop re-growth after its harvest is rationing. It is also a type of sequential cropping. In this, more than one harvest is done from one sowing/planting. Thus, ratooning consists of allowing stubbles of the original crop after harvesting and to raise another crop.

Fig: Sugarcane Crop for Ratooning.

B. Intercropping: Growing two or more crops simultaneously on the same piece of land. Crop intensification is in terms of both time and space dimensions.

Main Crop/Base Crop: It is one which is planted at its optimum population in an intercrop situation and the second crop is planted in between the rows of main or base crop, with a view to obtain some extra inter crop yield without sacrificing the main or base crop yield.

Intercrop: The short duration crop is raised in widely spaced crop for getting an additional income from the same piece of land.

Fig: Main Crop and intercrop.

Component Crop: It is used to refer either of the individual crops making the intercropping situation.

Benefits of Intercropping

1. Better utilization growth resources like light, nutrients and moisture.
2. Economy in space and time.
3. Suppression of weeds.
4. Serves as insurance against failure of any one of the component crops.
5. Reduces soil crust formation.
6. Improves soil fertility.

7. Ecological stability.
8. Controlling of soil erosion.
9. Serves as physical support or shading to some crops.
10. Additional yield from unit area.
11. Additional income.
12. Provides farmer's daily needs.
13. Provides employment and distribution of labour.
14. Cultivation practices for main crop supplement the requirement of companion crop.
15. Control of pests and diseases.

Limitations of Intercropping

1. Labour intensive.
2. Differential maturity and problem of harvesting.
3. Serves as alternate hosts for pests and diseases.
4. Control of pests, diseases and weeds is difficult.
5. Problem for intercultural operations.
6. Mechanization is difficult.
7. Competitive effects among component crops.
8. Allelopathic effect.

Criteria for Selection of Crops for Intercropping System

Care should be taken to select the crops with different growth habits, root growth, duration and families. The following points to be considered while selecting crops for intercropping system.

1. Tall growing crops with short growing crops.
2. Bushy crops with erect growing crops.
3. Fast growing crops with slow growing crops.
4. Deep rooted crops with shallow rooted crops.
5. Short duration crops with long duration crops.
6. Legume crops with non-legume crops.
7. Crops should have least allelopathic effect.
8. Crops selected should be of different families to avoid pests and diseases.

Types of Intercropping

1. **Mixed Intercropping/Mixed Cropping:** Growing of two or more crops simultaneously on the same piece of land with no distinct row arrangement.

2. **Row Intercropping:** Growing of two or more crops simultaneously on the same piece of land with distinct row arrangement. It is simply referred as 'intercropping'.

Fig: Row Intercropping.

3. **Patch Intercropping:** Growing of two or more crops simultaneously on the same piece of land in patches.

Fig: Patch Intercropping.

4. **Strip Intercropping:** Growing of two or more crops simultaneously on the same piece of land in strips wide enough to permit independent cultivation.

Fig: Strip Intercropping.

5. **Relay Intercropping/Relay Cropping:** Growing of two or more crops simultaneously on the same piece of land during the part of life cycle of each. The second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest.

Fig: Relay Intercropping.

6. **Parallel Intercropping/Parallel Cropping:** Growing of two or more crops which have different growth habits and which have a zero competition between each other and both of them express their full yield potential.

Fig: Parallel Intercropping.

7. **Multi Storied Intercropping/Multi Storied Cropping:** Growing of two or more crops of different heights on the same field at the same time. It is commonly practiced in orchard and plantation crops.

Fig: Multi Storied Intercropping.

8. **Alley Intercropping/Alley Cropping:** Food crops are grown in alleys formed by hedge or shrubs or trees. It is an agro-forestry system.

Fig: Alley Intercropping.

9. **Guard Crops:** The main crop is grown in the centre, surrounded by hardy or thorny crops. These crops protect the main crop.

10. **Trap Crops:** These crops are grown in the main cropped field in definite rows to trap insect pests.

Fig: Trap Crop.

11. **Filler Cropping:** Growing of short duration crops in between the newly established perennial crops for few years to fill the space and to utilize the resources.

Fig: Filler Cropping.

C. Mixed Cropping

Growing of two or more crops together on the same piece of land is called as mixed cropping. In this, the seeds of different crops are mixed together and then sown either in lines or they are board casted. This system is not scientific and it causes problem in performing all agricultural operations and harvesting of crops. This system of cropping is generally practiced in areas where climatic hazards such as flood, drought, frost etc. are frequent and common. The farmers always fear that their crops will fail. The time of sowing of all the crops is same; however they may mature either together or at different times.

CROP ROTATION

Growing of different crops alternatively on the same piece of land in a definite sequence or 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.

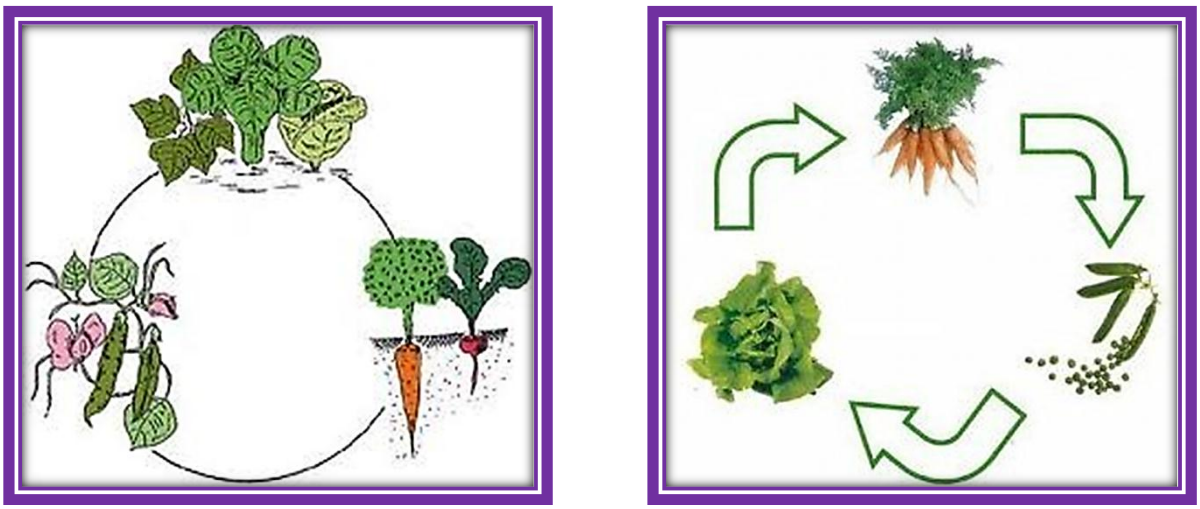

Fig: Crop Rotation.

Principles of Crop Rotation

1. The crops with tap roots should be followed by those with fibrous root system. This helps in proper and uniform use of nutrients from the soil.
2. The leguminous crops should be grown after non-leguminous crops. Legumes fix atmospheric nitrogen in the soil and add more organic matter to the soil.
3. More exhaustive crops should be followed by less exhaustive crops.
4. The crop of the same family should not be grown in succession because they act like alternate hosts for pests and diseases.
5. An ideal crop rotation is one which provides maximum employment to the family and farm labour, farm machineries and equipments are efficiently used.
6. Selection of the crop should be demand based.
7. The selection of crops should be problem based.
8. The selection of crops should suit to the farmer's financial conditions.
9. The crops selected should also suit to the soil and climate conditions.

Benefits of Crop Rotation

1. Beneficial to succeeding crops.
2. Soil fertility is restored by fixing atmospheric nitrogen.
3. Encourages soil microbial activity.
4. Improves physico-chemical properties of the soil.
5. Avoids accumulation of toxins (HCN etc.).
6. Soil is protected from erosion.
7. Controls pests and diseases.
8. Controls weeds in the fields.
9. The family and farm labour, power, equipment and machineries are well employed.
10. Differential extraction of nutrients and moisture from different depths.
11. Proper utilization of all the resources and inputs.

Limitations of Crop Rotation

1. Specialization in one crop is not possible.
2. Requirement of equipments and machineries varies from crop to crop.
3. Allopathic effect of preceding crop.
4. Serves as alternate hosts for pests and diseases.

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GREEN MANURING

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GREEN MANURING

Introduction

Green manuring is the practice of incorporating green plant tissues into the soil for improving the soil productivity. It is a low cost but effective technology in minimizing the investment cost of fertilizers and in safeguarding the productive capacity of the soil.

Criteria for selection of green manure crops

1. The green manure crops must develop good foliage and rapid growth.
2. They should have deep root system.
3. They should be able to grow well on poor soils.
4. Water requirement of green manure crops should be less.
5. Must have legumes to fix atmospheric nitrogen.
6. Should be of short duration.
7. Should be succulent, non-fibrous and non-woody in nature.

Benefits of green manuring

1. Adds nutrients and organic matter to the soil.
2. Improves physical, chemical and biological properties of the soil.
3. Serves as source of food and energy for the soil microbial population which multiplies rapidly in the presence of easily decomposable organic matter.
4. The enhanced activities of soil organisms not only cause rapid decomposition of the green manure but also result in the release of plant nutrients in available forms for use by the crops.
5. Promotes formation of crumbs leading to better aeration and drainage in the soils.
6. Builds up soil structure and improves tilth.
7. Improves water holding capacity of soils.
8. If green manure crop is a legume, it adds lot of nitrogen to the soil by fixing atmospheric nitrogen.
9. Uptake plant nutrients from the lower layers and adds them in the surface soil when turned under.
10. Green manure crops act as cover crop and reduce the soil temperature and protect the soil from erosion, crust formation and suppress the growth of weeds.
11. Help in conserving nutrients by taking up soluble nutrients which might otherwise been lost due to leaching or erosion.
12. Prevent leaching of nutrients to lower layers.
13. Helps in reclaiming the saline and alkali soils.
14. Many green manure crops have additional use as sources of food, feed and fuel.
15. They increase the yield of crops.

Methods of green manuring

Broadly the practice of green manuring can be divided into two types.

A. In-situ green manuring
B. Ex-situ green manuring/Green leaf manuring

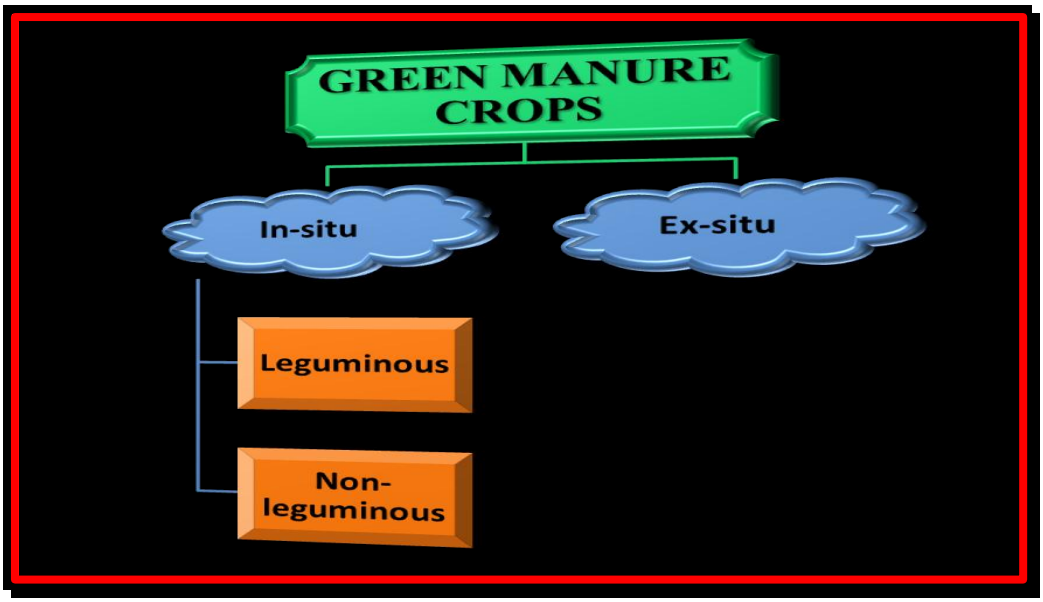

Fig: Classification of Green Manure Crops.

A. In-situ green manuring

It is a system by which green manure crops are grown and incorporated in to the soil of the same field in which it is grown.

a) Leguminous green manuring crops

1. Sunnhemp : *Crotalaria juncea*
2. Daincha : *Sesbania aculeate*
3. Sesbania : Sesbania speciosa
4. Indigo : *Indigofera tinctoria*
5. Wild Indigo : *Tephrosia purpurea*
6. Cow pea : *Vigna unguiculata/V. sinensis*
7. Green gram/Mung : *Phaseolus aureus/Vigna radiata*
8. Black gram/Urd : *Phaseolus mungo/Vigna mungo*
9. Horse gram : *Macrotyloma uniflorum*
10. Cluster bean/Guar : *Cyamopsis tetragonaloba*
11. Berseem : Trifolium alexandrium

Fig: Sunnhemp.

Fig: Daincha.

Fig: Sesbania.

Fig: Indigo.

Fig: Wild Indigo.

Fig: Cowpea.

Fig: Green Gram.

Fig: Black Gram.

Fig: Horse Gram.

Fig: Cluster bean.

Fig: Berseem.

b) Non-leguminous green manuring crops

Crops like maize, sorghum, barley and oats can be used as green manure crops.

Fig: Maize.

Fig: Sorghum.

Fig: Barley.

Fig: Oats.

B. Ex-situ green manuring/Green leaf manuring

The practice of collecting green leaves from all the available sources and incorporating them in the soil is called as green leaf manuring.

1. Glyrcidia : *Glyrcidia maculata*
2. Subabul : *Leucaena leucocephala*
3. Agase : *Sesbania grandiflora*
4. Pongamia : *Pongamia glabra*
5. Eupatorium : *Chromolaena odorata*
6. Neem : *Melia azadiracta*
7. Cassia : *Cassia siamea*
8. Ipomea : *Ipomoea carnea*
9. Yekka : *Calotropis gigantia*

Fig: Glyricidia.

Fig: Subabul.

Fig: Agase.

Fig: Pongamia.

Fig: Eupatorium.

Fig: Neem.

Fig: Cassia.

Fig: Ipomea.

Fig: Yekka.

Green manuring practices

1. Green manure crop can be grown in any type of soil provided there is sufficient rainfall or alternatively availability of irrigation water.
2. For leguminous green manure crop, the seeds should be inoculated with the proper strain of bacteria. Molybdenum seed treatment could also enhance N fixation.
3. The green manure crop should be sown with a higher seed rate than usual so that there will be a good canopy produced very quickly.

Table: Seed rate and biomass production of green manure crops.

Sl. No.	Green manure crop	Seed rate (kg/ha)	Biomass yield (t/ha)
1	Sunnhemp	25-40	21
2	Daincha	20-25	26
3	Cow pea	25-30	15
4	Indigo	25-30	12
5	Wild Indigo	25-40	16
6	Green gram	15	10
7	Black gram	15	10
8	Cluster bean	12-15	10

4. The production of green manures is limited by the deficiency of essential nutrients in the soil.
5. The application of phosphatic fertilizers improves the growth of leguminous crop markedly and promotes the fixation of nitrogen by profuse nodulation.
6. The best stage at which the crop should be incorporated into soil is when it reaches the flowering stage. For example sunhemp is ready for turning in at the age of 7-8 weeks whereas, daincha is ready for incorporation when it is 5-6 weeks old.
7. Incorporation of green manure crops should be done at least 3-4 weeks before sowing or planting of main crop.
8. Incorporation of green manure crop is done in the different ways. In some cases, the plants are cut close to the ground and the green material is put in the furrows opened by a mould board plough and is later buried. One of the methods is to plank the material down with a heavy plank or log and then plough the field. The other method is to mix the uprooted or cut plant material (green leaf manure) by means of disc

harrow.

9. Immediately after ploughing the material, care should be taken to cover it with soil by using suitable implements to ensure proper decomposition. Proper covering of material with the soil is especially necessary if the soil moisture supply is deficient.
10. Under certain favorable circumstances, green manure crop such as daincha can be sown in between the rows of main crops. When daincha is sufficiently grown, it can be uprooted and mixed with the soil by inter cultivation.
11. Under limited moisture supply conditions, it is advisable to go for green leaf manuring by growing the green manure crops in one field and add the green material to another field. By adding this, the moisture required for growing the green manure crop is saved.

Table: Nutrient content of green manures.

Sl. No.	Name	Nutrient content (%)		
		Nitrogen	Phosphorus	Potassium
1	Sunhemp	0.89	0.12	0.51
2	Daincha	0.68	0.13	0.40
3	Cowpea	0.71	0.15	0.58
4	Green gram	0.82	0.18	0.52
5	Black gram	0.82	0.18	0.52
6	Horse gram	0.91	0.18	0.65
7	Glyricidia	0.68	0.16	0.30
8	Pongamia	0.16	0.14	0.49

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RICE

(*Oryza sativa* L.)

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RICE

(*Oryza sativa* L.)

Introduction

Paddy is unprocessed part whereas, rice is the one which is processed from paddy. Rice is the staple food crop of more than 60 per cent of the world's population. About 90 per cent of all rice grown in the world is produced and consumed in the Asian region. In India, rice is the most important and extensively grown food crop.

Fig: Bunch of panicles.

Fig: Paddy grains.

Fig: Rice grains.

Rice is grown in diversified soil, topographical and hydrological situations ranging from sloppy uplands to deep water areas of above one meter depth. It is adapted to cold

temperatures that exist in hilly areas and also in adverse soil conditions such as salinity, alkalinity and acidity.

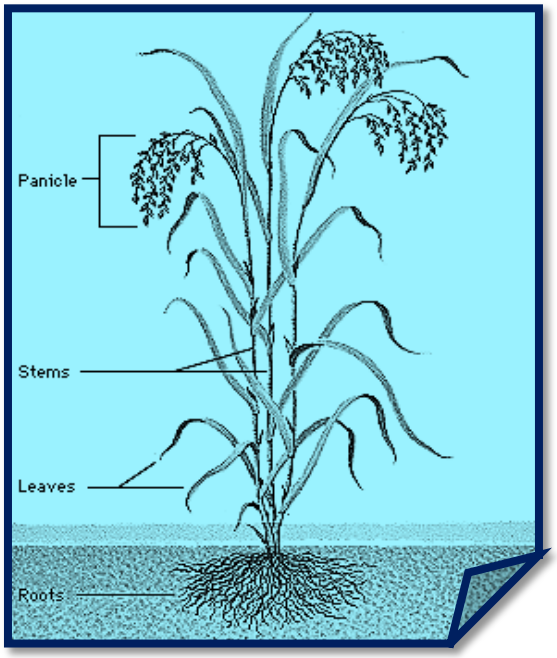

Fig: Parts of paddy plant.

Importance

Rice contains more carbohydrates (78.2 g/100 g), less protein (6.8 g), fat (0.5 g), crude fibre (0.2 g), mineral matter (0.6 g), calcium (10.0 mg) and phosphorus (160.0 mg). It is primarily a high energy or high caloric food. The milled rice losses valuable proteins, fats and minerals during milling process. Much of losses of nutrients can be avoided through parboiling process and with less polishing and washing.

1. Rice is mostly cooked with water and eat.
2. It is used for preparing other edible items like dosa, idli, roti, kadabu, paddu, uppama, papad, sandige,etc.
3. It is used for preparing puffed rice, rice flakes, rice wafers and canned rice.
4. It is also used in starch and brewing industry.
5. By-product of rice milling is rice husk which is used in hardboard and paper industries and also as fuel.
6. Other byproduct of rice milling is rice bran which is used for cattle and poultry feed.
7. The rice bran oil is used for cooking after refinement and soap making.
8. The straw is used as fodder and for making mats, hats and ropes.
9. The straw is also used for thatching, litter, mulching and mushroom cultivation.

Fig: Rice meals.

Fig: Dosa.

Fig: Idli.

Fig: Paddu.

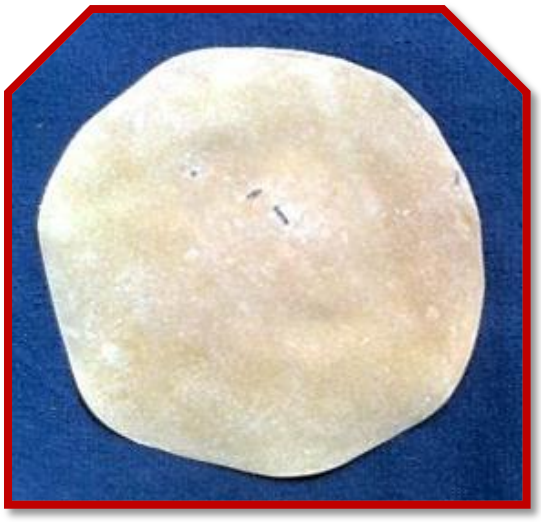

Fig: Papad.

Fig: Sandige.

Fig: Rice flakes.

Fig: Puffed rice.

Fig: Rice bran oil.

Fig: Beverages.

Origin

Rice is regarded as a first cultivated crop of Asia. Preserved rice grains were found in China around 3,000 B.C. Paddy grains were found in excavation at Hastinapur in India around 1000-750 B.C. considered as oldest sample in the world.

De condolle (1886) mentioned south India as its centre of origin. Vavilov (1926) concluded that South-west Himalaya has various types and varieties and indicated probable centre of origin. Thus based on all these archaeological evidences India is considered as centre of origin of rice.

Distribution

Rice cultivation is limited to north 49^{o} in Czechoslovakia and south 35^{o} in New South Wales. But most of the world's rice is grown in tropics which include countries of South and South East Asia, West Africa and Central and South America. Important rice growing countries are India, China, Indonesia, Thailand, Bangladesh, etc.

In India, rice is grown through out in all the states. It is a cosmopolitan crop grown in high altitude hills and also in regions below mean sea level (Kuttanad area of Kerala). The major rice growing states in India are West Bengal, Uttar Pradesh, Madhya Pradesh, Bihar, Orissa, Andhra Pradesh, Assam, Tamil Nadu, Punjab, Haryana, Karnataka, Maharashtra, etc.

Classification

Rice belongs to family Graminae (Poaceae). There are about 24 species of genus *Oryza* but only two species are under cultivation viz., *Oryza sativa* and *Oryza glaberrima*. *O. sativa* is most popular and grown in the most of the rice growing areas of the world, whereas *O. glaberrima* is mainly grown in South Africa.

O. sativa is further grouped into three types i.e., *indica*, *japonica* and *javanica*.

Characteristics	*indica*	*japonica*	*javanica*
Area of cultivation	India	Japan	Indonesia
Plant height	Tall	Dwarf	Tall
Leaves	Broad, light green and slightly pubescent	Narrow and dark green	Broad, hard and light green
Tillering	Very high	Medium	Low
Grain	Thin, flattened and elongated	Small and rounded	Broad and thick
Shattering	High	Low	Low

Climatic Requirement

Rice is majorly grown in tropics. It is heat and water loving plant and hence requires high temperature and more water. For germination a minimum of 10 ^{o}C, flowering 22-25 ^{o}C, grain formation 20-21 ^{o}C and ripening 20-25 ^{o}C is considered an optimum. Low temperature particularly during 10-11 days before heading causes considerable loss in grain yield because of sterility.

Rice is a short day, thermo sensitive but now many thermo insensitive varieties have been developed. It is mostly grown in the areas of 1,000-1,500 mm rain fall. Heavy winds results in severe lodging.

Rice is grown in different seasons in India. The temperature is the deciding factor for such adaptability of rice crop. In northern Indian states rice is grown during kharif season while in southern states like Tamil Nadu rice is grown throughout the year like early kharif, kharif, rabi and summer seasons.

Soil Requirement

Rice can be grown in diversity of soils like alluvial, lateritic, red, black, brown, saline, alkaline, acid soils etc. It can be grown not only in flat lands but also on a wide range of slopes.

Fig: Soil Requirement.

Rice under Different Ecosystems

In India, rice crop is grown in different ecosystems like rainfed upland, rainfed lowland and irrigated situations.

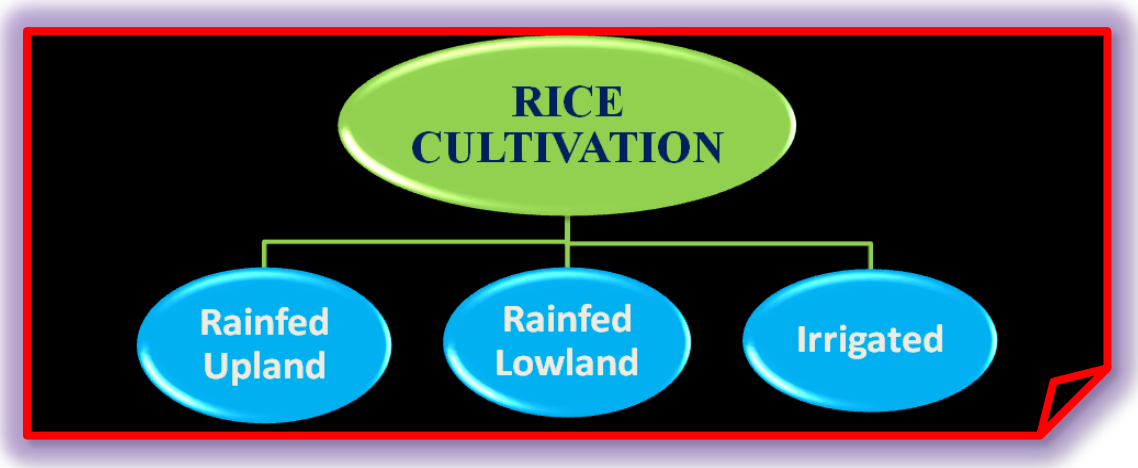

Fig: Types of Rice Cultivation.

The cultivation practices for different types of rice grown under different ecosystems vary.

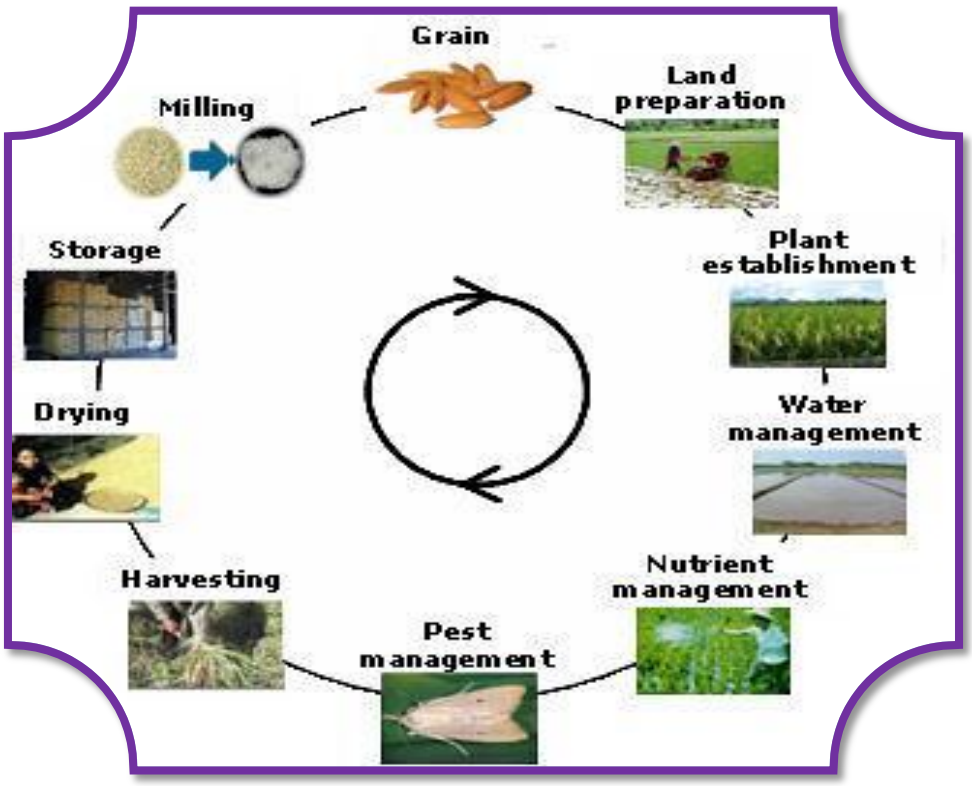

Fig: Stages of rice cultivation.

RAINFED UPLAND RICE

Rainfed uplands are those where aerobic soil environment exists for major period of crop growth and development. Rice is grown under rainfed condition in these uplands in monsoon season. Soil moisture stress is a major factor due to erratic distribution of rainfall which causes drought.

Fig: A view of upland rice cultivation.

Varieties

The ideal characters for upland rice varieties are early seedling vigour, intermediate height, moderate tillering, early maturity of around 75-105 days, deep roots, drought tolerant, tolerance to major pests and diseases. So far about 92 varieties have been released for upland situation in the country.

Some important varieties recommended are Heera, Kalinga III, Vandana, Subhadra, Rasi and Ananda.

Land Preparation

Proper land preparation and leveling should be followed for ensuring adequate crop stand and finally achieving higher yield. The land has to be opened after the harvest previous crop with a mould board plough. This prevents the land from getting hard on drying and conserves moisture at lower depths of soil. Pre-monsoon showers in April and May help to break the clods. Summer ploughing helps in controlling weeds like *Cyperus rotundus* effectively. Deep ploughing and sub-soiling across the slopes help to conserve the moisture in the wet season. It enables enhanced root growth and extraction of soil moisture from deeper layers.

Fig: Land preparation.

Sowing

Time of Sowing

Optimum time of sowing is one of the important non-monetary inputs for raising crop production. It is decided by the onset of monsoon rains. Second fortnight of June is the optimum time for realizing higher yields from rainfed uplands.

Seed Rate

Seed rates of 70-90 kg/ha for drilling and 100-120 kg/ha for broadcasting is recommended.

Spacing

Inter-row spacing of 20 cm and intra-row spacing of 10-15 cm is being followed.

Method of Sowing

Farmer's traditional practice of broadcasting method of sowing results in uneven stand. Dibble seeds behind the plough at proper depth (5 cm) proved superior in establishing optimum crop stand. Row seeding can be done by making furrows with a country plough and seeding in those furrows. Line sowing is better method than broadcasting as it ensures better crop stand and facilitates easy mechanical weed control. Alternatively seed drills may be used for establishing good crop stand.

Fig: Seed drill.

Fig: Rice field.

Nutrient Management

Most of the uplands are poor in fertility status. Due to higher elevation and light textured soils, percolation losses may result in low availability of N due to excessive leaching. Application of well decomposed farm yard manure is very essential to increase the water holding capacity of soil and supply of nutrients.

Application of 10 tons of farm yard manure, 40-60 kg of nitrogen, 30 kg of phosphorus and 30 kg of potassium per hectare helps in improving the yield. If the soils are acidic in nature a dose of 1.5 t/ha of lime application will improve the yield of rice.

Weed Management

In upland rice weed competition is more. Weeds emerge along with rice crop and compete with it for light, nutrients, moisture and space. First 30-40 days period is considered critical for crop-weed competition.

Hand weeding or hoeing twice at 20 and 40 days of sowing effectively control the weeds. Application of pre-emergence herbicides Pendimethalin or Butachlor @ 1.5-3.0 kg/ha or Anilophos @ 0.4-0.5 kg/ha and post-emergence herbicide Propanil @ 2-3 kg/ha effectively control weeds. Integrated approach is very effective in controlling weeds.

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RICE (Contd…)

(*Oryza sativa* L.)

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RICE (Contd…)

(*Oryza sativa* L.)

RAINFED LOW LAND RICE

The rainfed lowland rice areas include the areas where the rain water stagnates in low lying areas up to a depth of 100 cm or more. Water starts accumulating as the monsoon becomes active and reaches its peak in August-September and thereafter comes down gradually towards crop maturity in November-December. Frequent and heavy rains bring in flash floods because of over flowing of rivers in the catchment areas and drainage congestion in the coastal areas. Based on the depth of water stagnation in the fields, the rainfed lowland rice areas are classified as follows.

1. Shallow Low Land: The water stagnation is up to 0-30 cm depth. It is temporary and is confined mostly to peak period of rainfall during monsoon season. The crop may suffer due to drought at seedling stage.
2. Intermediate Low Land: The water depth ranges from 0-50 cm. The drought at seedling stage is likely to be a problem.
3. Semi-Deep Low Land: In these areas water may stagnates for 5-6 months during wet season up to 0-100 cm.
4. Deep Water Low Land: In these areas generally water level is more than one meter and it may reach 3-5 meters. The type of rice cultivation in these areas is called as 'floating rice'. Inter nodal length of these rice plants will be more.

Varieties

Varieties with broad spectrum of tolerance to stress and yield potential are desirable for rainfed low land rice cultivation. Some of the promising high yielding varieties recommended for different rainfed low land cultivation are as follows.

1. Shallow Low Land: Radha, Jayashree, Pankaj, Ramakrishna, Mahalakshmi, Kushal, Mahsuri, Madhuri, etc.
2. Intermediate Low Land: Vaidehi, Dinesh, Kalashree, Gayatri, Manoharsali, Madhukar, etc.
3. Semi-Deep Low Land: Janaki, Suresh, Ramba, Jalpriya, etc.
4. Deep Water Low Land: Sabitha, Jalamagna, Jalnidhi, etc.

Land Preparation

Light showers received during May should be used to prepare the land well. It would be more appropriate to give first ploughing after harvest of the previous kharif crop in December/January itself to control problematic weeds and this also facilitates better pulverization of the land in May.

Sowing

Time of Sowing

Optimum time of sowing is decided by the onset of monsoon rains. First fortnight of June is the optimum time for getting higher yields from rainfed lowlands.

Seed Rate

Seed rates of 75-100 kg/ha is recommended for rainfed lowlands.

Spacing

Seeds are placed at a spacing of 20 x 15 cm is considered more useful than broadcast method of seeding which results in uneven crop stand.

Method of Sowing

In the rainfed lowland areas, rice crop is either through direct seeding in relatively dry soil or are transplanted after accumulation of water in the field. Transplanting in excess water results in a shock to the seedlings and greater part of the plant remains in water, resulting in poor stand establishment. Direct seeded crop does not experience any such shock and the crop already established acclimatizes faster to the greater depths of water stagnation and maintain most of the plant parts above the water, thereby resulting in greater survival. Therefore, direct seeding is better than transplanting under rainfed flood-prone condition. Country plough or seed drills are used for the purpose of row seeding.

Nutrient Management

Most rainfed lowland farmers do not apply fertilizers due to the risk involved in successful crop production. Well decomposed farm yard manure @ 10 t/ha need to be applied two weeks in advance. Application of nitrogen @ 40-60 kg, phosphorus 20-40 kg and potassium 30 kg/ha meets the requirement of rice plants.

Weed Management

Weed competition is less in lowland situation compare to uplands. Some of the common weed floras of low land are sedges like *Cyperus difformis, C. iria, Fimbristylis miliaceae*, dicots like *Ludwigia* sp., *Eichhornia crassipes, Salvania molesta* and monocots like *Echinochloa* sp.

Weed control is practiced manually by hand weeding, hoes, rotary weeder, pre-emergence application of herbicides like Butachlor or Thiobencarb @ 2.0 kg/ha. Integrated weed control is very effective in controlling weeds.

IRRIGATED RICE

Generally yields are higher in irrigated rice than the rainfed conditions because of assured irrigation facility. The irrigation may be well irrigation, tank irrigation or canal irrigation. But all these irrigations depend on rainfall as source.

Varieties

Out of 427 varieties so far developed in the country, 227 varieties are for irrigated conditions. Some of the important varieties recommended for cultivation are Tella Hamsa, Pushkali, Rasi, Divya, Lachit, Govind, Vishnu, Sita, Gaur 4, Mangala, Pushpa, Mandyavani, Sonasali, Jyothi, Madhuri, Kranti, Ratnagiri, Ratna, Seema, Bharathidarshan, PR 103, PR 106, Jaya, TKM 9, CO 41, IR 50, Lakshmi, Kunti, Vikas, Pusa 169, etc.

Scented fine quality rice popularly known as basmati rice characterized by pleasant aroma, long slender grains, extreme grain elongation on cooking and soft texture of cooked rice. Basmati 370 (Punjab Basmati), Type 3 (Dehradun Basmati), Karnal Local (Travadi Basmati) and Pakistan Basmati are important scented rice varieties cultivated in India.

Hybrids recommended in the country are APHR-1, DRRH-1, APHR-2, KRH-1, KRH-2, MGR-1, CNHR-3, PHR-1, NDRH-1, etc.

Fig: Types of rice grains.

Fig: Rice field with different coloured varieties.

Land Preparation

The land has to be ploughed thoroughly with the help of mould board plough. Ploughing is followed by puddling which is nothing but churning of soil in presence of excess or standing water. Puddling reduces percolation loss of water. Puddling is done by using puddler drawn either by bullocks or power tiller or tractor. Puddling is followed by leveling operation by using leveler. Leveling helps for maintaining uniform standing of water in the plot.

Fig: Land preparation.

Sowing

Time of Sowing

For achieving higher yields early planting in July in the wet season and the first week of January in dry season are considered essential. Progressive delay in planting results in reduction in grain yield.

Seed Rate

Broadcasting of seeds require about 75 kg/ha while, transplanting requires about 40-60 kg/ha depending on size of the seeds. Select healthy, bold and good seeds by following the procedure.

1. Prepare salt solution by mixing salt (1.65 kg) in water (10 liters).
2. Test the salt solution concentration with fresh egg which would float in the solution. If egg sinks, add more salt to increase the concentration.
3. Pour the seeds in to the solution, stir well and allow it to settle down.
4. Discard the floating seeds and select the seed which has settled down in the solution.
5. Wash the seeds thoroughly with fresh water.
6. Same salt solution may be used again to test other lots of seeds.

Fig: Salt water preparation.

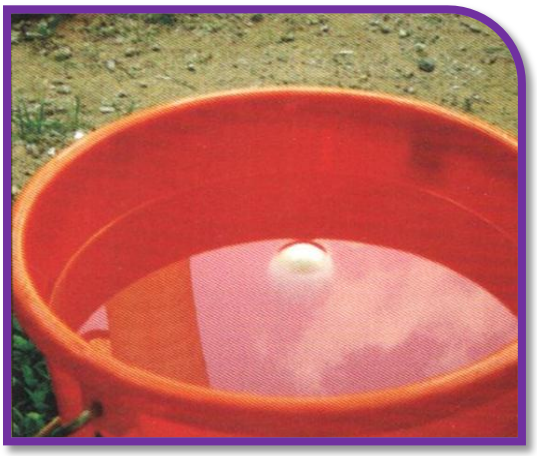

Fig: Testing of salt water with egg.

Fig: Mixing of seeds in salt water.

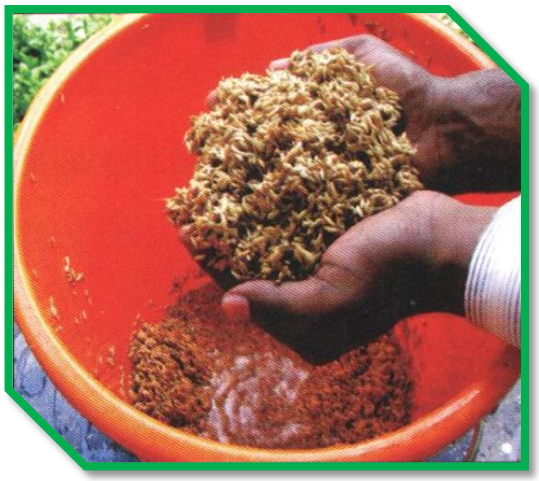

Fig: Selection of good seeds.

Spacing

The spacing followed in broadcasting or dibbling of seeds or transplanting of seedlings is 20 cm in between rows and 10-15 cm between plants.

Method of Sowing

There are two methods of crop stand establishment under irrigated situation. They are direct seeding on puddled soil and transplanting.

1. Direct Seeding on Puddled Soil: In this system the land is well puddled and sprouted seeds are either broadcasted or dibbled. Drum seeder can also be used for sowing. Direct seeding saves labour as it does not involve nursery raising, uprooting and transplanting of seedlings.

Fig: sowing by using drum seeder.

2. Transplanting System: It is more common in irrigated condition in India. Here nurseries are raised well in advance to produce the seedlings. Later transplanting is done using the seedlings. It is highly labour intensive system. But it has got the advantage of less weed problems.

For raising nursery, fertile well drained field is selected near source of water. To raise seedlings for one hectare 750 m^2 area is required. After adequate land preparation 1,000 to 1,500 kg of well decomposed farm yard manure has to be incorporated 2-3 weeks before sowing. Prepare raised beds of 7.5 m length, 2.0 m width and 10 cm height. For one hectare area nearly about 50 beds are required. For each bed, 90 g N + 45 g P_2O_5 + 45 g K_2O/bed should be applied.

There are three types of nurseries are followed for raising the seedlings for transplanting. Those are dry bed nursery, wet bed nursery and dapog method of nursery.

a) Dry Bed Nursery: It is followed in areas where the water is insufficient. In this method, dry tillage is followed. Sowing of pre-germinated seeds may be done by broadcasting or sown in hand drawn shallow furrows spaced at 8-10 cm and covering with soil. Irrigation is done frequently to keep the beds moist. Dry nurseries are well suited for wet season and the seedlings obtained from these nurseries are hardy and can tolerate adverse conditions better. But weeds problem is more than wet bed method.

b) Wet Bed Nursery: In wet bed nursery, wet tillage is practiced and pre-germinated seeds are broadcasted uniformly on raised beds of puddled soil.

The seedlings are ready in 20-25 days. The seedlings produced from the well managed nurseries are expected to give better yields. Line planting ensures proper crop stand and facilitates working of rotary weeder for controlling weeds as well as incorporation of N fertilizers. Shallow planting of 3-4 cm deep with a spacing of 20 x 10-15 cm @ 2-3 seedlings per hill is desirable. If need arises, gap filling has to be done.

Fig: Application of compost.

Fig: Sprouted seeds.

Fig: Broadcasting of seeds.

Fig: Covering of seeds with soil.

Fig: Wet bed nursery.

Fig: Transplanting of seedlings.

c) Dapog Method of Nursery: Dapog method of nursery is used for machine transplanting. In this method, the raised beds of one meter width, 10 cm height and convenient length are prepared. On these beds a polythene sheet is placed and above which a mixture of FYM and soil (1:1) of 2.0 cm thickness is placed. Pre-germinated seeds are broadcasted @ 1.0 kg/m^2 and covered with straw mulch. Irrigation is done frequently to keep the beds moist. Seedlings are ready for transplanting in 18-20 days. For machine transplanting mats of seedlings are used.

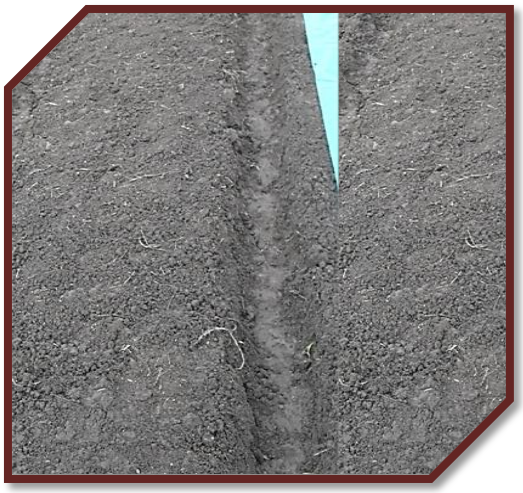

Fig: Bed preparation.

Fig: Covering of polythene sheet.

Fig: Spreading of soil.

Fig: Sprouted seeds ready for sowing.

Fig: Covering of straw mulch.

Fig: Nursery ready for transplanting.

Nursery rising by using trays

Fig: Filling of trays with soil & F.Y.M.

Fig: Seedlings in nursery trays.

Fig: Seedlings ready for transplanting.

Fig: Rolling of seedlings mat.

Fig: Eight rows transplanter.

Fig: Four rows transplanter.

Fig: Loading of seedlings.

Fig: Machine transplanting.

Fig: Machine transplanting.

Fig: Machine transplanted field.

Nutrient Management

Responses to fertilizer application are higher in dry season as compared to wet season. This is mainly due to higher solar radiation and lack of rains and better possibility of irrigation water management.

Incorporation of well decomposed farm yard manure @ 10 t/ha or green manure @ 5 t/ha 2-3 weeks in advance is essential. Nitrogen @ 60-100 kg/ha, phosphorus and potassium 50 kg/ha may be considered desirable for wet season; for the dry season, a rate of 80-120 kg N/ha, 60 kg P_2O_5 and K_2O/ha may be considered.

Fig: Green manure crop.

Fig: Well decomposed F.Y.M.

Fig: Vermicompost.

Regarding the form of nitrogenous fertilizers, ammonical forms are better than nitrates. However, urea, which is the cheapest fertilizer, is widely used in the country. Nitrogen recovery in low land rice is less (30-40 %). Nitrogen use efficiency can be increased by effective water control, use of slow releasing nitrogen fertilizers, split application and method of application.

A better return can be obtained from a given amount of nitrogen when it is applied in splits and the application is suitably synchronized with active growth of the crop. Application of nitrogen in three splits viz., 50 per cent at planting, 25 per cent each at active tillering and at panicle initiation stages have been found to be appropriate for increasing nitrogen use efficiency and yield of rice. The entire dose of phosphorus and potassium preferably applied as basal dose at the time of planting.

Nitrogen has to be applied to reduced zone and incorporated at the time of puddling or manually placed to avoid conversion of ammonia to nitrate and subsequent loss by leaching.

Use of biofertilizers like *Azolla*, blue green alga, *Azatobacter*, *Azospirillum* saves about one-third of the recommended N fertilizer without sacrificing the yield.

Fig: Azolla.

Among micronutrients, zinc has been found to be a limiting nutrient in realizing normal yield of rice. The practice of applying zinc sulphate @ 25 kg/ha or foliar spay of zinc sulphate @ 0.5 per cent and 0.25 per cent of lime in zinc deficient soils has been found profitable and bringing synergistic effect with nitrogen and phosphorus. Deficiency of zinc leads to khaira disease.

Water Management

In rice, water requirement is the total amount of water needed from sowing till ripening, to meet the losses due to evaporation, transpiration and economically unavoidable losses in the form of deep percolation and seepage. It also includes water required for raising nursery and for special purposes like puddling. The total water requirement of rice varies from less than 800 mm to more than 2,500 mm depending upon the duration of the variety, characteristics of the soil and climatic conditions of the locality. Rice is grown under continuously flooded condition with 2-7 cm standing water throughout the season to achieve higher yield and weed control.

Fig: Irrigation.

Weed Management

The competitive effects in transplanted rice are generally lower than puddled seeded system because generally rice seedlings of some age are planted in this system which has a head start over weeds initially. In puddled seeded rice the extent of competition is higher due to the fact that young seedlings suffer more from simultaneously emerging weed seedlings. Generally flooded conditions reduce the grassy weeds to a large extent.

The common weeds found in irrigated rice are sedges like *Cyprus difformis, C. iria, Fimbristylis miliacea*, dicots like *Ludwigia parviflora, Marselia quadrifolia, Monochoria vaginalis* and monocots like *Echinochloa crusgali, E. colonum*, etc.

There is a need to keep fields weed free for the first four weeks after transplanting. Hand weeding twice at 20 and 40 days after planting is a common practice for controlling weeds in irrigated rice. Alternatively, rotary weeder can be used in row seeding or transplanted crop very effectively. Chemically, pre-emergence herbicides like Butachlor, Thibencarb, Pretilachlor @ 1.0-1.5 kg/ha and Anilofos @ 0.4 kg/ha and post-emergence herbicides like Propanil, 2,4-D and MCPA @ 0.5 kg/ha are applied for controlling weeds.

Plant Protection

Insect Pests

1. Termites: Termites infest upland rice and can be effectively controlled by seed treatment with Chlorpyriphos @ 0.5 kg/100 kg seed.

2. Gundhy Bug: Spray the crop with Monocrotophos or Chloropyriphos @ 0.5 kg a.i./ha in the forenoon hours.

3. Mealy Bug: Spray Phophamidon or Malathion at 0.1 per cent.

4. Stem Borer and Gall Midge: Stem borer attack results in dead hearts. Root dipping prior to transplanting in 0.02 per cent Chlorpyrifos for 12 hours or 0.02 per cent Chlorpyriphos + 1.0 per cent Urea for three hours will control up to 30 days. Soil

incorporation of Carbofuran or Phorate or Quinolphos @ 1.0 kg a.i./ha gives good control in vegetative stage. At heading stage, two rounds of foliar sprays of Quinalphos or Chlorpyriphos or Phosphamidon @ 0.5 kg a.i./ha.

5. Green Leaf Hopper: Foliar spray with Phosphamidon, Monocrotophos, Carbaryl @ 0.5 kg a.i./ha.

6. Cut Worm: Spray Chlorpyrifos, Quinalfos, Methyl parathion and Endosulfan @ 0.4 kg a.i./ha at dough stage.

7. Case Worm, Leaf Folder, Hoppers and Whorl Maggot: Spray Quinalfos, Endosulfan, Chlorpyriphos @ 0.5 kg a.i./ha.

8. Brown Plant Hopper (BPH): Spray Carbaryl 0.75 kg a.i./ha or Carbofuran @ 0.75 kg a.i./ha or apply Phorate granules @ 1.25 kg a.i./ha.

Fig: Brown plant hopper.

Diseases

1. Blast: Adopt seed dressing with Carbendazim (Bavistin) @ 4g/kg of seeds. Spray the Carbendazim @ 0.1 per cent.

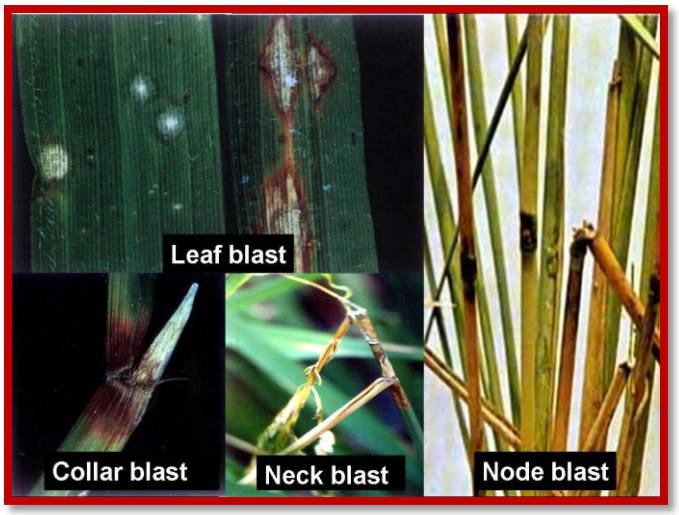

Fig: Blast disease.

2. Brown Spot: Deficiency and imbalance of nutrients influences disease intensity. Seed dressing with Indofil M-45 @ 2g/kg seeds and its spray @ 1.25 kg a.i./ha.

Fig: Brown spot disease.

3. Bacterial Leaf Blight: Reduce nitrogen application and apply nitrogen in split doses.

Fig: Leaf blight disease.

Harvesting and Threshing

Drain out the water from the field when grains in the lowest portion of the panicle are in dough stage (about 20 days from 50 per cent flowering). Allow the grains to harden. Harvest the crop at 30-35 days after flowering when stalks still remain green to avoid grain shedding. At this stage at least 80 per cent of the grains are straw coloured. Moisture content in the grains should be around 20 per cent.

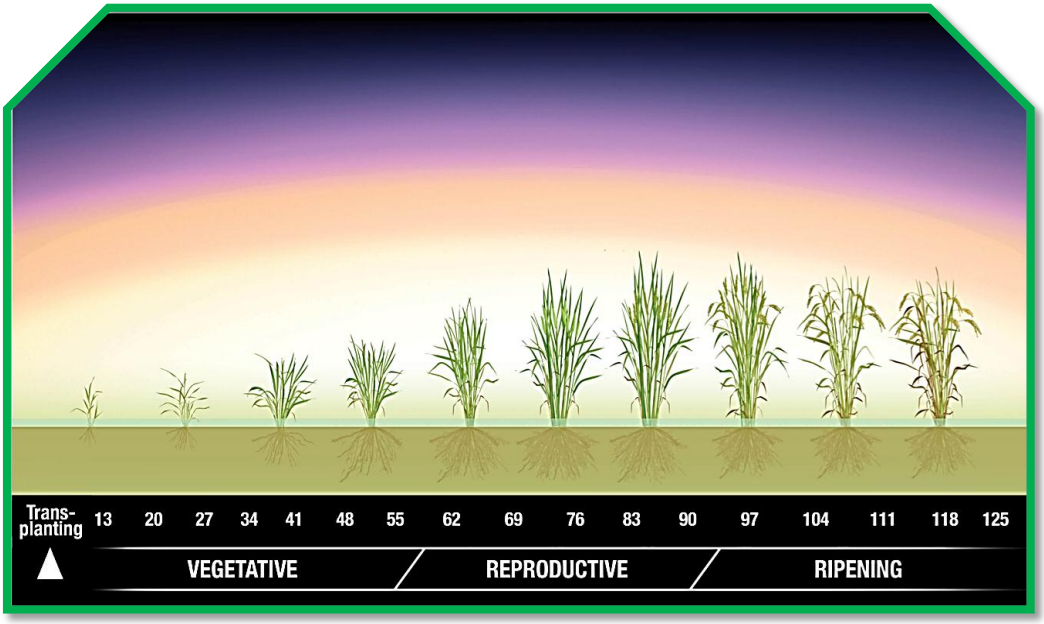

Fig: Stages of plant growth.

Fig: Ripening stage.

In general, the crop is harvested with traditional sickles. With the improved design of sickles fabricated from high carbon steel and fitted serrated blades, harvesting is done faster.

The improved design requires less muscle power and results in saving of human energy. Harvesting of rice is also done by cutter or power tillers/tractor drawn reapers.

Fig: Manual harvesting.

Fig: Machine harvesting.

Often heavy rains at the time of maturity of the crop may cause germination of grains in the panicles. After the harvest of rice bundles are kept lying in the field for sun drying for about 3-5 days. Afterwards bundles are transported to threshing yard. In general, threshing yard is locally prepared in the field itself in one of the plots. Tarpal or plastic sheet are used to avoid mixing of soil or stones during threshing.

Conventional way of threshing is beating on hard surface manually which consumes more time. Threshing is also done mechanically by using pedal operated thresher or power thresher. Mechanical harvester cum thresher does harvesting and threshing simultaneously in the field itself which saves lot of time.

Fig: Manual threshing.

Fig: Combined harvester cum thresher.

After threshing, cleaning is done manually by using winnowers. Cleaning of grains depends on natural wind or electrical or power tiller operated fans. For storage the grains are dried so that the moisture content should be around 10-12 per cent. After drying grains are stored in gunny bags or closed containers or storage structures.

Yield

With good management, grain yield of 3.0-5.0 t/ha and straw yield of 5.0-5.5 t/ha can be obtained depending on varieties, season, locality and method of cultivation. Hybrids can yield up to 6.0-8.5 t/ha.

Cropping System

Mixed cropping

1. Rice + Rice: Growing two rice varieties together differing in plant height and growth duration in alternate lines.

2. Rice + non rice crop: Non rice crop like green gram, sesame, black gram, jute, maize, forage sorghum etc. Both the crops are sown in March-April and the intercrop is harvested before the advent of flooding in June. In case of green gram, only the pods are picked and the remaining portion provides nutrition to rice plant after decomposition.

3. Rice + *Azolla*: *Azolla* is grown along with rice as green manure crop. After incorporation it supplies nitrogen to rice crop.

4. Rice + Fish/Prawn culture: Integration of aquaculture with rice faring in flooded rice augments farm output and income and also benefits rice by improving its environments. This system has been found to be economically beneficial, besides reducing the stem borer infestation and working as predator of several pests of rice. Many fish species like catfish, snake head, *Anabas* sp. and *Trichogaster* sp. are adapted to swamp conditions.

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RICE (Contd…)

(*Oryza sativa* L.)

Aerobic Method of Rice Cultivation

In the uplands rice is grown in non-puddled fields without bunds, without irrigation, and without ponded water. The soil is aerobic throughout the growing season. Upland rice environments are very heterogeneous but a common characteristic is that water is a major limiting factor, soils are often problematic, soil erosion is frequently severe, and farmers are among the poorest, with little means to supply external inputs and the average yields are lower. In aerobic method, growing of rice in aerobic soil, but with the use of external inputs such as supplementary irrigation and fertilizers, and aiming at high yields. The target environments are lowlands where water is scare with the more favourable upland conditions.

In China, developments in this new way of growing rice started in the mid-1980s. To differentiate it from the traditional upland rice, I.R.R.I. recently coined the term 'aerobic rice', high yielding rice grown in non-puddled and non-flooded aerobic soil.

Lowland rice ecosystem however is increasingly threatened by water shortage. The reasons are diverse and location specific, but include decreasing sources (falling groundwater tables, silting of reservoirs), decreasing quality (chemical pollution, salinization), and increased competition from other sectors such as urban and industrial users. In Asia, more than 50 per cent of water used for irrigation is used to irrigate rice. Therefore, there is a need to decrease water use in rice production and increase its use efficiency. Aerobic rice is a new way of cultivating rice that requires less water than low land rice.

Benefits of aerobic method of rice cultivation

1. Puddling of soil is not required.
2. Nursery rising is not necessary.
3. Direct seeding in the main field and hence, transplanting of seedlings is not necessary.
4. Saving of seeds to an extent of about 80 per cent.
5. Saving of water up to 40-50 per cent.
6. More area can be brought under irrigation with the available water.
7. Labour requirement is less.
8. Soil structure is not spoiled.
9. Nitrogen use efficiency is more.
10. Fewer incidences of pests and diseases because of more aeration, sunlight and less humidity.
11. More number of productive tillers.
12. Higher yield.
13. More profit with reduced cost of cultivation.

14. Less methane production as moisture is maintained at field capacity. Hence, less effect on pollution.
15. Mosquito's production is reduced.

Varieties

Some of varieties used for aerobic rice cultivation are Rasi, Maas 946-1, KRH-2 (hybrid), etc.

Land Preparation

Proper land preparation and leveling should be followed for ensuring adequate crop stand and finally achieving higher yield. Ploughing 2-3 times followed by 2-3 harrowings and planking are necessary for this crop.

Sowing

Time of Sowing

Sowing of aerobic rice may be taken up as kharif (June-July) and summer (February) crop.

Seed Rate

Seed rate of 5-6 kg per hectare is used for this method of cultivation.

Spacing

Wider spacing of 25 cm. x 25 cm. or 30 cm. x 30 cm. is followed. This type of square method helps to carry out intercultural operations in both directions.

Method of Sowing

Dibbling method of sowing is practiced by dibbling two seeds per hill at five centimetre depth.

Nutrient Management

Incorporate 10 tons of well decomposed farm yard manure or compost 2-3 weeks in advance helps for better availability of nutrients. In addition, crop demands 100 kg of nitrogen, 50 kg each of phosphorus and potassium per hectare. Apply 50 per cent of nitrogen and potash and full dose of phosphorus at the time of sowing. Top dressing of 25 per cent

nitrogen and 50 per cent potash should be given at 30 days after sowing and remaining 25 per cent nitrogen at 60 days after sowing.

Water Management

Germination, Tillering and panicle initiation stages are considered as critical period for moisture. Hence, moisture should be maintained during these stages and more particularly from 75 to 110 days otherwise, it leads to chaffiness of panicles. Irrigate five days once starting from sowing till harvest and this depends on season and soil characteristics.

Weed Management

Intercultivation should be done once in 15 days by using hoes till panicle initiation. Intercultivation could be done in two directions which are facilitated by square method of sowing. Intercultivation helps not only in controlling weeds, but also aerates the soil and increases infiltration of water.

Yield

By following recommended practices, grain yield of 4.5-5.0 t/ha and straw yield of 5.0-5.5 t/ha may be obtained from aerobic rice cultivation.

S.R.I. Method of Rice Cultivation

The System of Rice Intensification, known by its acronym 'S.R.I.' is gaining popularity among rice farmers in several states. It is a method of rice cultivation enunciated by Father Henry de Laulanie, a French Jurist Priest of Madagascar in 1980s which involves the comprehensive effective management of resources such as land, seeds, water and labour. This system has been tried successfully in 40 countries across the world.

S.R.I. is a system of growing rice which involves principles that are at times radically different from the traditional ways of growing rice. It involves planting of single and young seedlings with care instead of conventional method of multiple and old seedlings from the nursery. This method spaces rice plants more widely and does not depend on continuous flooding of rice fields. It uses lesser seed, chemical inputs and promotes soil biotic activities in and around the root zone, due to liberal application of compost and weeding with a rotating hoe that aerates the soil. These changed practices with lower inputs lead to enhanced yields with considerable savings of inputs, especially the water which is becoming scarce over the years.

Benefits of S.R.I. method

1. Saving of seeds and nursery area as result of adopting wider spacing and planting of single seedling per hill. Highly suitable for hybrid rice cultivation and seed multiplication.
2. Saving of water to an extent of 30-40 per cent.
3. More area can be brought under irrigation with the available water.
4. Activity of the beneficial microbes in the root zone is enormously increased due to aerobic condition.
5. Reduction in the duration of crop as using of 8-12 days old seedlings.
6. Planting of young seedlings prolongs the vegetative growth period in the main field before panicle initiation and facilitates the production of maximum number of tillers.
7. The aerobic condition created by alternate wetting and drying and mechanical weeding facilitates profuse root growth and tillering.
8. Mechanical weeding with cono weeder facilitates soil churning and incorporation of weeds which adds biomass to the soil.
9. Earthing up action done by mechanical weeder results in formation of new roots above the original soil level and also reduces lodging problems.
10. Reduces the leaching loss of nutrients.
11. Maximum utilization of nutrients due to favourable conditions.
12. Reduces the need for supplying of nutrients through fertilizers.
13. Improves the yield.
14. Reduces the cost of cultivation.
15. More profit.

Varieties

Generally most of the high yielding varieties recommended for the region can be successfully grown under S.R.I. However, high tillering varieties and hybrids are most suitable for this method of cultivation.

Land Preparation

Preparation of main field in S.R.I. is the same as in conventional method. However, care should be taken to level the field perfectly with suitable levelers after puddling. Divide the field into small pieces by opening channels for every two meters to avoid inundation.

Fig: Land preparation.

Sowing

Seed Rate

Seed rate of five kilogram of healthy and well filled bold seeds are required per hectare.

Spacing

Reduce the plant population radically by spacing the hills widely and squarely so that both the roots and canopy have room to grow and access nutrients, sunlight, etc. The recommended spacing is 25 cm x 25 cm.

Method of Sowing

Nursery: Select about 100 m^2 nursery area preferably nearer to the main field. Prepare five beds of 1 m x 20 m/ha with sufficient provision for irrigation and drainage channels (30 cm). Prepare raised beds of 8-10 cm height by taking the soil from channels as the roots of 8-12 day old seedlings grow up to 7.5 cm deep. Apply farm yard manure or vermicompost and mix it thoroughly.

Soak the selected seeds for 12 hours in water and drain the water. Incubate it in a gunny bag for about 24 hours to facilitate just sprouting. Broadcast the sprouted seeds on the raised bed and grow them as like in conventional method.

Fig: Nursery.

Transplanting: Very young seedlings should be used, to preserve the plant's inherent growth potential for rooting and tillering. At the time of transplanting there should not be any standing water in the field. It is desirable to take up planting a day after final land preparation. Make intersections of 25 cm x 25 cm distance for facilitating square transplanting of seedlings by running appropriate marker over the prepared field both lengthwise and widthwise (crisscross). Transplant 8-12 days seedlings (2-3 leaf stage). It takes around 15-18 days during winter season. Remove the seedlings by scooping out with the help of a thin metal sheet by inserting below the seed bed to get seedlings intact with seed and soil without damaging roots and avoid transplanting shock. Place one young seedling per hill at each intersection of 25 cm x 25 cm very gently at shallow depth (2-3 cm). Interval between uprooting and planting should be less (not beyond one hour) and hence keep the nursery nearer to the main field.

Fig: Roller marker.

Fig: Wooden marker.

Fig: Marking the field.

Fig: Field after marking.

Fig: Seedlings ready for transplanting.

Fig: Transplanting.

Fig: Initial growth stage.

Fig: Tillering stage.

Fig: Profused tillering.

Fig: Comparison of root growth (Conventional v/s S.R.I.)

Nutrient Management

In S.R.I. method, encourage application of organic manures as it enhances the macro and micro nutrients in the soil in an eco-friendly way, helps in optimum utilization of some of the chemical fertilizers and protects the soil from degradation and other hazardous effects. Apply well decomposed farm yard manure or compost @10-12 t/ha before ploughing and incorporate them uniformly. Use different sources of organic manures such as azolla, pre-kharif green manures, crop rotations with legumes and crop residues, etc. rather than single source.

Apply and incorporate 50 per cent recommended fertilizers (NPK) through inorganics depending on soil test values. Though complete organic manuring is recommended for S.R.I., in case of short supply or organic manure this supplementation may adopted for better yield. Apply 50 per cent of the recommended nitrogen and 75 per cent of potassium as basal dose before last puddling and incorporate. Apply second dose (25 %) of nitrogen at the time of second weeding (20 DAT) and final dose of 25 per cent nitrogen and remaining 25 per cent potassium a week before panicle initiation stage.

Water Management

Although it is generally assumed that rice requires an abundant supply of water, it can be cultivated with the same supply of water as other cereals and the distinguishing feature lies in the fact that unlike other cereals it can tolerate standing water or swampy condition for its growth. Rice in not an aquatic plant and does not necessarily need to be grown under inundated conditions. S.R.I. advocates growing rice plants with sufficient but never excess water so that the roots do not suffocate and degenerate and the agronomic management aims at alternate wetting and drying management. Intermittent irrigation helps to increase the root activity which is closely related to carbon assimilation. This also prevents various diseases and root rot induced by the excessive reductive conditions of the soil.

Maintain water at just soil saturation level by intermittent light irrigation (1-2 cm) coinciding with appearance of fine hair cracks (alternate wetting and drying). However, maintain thin film of water while operating the weeder and same water is retained for weed incorporation. Provide sufficient drainage channels to drain the excess water and also to

avoid submergence. Maintain shallow submergence (2-3 cm) from panicle initiation to maturity. Dry the field completely about 10-15 days before harvest.

Weed Management

Weed growth is generally more in S.R.I. due to wider spacing and alternate wetting and drying. Effective and timely weed management is crucial for the success of S.R.I. Adopt invariably mechanical weeding so as to incorporate the weeds and to provide aeration to soil. Weeding should be done from 10 days after transplanting using suitable mechanical weeder and perform at least four weedings at an interval of 10 days. Manual weeding may be taken to remove weeds which are not incorporated by the weeder.

Use of mechanical weeder in S.R.I. not only remove the weeds but also incorporate them into the soil thereby adding organic matter to the soil. In addition, it does intercultural operation which results in aeration to roots and some earthing up action also. This earthing up results in formation of new roots above the original soil level and also reduces lodging problems.

Fig: Rotary weeder.

Fig: Motorised weeder.

Fig: Weeding.

Yield

Increase in the yield to an extent of 20-30 per cent in S.R.I. method compared to that under conventional method.

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WHEAT

(*Triticum aestivum* L.)

CONTENTS

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WHEAT

(*Triticum aestivum* L.)

Fig: Decoration from wheat panicles.

Introduction

In most areas of the world, wheat is the principle food of man. In India it is the second important staple food next to rice.

Fig: Wheat panicles.

Fig: Wheat grains.

Fig: Wheat field.

Importance

Wheat compares well with other important cereals in its nutritive value. It contains more protein than other cereals. Wheat has a relatively high content of niacin and thiamine. Grain contains 60-68 per cent starch, 8-15 per cent protein, 1.5-2.0 per cent fat, 2.0-2.5 per cent cellulose and 1.5-2.0 per cent minerals.

Wheat proteins are of special significance. Besides, their significance in nutrition, they are principally concerned in providing the characteristic substance 'gluten' which is very essential for bakers. The properties of gluten in wheat are such that it produces structural framework for the familiar spongy, cellular texture of bread and other baked products generally superior to those from any of the other cereal grains.

Wheat is being used in varies forms like roti, chapatti, paratha, puri, dosa, noodles, upma, halwa, kheer, payasam, laddoo, bread, bun, cake, biscuits, flakes, etc. It is also used for the manufacture of dextrose, alcohol and certain breakfast foods.

Fig: Chapati.

Fig: Puri.

Fig: Dosa.

Fig: Noodles.

Fig: Upma.

Fig: Khichdi.

Fig: Halwa.

Fig: Laddoo.

Fig: Kheer.

Fig: Payasam.

Fig: Bread.

Fig: Bun.

Fig: Cake.

Fig: Rusks.

Fig: Biscuits.

Fig: Wheat rings.

Fig: Wheat pellets.

Fig: Wheat grass as medicinal value.

Fig: Wheat germ oil.

Fig: Wheat beer.

Fig: Wheat germ cream.

The by-products derived from the milling of wheat include wheat bran, middling and shorts. All these by-products are higher in protein content than wheat itself and serve as a valuable protein supplement in many livestock rations.

Wheat straw is used as excellent fodder for livestock. It is also used for paper making, litter, mulching in the field, etc.

Origin

The growing of wheat began very early in the pre-historic period so long ago that the origin of wheat is still a matter of speculation. De Condolle believed that wheat is originated in the valley of Euphrates and Tigris. Later spread over to China, Egypt and other parts of the world. In India, evidences from Mohan-jo-daro excavations indicate that wheat was cultivated here more than 5,000 years ago.

Distribution

Wheat is most widely cultivated all the cereals. It is commonly grown in North American continent, Latin American including Europe, West Asia, North Africa, South Africa, East Africa, South Asia and Australia. In India, Uttar Pradesh, Punjab, Madhya Pradesh, Rajasthan, Bihar and Haryana are the main wheat producing states.

Classification

Wheat belongs to family Gramineae (Poaceae) and the genus *Triticum*. Although as many as 18 species of wheat have been described and recognized, commonly cultivated species are *Triticum monococcum* (Einkaran wheat), *Triticum dicoccum* (Emmer wheat), *Triticum duram* (Duram wheat) *Triticum vulgare/aestivum* (Common wheat).

Climatic Requirement

Wheat is cultivated over a wide range of latitudes ranging between 60^0 N to 60^0 S, altitudes ranging from the sea level to an elevation up to 3,500 m in the tropics and sub tropics. Normally, the most ideal conditions for wheat growth are cool and moist weather during vegetative growth period and warm and dry weather during grain formation. Because of this reason the great wheat regions of the world are found in the temperate zones between 30-60 ^{o}N and 25-40 ^{o}S.

The optimum temperature for the germination of wheat is between 20-22 ^{o}C, vegetative growth 16-22 ^{o}C and grain development maximum temperature of about 25 ^{o}C. The annual rainfall ranges between 250 and 1800 mm. Low as well as high rainfall is detrimental to wheat yield. Short days increase the vegetative growth of wheat, whereas, longer days hasten the formation of inflorescence.

Soil Requirement

Deep well drained sandy loam, loam or sandy clay loam with nearly neutral pH are most suitable for wheat cultivation. In heavy soils crop may suffer due to poor drainage.

Fig: Soil Requirement.

Varieties

The varieties recommended for rainfed condition are C-306, Mukta, Meghdoot, Sujata and for irrigated condition HD-2329, PBW-343, Girija, Sonalika, Jairaj, Janak, DWR-1006, etc.

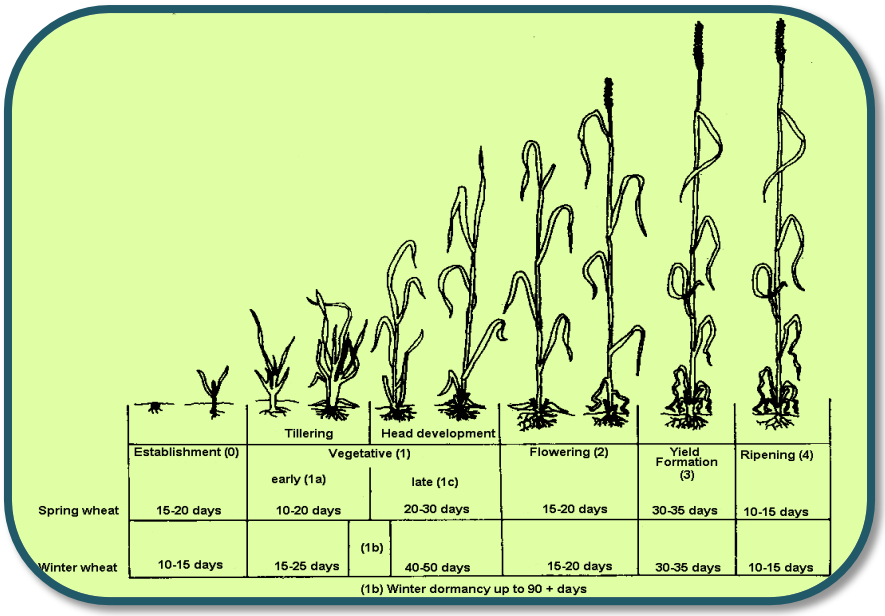

Fig: Growth periods of spring and winter wheat.

Land Preparation

Traditional system of land preparation for wheat includes one deep ploughing followed by 2-3 harrowings and planking. In rainfed areas, summer ploughing is useful for soaking the rain water in to deeper layers.

Fig: Land preparation.

Sowing

Time of Sowing

Time of sowing depends on climatic conditions, soil conditions and irrigation facility. In irrigated areas sowing should be done during the month of November and in rainfed areas during second fortnight of October to early November to realize the maximum advantage from the residual soil moisture.

Seed Rate

Broadcasting of seeds require 150 kg/ha while seed drills 100-125 kg/ha and dibbling 25-30 kg/ha. Under late sown situation or when the soil moisture is less at the time of sowing seed rate should be increased by 25 per cent.

Spacing

Irrigated wheat is spaced 22.5 cm between rows and 8-10 cm between plants. Rainfed wheat is spaced 25-30 cm between rows and 5-6 cm between plants. When sowing is delayed a closer spacing of 15-18 cm between rows is recommended.

Method of sowing

Sowing of wheat is generally done by following methods.

1. Broadcasting: It the most prevailing and simple method of wheat sowing in India. Seeds are broadcasted on soil surface, then worked in by harrowing and covered by planking.

2. Behind the Plough: In this method, the seeds are dropped by hand into the furrows that have been opened with local plough. The seeds are dropped at a desired depth by hand (kera method) or special attachment with local plough (called pora method).

3. Drilling: Drilling of seeds with the help of seed drill or seed-cum-fertilizer drill is the best method of sowing.

4. Dibbling: Sowing of seeds is done with the help of a small implement known as dibbler. Dibblers are pressed into the soil to make the holes and one or two seeds are dropped by hand in each hole and seeds are covered. Though this method greatly economies the seed, it is time consuming and labour intensive.

Nutrient Management

Application of nitrogen up to 40-60 kg/ha for rainfed condition and 120-150 kg/ha for irrigated condition is recommended. Use of farm yard manure, green manure, nitrogen fixing micro-organisms like *Azatobacter*, *Azospirillum*, etc. reduces nitrogen requirement by one-third. Nitrogenous fertilizers should be applied in two splits; 50 per cent each as basal dose at the time of sowing and top dressing at 30 days after sowing.

Requirement phosphorus for the wheat crop is up to 60 kg/ha and potassium is 40-50 kg/ha and both are applied at the sowing as basal dose.

Zinc deficiency soils require application of 25 kg/ha of zinc sulphate or foliar spray of $ZnSo_4$ @ 0.5 per cent. For this 5 kg of $ZnSo_4$ and 2.5 kg of slaked lime is dissolved in 1,000 litres of water to spray an area of one hectare. For manganese deficient soils, foliar spray of 0.5 per cent $MnSo_4$ is recommended.

Water Management

The response of wheat to irrigation depends upon the soil and climatic conditions. About 4-6 irrigations are required for wheat. Flooding method of irrigation is commonly practiced by the farmers in India.

The most critical stage for moisture stress is crown root initiation stage (20-25 days after sowing) and flowering stage (80-85 days after sowing).

Weed Management

Weeds emerge with the crop and if not controlled in the early stages of crop growth they may cause reduction in yield. First 30 to 40 days are regarded highly critical for crop-weed competition.

The major dicot weeds like *Chenapodium album*, *Melilotus alba*, *Circium arvense* and monocot weeds like *Phalaris minor*, *Avena fatua*, *Cyperus rotundus*, *Cynadon dactylon* are most commonly found in wheat fields.

Generally weeds are controlled by hand weeding with hoe or khurpi, etc. First hand weeding is done with the appearance of thick flush of weeds. Second hand weeding may be repeated after two weeks.

Pre-emergence application of Pendimethalin @1.0 kg/ha and post-emergence application of 2,4-D (ethyl ester) @ 0.3-0.4 kg/ha, Isoproturon, Metoxuron @1.0-1.5 kg/ha in 700-800 litres of water within 30-35 days after sowing effectively control broad spectrum of weeds in wheat. During initial growth stages, the morphological features of *Phalaris minor* (little canary grass) and *Avena fatua* (wild oats) are closely resemble the traits of wheat seedlings. Therefore, it is difficult to recognize them during hand weeding. They can be controlled by post emergence application of Isoproturon, Metoxuron @1.0-1.5 kg/ha.

Fig: Weeding.

Plant Protection

Insect Pests

1. Termites: Infestation of termites is more under un-irrigated conditions and in the field where un-decomposed compost is applied. Termites can be controlled by the use of 4 per cent Endosulfan dust @ 20-25 kg/ha.

2. Gujhia Weevil: Control measure is same as of termites.

3. Army Worm: Army worms feed on plants during night time and during day time pick them and kill. They may be controlled by dusting 4 per cent Endosulfan @ 20-25 kg/ha or by spraying Carbaryl @ 2.5 kg/ha.

Fig: Army worm.

Diseases

1. Rusts: Grow rust resistant varieties. Avoid late sowing because late sown crop is more susceptible to rusts. High dose of nitrogen favours rust infection, whereas, high potash dose reduces rust infection. Spray Zineb at 0.2 per cent or Dithane M-45 at 0.1 per cent after appearance of pustules. Second and third spray may be repeated with an interval of 10-15 days.

Fig: Stem rust.

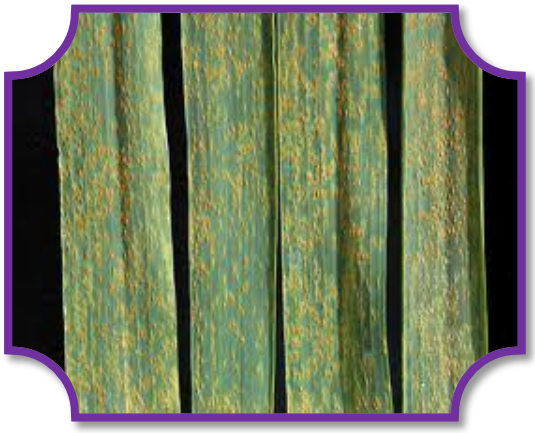

Fig: Leaf rust.

2. Loose Smut: Grow loose smut resistant varieties. Production of black powder in place of wheat grains in the ears. Uproot the infected plants, burry them into soil or burn. Seed treatment with Vitavex @ 2.5 g/kg of seed before sowing.

3. Kernel Burnt: Black powder in the grains and foul smell. Select resistant varieties. Avoid continuous cropping of wheat in the same field. Avoid excessive irrigation during flowering stage. Select disease free seeds and treat the seeds with Cerason Agrosan @ 2.5g/kg seed.

4. Alternaria Leaf Blight: Apply adequate quantity of fertilizer and water. Treat the seeds with Vitavax @ 2.5g/kg seed. Spray Dithane M-45 or Zineb @ 0.2 per cent.

5. Powdery Mildew: Select resistant varieties. Spray mixture of Dithane M-45 and Karathane in the ratio of 4:1 @ 2 kg/ha. The spray should be repeated twice at an interval of 10-15 days.

Field Rats

Rats cause heavy loss to wheat crop in the field. For their control fumigate the burrows of rats with Aluminium phosphate at one tablet of 0.5 g for small burrow and 3.0 g for large burrow.

Fig: Field Rats.

Harvesting and Threshing

When straw turns to yellow and dry is the visual indicator for harvesting of wheat crop. Delay harvesting leads to shredding, breaking of spikes and shattering of grains. Grain should be hard and should have 20-25 per cent moisture content at the time of harvesting. Harvesting is generally done manually with sickle or serrated sickle. Bullock driven reapers are also used. After harvesting, the crop is dried for 3-4 days on the threshing floor and threshing is done by threshers. Combined harvester cum thresher is used for harvesting, threshing and winnowing in single operation. For storage purpose, the moisture content in the grains should be around 10-12 per cent.


Fig: Reproductive stage.


Fig: Maturity stage.

Fig: Matured panicle.

Fig: Harvesting.

Fig: Transportation.

Fig: Threshing.

Fig: Cleaning.

Fig: Mechanical harvester cum thresher.

Fig: Threshed grains.

Fig: Loading.

Fig: Bagging.

Fig: Storage.

Yield

The potential yield of semi-dwarf wheat varieties varies between 6.0-7.5 t/ha. Grain yields of 4.0-5.0 t/ha is obtained in the farmer's field.

Fig: Wheat grains ready for milling.

Fig: Flour machine.

Fig: Wheat flour.

Cropping System

In traditional wheat belt of northern India, farmers practice rice - wheat, rice - wheat - green gram, maize - wheat, maize - wheat - green gram, maize - potato - wheat - green gram, cotton - wheat, pigeon pea - wheat, pearl millet - wheat cropping system. In non-traditional wheat belt, rice - rice - wheat, jute - rice - wheat, rice - wheat - maize are followed.

Wheat can also be intercropped with a number of crops like mustard, chick pea, lentil, safflower and linseed.

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Maize

(*Zea mays* L.)

CONTENTS

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Maize

(*Zea mays* L.)

Introduction

Maize is third important cereal crop next to rice and wheat. It is one of the most important cereal crops in the world agricultural economy both as food for man and feed for animals. It is a miracle crop. It has very high yield potential, there is no cereal on the earth which has so immense potentiality and that is why it is called 'queen of cereals'.

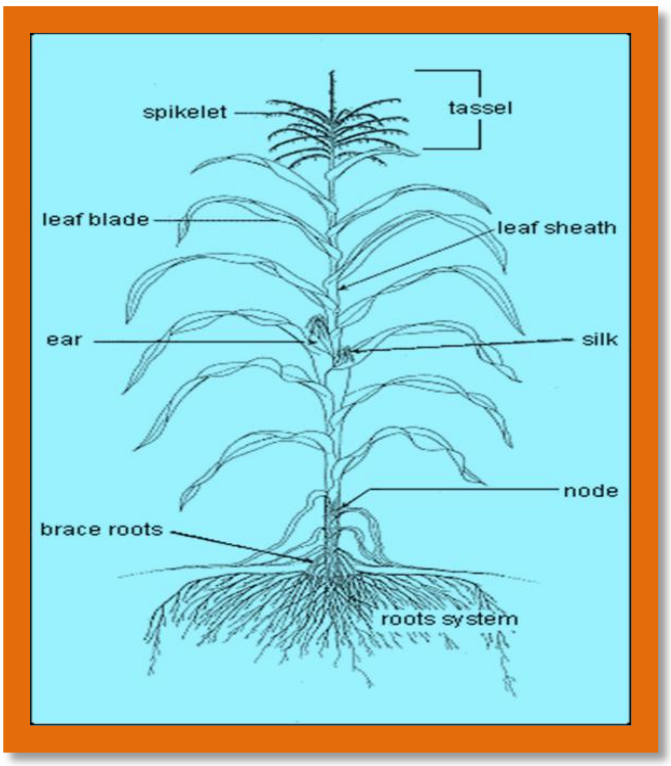

Fig: Maize plant.

Importance

Maize grain contains about 71.5 per cent starch, 1.97 per cent sugar, 10.3 per cent protein, 4.8 per cent fat and 1.44 per cent ash. The protein content varies between 6-15 per cent in different strains. Maize is the richest of the cereals in fat, with the exception of oats, and strains of maize may contain as much as 7.0 per cent fat. Maize is poor in Ca but rich in P and K like other cereals. Mg, Na and Cl are very less and Fe is sufficient.

Fig: Maize grain.

Maize is used locally as the major cereal in the traditional areas in the form of chapatti. In addition, tender ears are consumed in roasted form. Pop corn is consumed upon heating. Use of flakes, bread, buns, rusks and biscuits etc. is becoming popular. Baby corn is used as vegetable as salads, manchuri, etc.

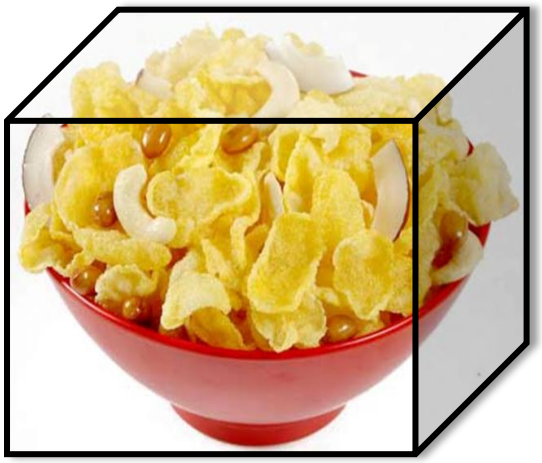

Fig: Corn flakes.

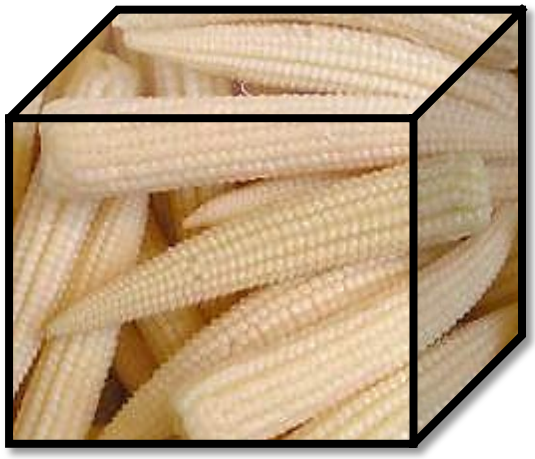

Fig: Baby corn.

Maize is used as an important ingredient in animal feed. It is a basic ingredient of swine and poultry rations. Maize stover is used as fodder for animals.

Maize starch is used in textile industry, paper industry, oil well drilling, batteries, leather and foods materials. Maize starch is the raw material for sweeteners. The maize syrups and high fructose corn syrups (HFCS) are sold as liquids.

Maize oil is a very fine cooking medium when fully refined with nearly 90 per cent polyunsaturated fats e.g. corn oil. It is only the cereal from which oil can be extracted. Maize oil cakes can be used as organic manure.

Alcohol extracted from maize is used both as a substitute for petrol as being developed in Brazil and as industrial ethyl alcohol. Bio-degradable plastics made by co-

polymerizing organic (starch) and synthetic polymers are already in use for agriculture and other purposes.

Origin

Maize has been cultivated for thousands of years. During archeological excavations in New Mexico, grains of maize and parts of maize ears found in caves and rocks shelter, which are thought to be about 4,500 years old.

Distribution

Although in the first instance maize was grown in the gardens rarely, its value was very soon recognized as a food crop. So maize spread over large area of Spain, Portugal, France, Italy, South Eastern Europe and North Africa in the years following its introduction. The Portuguese brought it to West Coast of Africa in the beginning of 16th century and somewhat later to India and China.

Classification

Maize is an annual plant belongs to family Graminae/Poaceae and the genus *Zea*. The genus *Zea* has only one species *Zea mays* (L.). It is divided into seven groups. The classification is based on largely on the character of the kernels.

1. **Flint Corn (*Zea mays indurata*):** The endosperm in this type of maize kernel is soft and starchy in the centre and completely enclosed by a very hard outer layer. The kernels are usually rounded but are sometimes short and flat. Colour may be white or yellow. This is the type most commonly cultivated in India.

2. **Dent Corn (*Zea mays indentata*):** Kernels have both hard and soft starches. The hard starch extends on the sides, and the soft starch is in the centre and extends to the top of the kernels. Rapid drying and shrinkage of the soft starch results in characteristic denting. This is the most common type of maize grown in U.S.A.

3. **Pop Corn (*Zea mays everta*):** It possesses exceptional popping qualities. The kernels are usually small and contain an even higher percentage of hard starch than flint corn. When they are heated the pressure buildup within the kernel suddenly results in an explosion and the grain is turned inside out. The corn is used for human consumption as freshly popped maize.

4. **Sweet Corn (*Zea mays saccharata*):** Sweet corn contains glassy, sweetish starch. It is characterized by a translucent sweet horny appearance when immature and a wrinkled condition when dry. The ears are picked green for table use and canning. It contains 5.0 per cent sugar as compared to 2.0 per cent in dent and 2.3 per cent in flint type.

5. **Floor Corn or Soft Corn (*Zea mays amylacea*):** Floor maize is somewhat similar to Flint corn in plant and ear characteristics. Kernels are composed of entirely of soft starch. They especially develop no dent or only a very small one.

6. **Pod Corn (*Zea mays tunicata*):** Pod corn is characterized by having each kernel enclosed within a pod or husk. It belongs to one of the earliest domesticated types and hence it is not grown commercially.

7. **Waxy Corn (*Zea mays ceretina kulesh*):** The endosperm of the kernel when cut or broken gives a waxy appearance. The starch is gummy and has some of the characteristics of tapioca. It is now being grown commercially on a small scale to produce starch similar to tapioca starch.

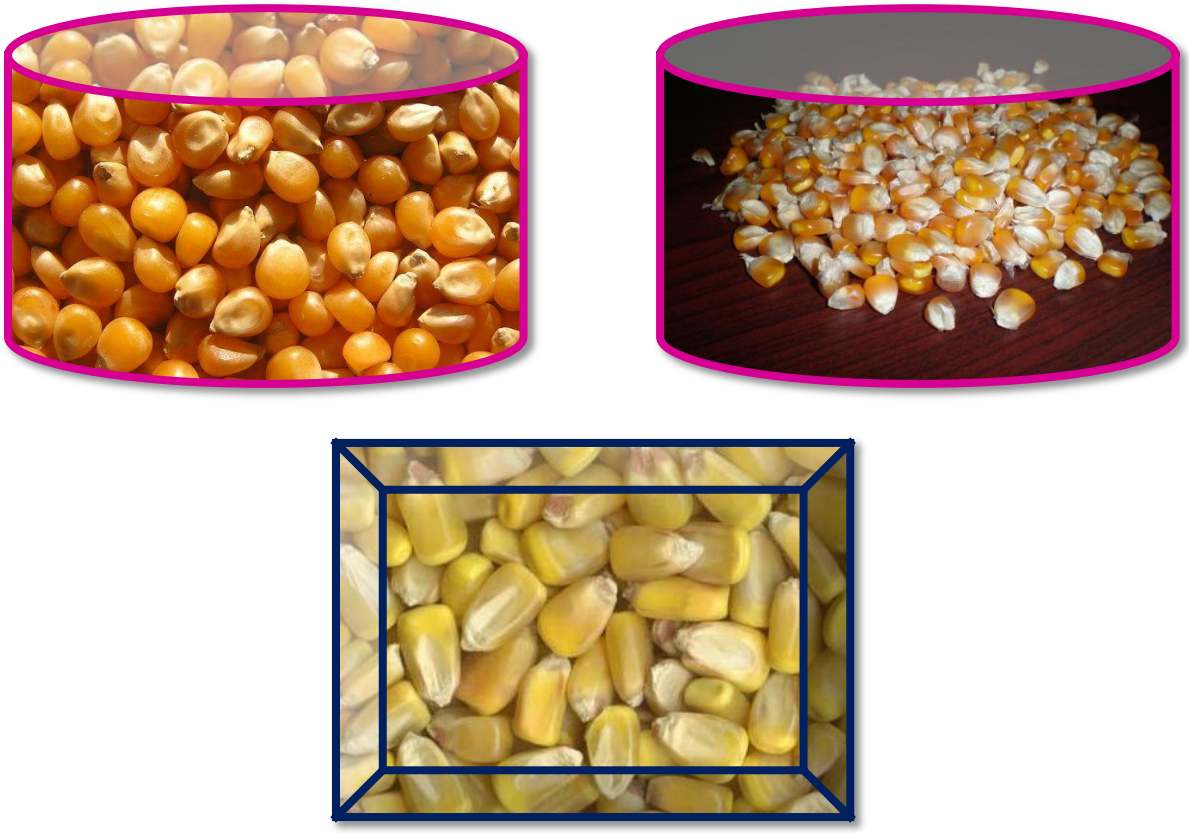

Fig: Types of maize grains.

Climatic Requirement

Maize crop is being cultivated in the latitude of 58 ^{o}N to 35-40 ^{o}S. Though the crop is cultivated on a very wide range of agro-climatic conditions, yet moderate temperature with sufficient supply of water are most favourable. Temperature below 12 ^{o}C and higher than 30 ^{o}C does not favour its cultivation.

Soil Requirement

Maize requires well drained soil and cannot with stand water logged situation. It can be grown on the soils having pH ranging from 5.5-8.0.

Fig: Soil Requirement.

Varieties

A number of maize hybrids and composites for *kharif* and rabi seasons have been recommended. Hybrids like Ganga safed-2, Ganga-5, Ganga-9, Deccan, Deccan-103, composites like Kisan, Tarun, Harsha, Arun, Renuka, Kiran and fodder varieties like African tall, Deccan, Deccan 103, Ganga-5, CO-1 etc. are recommended for cultivation.

Land Preparation

The main objectives of land tilling are to prepare a good tilth in the soil for seed germination, scrap the weeds and stubble of previous crop and conserve moisture for the crop. One deep ploughing followed by 2-3 harrowings and planking are necessary for this crop. In rainfed areas, summer ploughing is useful for soaking the rain water in to deeper layers.

Fig: Land preparation.

Sowing

Time of Sowing

Time of sowing is indirectly determined by the soil and atmospheric temperature as well as by the supply of water. Thus, there is a general preference for sowing of the crop at the time of onset of monsoon. Late planting in mid-monsoon period creates numerous problems.

Seed Rate

The quantity of seed required for dibbling method is about 15 kg/ha. However, in planting by other mechanical methods one may use as high as 25 kg seeds/ha. The seed rate should be so adjusted as to obtain the desired plant population.

Spacing

To obtain desired plant population one may sow the seeds into rows spaced from 60-90 cm apart and seed to seed distance of 20-30 cm within the row. However, for practical ease a spacing of 75 x 20 cm is more appropriate which is convenient for machine drawn by tractor or bullock power.

Depth of sowing

For obtaining perfect germination and uniform stand, placement of seed at a desired depth is one of the most important factors. A uniform depth of 5.0 cm is ideal for better germination.

Method of Sowing

Three methods of sowing are commonly followed under Indian conditions.

1. Flat Sowing: On light soils crop is sown on the smooth seed bed. If necessary crop can be earthen up subsequently to avoid plant lodging.
2. Ridge Sowing: Ridges are prepared and the sowing is done on top. This system of planting is very useful under high rainfall area of heavy soil. Excess water flows through the trenches and thus contact with seed or plant is avoided.
3. Furrow Sowing: Under low moisture condition, this is one of the most effective methods of sowing. Moisture in furrows continues to be available for longer period.
4. Transplanted Maize: Can be successfully cultivated by transplanting in winter season. The nursery sown from 10-20 November can be transplanted from mid-December to mid-January. Only one month old seedling may be used for transplanting.

Fig: Mechanical seed drill.

Fig: Seedling stage.

Fig: Two-leaf stage.

Fig: Four-leaf stage.

Fig: Knee-hight stage.

Fig: Rapid growth stage.

Fig: Roots.

Fig: Reproductive stage.

Fig: Tassels (Male).

Fig: Cob with silk (Female).

Fig: Immature cobs.

Fig: Matured cob.

Fig: Types of cobs.

Nutrient Management

Requirement of nutrients by hybrids is higher because of its greater potentially for grain production.

Manures

Application of 10 tons of well decomposed farm yard manure per hectare helps in improving the yield under irrigated condition and 7.5 t/ha under rainfed condition.

Fertilizers

Nitrogen: Nitrogen level in the range 100-120 kg/ha is applied. There is gradual increase in the requirement of nitrogen by the growing crop, the highest nitrogen requirement being exhibited at the flowering stage. Subsequently, the demand for nitrogen starts declining. Therefore, adequate nitrogen supply should be ensured from germination to the flowering stage. To achieve this, nitrogen is usually applied in three equal splits at sowing, knee high stage and tasseling stages.

Phosphorus: It is the next most important plant nutrient after nitrogen which is found deficient in most soils. It has a beneficial effect on root growth and plant health. Application of 40-60 kg/ha of phosphorus is necessary for getting better yields. Its application in single dose as a placement below seed is highly desirable.

Potassium: Potassium is essential for vigorous growth of the plant and for so many other metabolic activities. Placement of 30-40 kg/ha potassium little away from the seed is generally found to be quite adequate.

Zinc: Higher uptake of other nutrients increases the demand of zinc. It is, therefore, advisable to apply zinc sulphate @ 20-25 kg/ha in those conditions where its deficiency is more conspicuous.

Water Management

A total rainfall in the range of 500-600 mm during the crop season would be quite enough for maize, if the water losses through different sources are kept to the minimum. It is important to note that few hours water logging at germination stage may cause complete wipe out of the crop. Flooding the crop for duration of 24 to 72 hours may cause 30-40 per cent damage in crop yield. It is, therefore, essential to prevent such a high loss by proper water management. Wherever possible, maize sowing may be undertaken before onset of monsoon preferably 10 to 20 days in advance. By doing so the high rainfall period will coincide with grand growth period of the crop and may not have any adverse effect on the crop yield. Under moisture stressed conditions to achieve higher water use efficiency, crop has to be sown in furrows instead of ridges.

Adequate soil moisture content throughout the crop growth period resulted in maximum grain yield. The optimum availability of moisture may be maintained by irrigation crop at critical stages. Six critical stages i.e. early knee, late knee, flowering, silking, milk and dough stages for growth and development have been identified for the purpose of irrigation.

Fig: Surface Irrigation.

Fig: Sprinkler Irrigation.

Weed Management

Weeds have an inherent fast growing and fast multiplying capacity. They pose a serious threat in fields of wider spaced crops like maize. Most common weeds in maize are *Cyperus rotundus*, *Cynadon dactylon*, *Digitaria sanguinalis* among monocots and *Tribulus terrestris*, *Trainthema portulacastrum*, *Traintheme monogyna*, *Corchorus actangulus* among dicots.

Weeding may be undertaken as soon as the crop germinate and attains 3-4 leaf stage (about 25 days after sowing) and may be continued till 75 days after sowing. Any delay in weed removal may cause fall in grain yield. Unweeded crop is likely to give 50 per cent less yields as compared to clean seed bed. Weeds are usually controlled by manual labourers in 2-3 operations. Atrazine at 2.5 kg/ha is one of the most efficient herbicides which remains effective for a maximum period of 30 days. In legume-cereal mixture, Pendimethalin at 2.5 l/ha has been found to be the most effective and protects both the legume and cereal crop in pre-emergence application.

Fig: Manual weeding.

Fig: Intercultivation.

Fig: Polythene mulching.

Plant Protection

Insect Pests

Stem Borer: Pull out all dead hearts and destroy them to kill the lingering stages of the pest in the stubbles. Plough up the field soon after harvesting of maize, collect and burn the stubbles. Grow resistant/tolerant varieties. Sowing of crop in the first week of July evades borer infestation. Use higher seed rate and remove the plants showing severe borer injuries at thinning. Spray Endosulfan 35 EC 0.1 per cent, Lindane 20EC 0.05 per cent or Carbaryl 50 WP 0.1 per cent.

White Grubs: Hand collection of adults and their killing in kerosene water helps in reducing future generations. Spray Carbaryl 50 WP or Monocrotophos 36 WSC 0.05 per cent or Quinalphos 25 EC 0.3 per cent on host trees. Use Phorate 10 per cent or Quinalphos 5.0 per cent granules in rows @ 25 kg/ha before sowing crop in endemic areas.

Termites: Mix 4.0 per cent Endosulfan dust @ 25 kg/ha in the soil before sowing in termite prone areas.

Hairy Caterpillars and Climbing Cutworms: Spray Endosulfan 35 EC 0.1 per cent after the appearance of pests.

Fig: White Grubs.

Fig: Stem Borer.

Diseases

Leaf Blight: Grow resistant maize cultivars such as Deccan, Deccan-103, Ganga-5, Deccan-101, VL-42 and Ganga-4. Use protective fungicides of Dithane M-45, Zineb @ 2.0-3.0 kg/ha as soon as first symptoms of the disease appear at knee high stage of the crop growth.

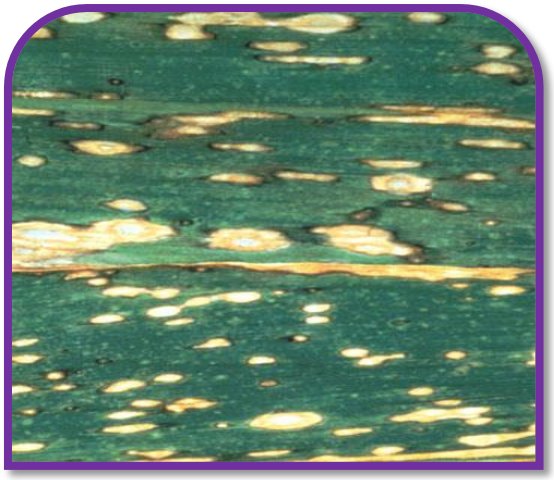

Fig:: Leaf Blight.

Rust: Select resistant maize cultivars for planting in areas where rust becomes problem, e.g., hybrid Ganga-4. The severity of the disease during rabi season can be reduced by spraying Mancozeb or Zineb @ 2.5-3.0 kg/ha. The first spray should be given as soon as rust pustules appear on the foliage and then two or three more sprays at 10-15 days intervals.

Fig: Rust.

Downey Mildew: Resistant maize cultivars such as hybrids Ganga-5, Ganga-9, composites Kisan, Tarun, Naveen, Sweta, Kanchan and others offer the best means of control. Planting of maize at least a fortnight before the onset of rains reduces the incidence and the disease becomes less if planting is done during dry season. Select well drained fields for maize planting, if this disease is problem in the area arrange proper drainage to drain out the excess rain water. The disease can be minimized by spraying the foliage with fungicides such as Mancozeb (0.3%). First spraying should be done about a month after planting or as soon as the disease symptoms are seen. Other 3-4 sprays should be done at 10-15 days intervals depending on severity of the disease. Burn the crop residue after the harvest. Practice three year crop rotation to minimize the initial inoculum load in the field.

Harvesting and Threshing

Harvest maize cop when husk has turned yellow and grains are hard enough having less than 30 per cent moisture. Do not wait for stalks and leaves to dry because they remain green in most of the hybrids and composites.

Remove the husk from the cobs and then dry them in sun for seven to eight days. Thereafter grains are removed either by beating the cobs by sticks or with the help of maize threshers. After threshing dry them under sunshine and bring the moisture to 10 to 12 per cent and store them. The stover may be harvested and fed to animals.

Fig: Harvesting of cobs.

Fig: Removal of husk from the cobs.

Fig: Drying of cobs.

Fig: Harvesting of stover.

Fig: Threshing of cobs.

Fig: Bagging of grains.

Fig: Mechanical harvester cum thresher.

Fig: Waste after de-husking.

Yield

By following improved cultivation practices, maize yields 5-6 t/ha of grain in case of hybrids and 4.5-5.0 tons in case of composites under irrigated conditions. In case of rainfed crop yield levels are about 2.0-2.5 tons for hybrids and 1.5-2.0 tons for composites.

Cropping System

Maize based crop rotations and intercrops followed are as follows.

Crop Rotations: Maize - wheat, maize - potato, maize - potato - cowpea, maize - mustard, maize - barley, maize - ragi, maize - sunflower, maize - groundnut and maize - safflower.

Intercrops: Maize + red gram, maize + soybean, maize + onion, maize + cowpea, maize + black gram, maize + green gram, maize + cluster bean, maize + sesame, maize + groundnut and maize + horse gram.

Fig: Maize + Onion

Fig: Maize + Soybean

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SORGHUM

(*Sorghum bicolor* L. Moench)

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SORGHUM

(*Sorghum bicolor* L. Moench)

Introduction

Sorghum is also called as jowar. It is the forth in importance among the world's leading cereals. Millions of people in Africa and Asia depend on sorghum as the staple food. It is one of the most widely grown dry land food grains in India. It has capacity to withstand drought. It makes comparatively quick growth and gives not only good yields of grain but also very large quantities of fodder.

Importance

Sorghum grain contains about 70 per cent carbohydrates, 10-12 per cent protein and three per cent fat. It can satisfactorily replace other grains in the feeding programme for dairy cattle, poultry and swine.

Sorghum is used for food, feed and forage. The grains are used in Chapati or eaten like rice after boiling or as popped grains. The grains are also used as a feed for cattle, swine, poultry and birds. Green fodder and stover is palatable to milch and draft animals. Industrial uses of sorghum are in fortification of food, preparation of malt, beverage alcohol. Sweet sorghum varieties (17.8 % brix) are used in extraction of raw sugar.

Fig: Roti.

Fig: Juice extraction.

Fig: Beverages.

Origin

The cultivated sorghum probably originated in East Central Africa, in or near Ethiopia or Sudan because of the great diversity of types growing in that region. The diversity of cultivated sorghum types decreases towards Southern Africa, and Asia. The crop was introduced in India around 1,500 B.C.

Distribution

Important sorghum growing countries are U.S.A., India, China, Nigeria, Sudan and Argentina. In India, important sorghum growing states are Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh, Gujarat, Tamil Nadu, Rajasthan and Uttar Pradesh.

Classification

Sorghum bicolor (L. Moench) belongs to family graminae. On the basis of spikelet types and grains *Sorghum bicolor* is divided into five basic races as bicolor, guinea, caudatum, kafir and durra.

Fig: Types of sorghum.

Climatic Requirement

Sorghum requires warm climate but can be grown under a wide range of conditions. It can tolerate drought conditions very well because it remains dormant during moisture stress conditions but resumes growth when favourable conditions reappear. Leaves possess waxy coating and presence of motor cells in leaves rolls the leaves under moisture deficit conditions. It has a high resistance to desiccation, low transpiration ratio and a large number of fibrous roots.

Sorghum can also tolerate water logging conditions better than any other cereal except rice. Therefore, sorghum can be grown successfully in areas having an average annual rainfall between 600 and 1,000 mm. High rainfall at heading reduces pollination and gives poor yield, though crop is tolerant to water logging. Sorghum is grown both in kharif and in rabi. Minimum temperature required for germination is 7-10 °C, germination does not take place if temperature is less than 7 °C. Optimum temperature for growth is 25-30 °C. Sorghum plants can tolerate high temperatures throughout their life cycle better than any other cereal crop. Crop is sensitive to low temperature. Temperature below 15 °C affects crop growth adversely. It is a short day plant.

Soil Requirement

Sorghum is raised predominantly in vertisols and to lesser extent in alfisols. Soils having good water holding capacity, rich in humus are best suited. Black cotton soils are categorized as best soils for its cultivation. It does not thrive in sandy soils but does better on heavier soils. Crop is grown in pH range of 6.0-8.5. It tolerates considerable salinity and alkalinity.

Fig: Soil Requirement.

Varieties

Large number of varieties/hybrids with higher yield potential than that of local has been released. Varieties recommended for kharif season are CSV 10, CSV 11, SPV 462, SPV 475, etc. and rabi season are CSV 11, M 35-1, A 1, CSV 8R, Swathi, etc. Hybrids recommended for kharif season includes CSH 1, CSH 5, CSH 6, CSH 9, CSH 10, SPH 468, etc. and rabi season includes CSH 12R, CSH 13R, CSH 5, CSH 10, SPH 677, etc.

Land Preparation

Crop needs good tilth. Field is prepared by one deep ploughing followed by 2-3 harrowings or ploughings with country plough immediately after onset of monsoon. Planking should be done after each ploughing to break the clods and to level the field.

Fig: Land preparation.

Sowing

Time of Sowing

Sorghum is sown thrice in a year. In north it is sown in kharif and summer and in west and south besides kharif, rabi crop is also taken. Kharif sorghum is generally sown with the onset of monsoon. Late sown crop is susceptible to shoot fly and midge. Dry sowing just before onset of monsoon is the best. Rabi crop of sorghum should be sown around middle of September. Summer sorghum is mainly raised for fodder and crop is generally sown in March-April in north India. In Tamil Nadu, Andhra Pradesh and Karnataka summer crop is sown in January-February under irrigated conditions.

Seed Rate and Spacing

Sorghum crop is sown at 45 x 12 cm using 9-10 kg seeds/ha.

Method of Sowing

Crop is sown with country plough; however seed cum fertilizer drill is efficient. Sowing sorghum in ridge and furrow system is recommended in low rainfall areas. Generally, the depth of sowing is 3-4 cm.

Fig: Sowing of seeds.

Fig: Seedling stage.

Fig: Vegetative stage.

Fig: Reproductive stage.

Fig: Ripening stage.

Nutrient Management

Application of FYM at 8-10 t/ha prior to sowing not only provide essential nutrients but also improve germination by reducing crust and also increases water retention capacity of soils. Sorghum is a heavy feeder of plant nutrients. General recommendation is 60 kg N, 30 kg P_2O_5 and 30 kg K_2O for rainfed areas and 80 kg N and 40 kg P_2O_5 and 40 kg K_2O for irrigated areas. For hybrids 100 kg N/ha is beneficial under irrigated conditions. In intercropping system with pulses, sorghum is to be supplied with 50 per cent of recommended levels of nitrogen, phosphorus and potassium.

Full quantity of phosphorus and potassium and half quantity of nitrogen should be drilled at 10 cm below at the time of sowing. Remaining half quantity of nitrogen should be given 30-35 days after sowing at knee high stage of crop. If moisture is scarce, avoid top dressing.

In zinc deficient area, apply 20-25 kg $ZnSO_4$ or 0.2 per cent $ZnSO_4$ with half quantity of lime to prevent burning of laves.

Water Management

Sorghum is drought tolerant crop. They have extensive and deep root system capable of extracting soil moisture from deeper soil layers. High yielding varieties respond well to irrigation. Early seedling stage and flowering primordial stages are considered most critical for moisture stress. Generally 1-8 irrigations are needed, depending on soil and climatic conditions.

Weed Management

Most common weeds found in sorghum fields are *Amaranthus viridis*, *Euphorbia macrocephylla, Phyllanthus niruri, Commelina benghalensis* among broad leaf weeds; *Cyperus rotondus, Cynodon dactylon, Sorghum halepense, Dactyloctenium aegyptium* among grassy weeds.

First 30-40 days after sowing is considered as critical period for weed competition. Inter row weeds may be controlled mechanically by running blade harrow, but intra row weeds remain. Hand weeding with *khupi* or hand hoe is most common practice. Two hand weedings at 15 and 30 days after sowing effectively control the weeds. Both in inter and intra row weeds can be controlled by using herbicides efficiently. Pre-emergence application of atrazine or Simazne @ 0.25-0.75 kg/ha and post-emergence application of 2,4-D @ 0.50-0.75 kg/ha 15-20 days after sowing direct spraying in between rows control the weeds effectively.

Striga (Striga lutea) a parasitic weed causes 15-100 per cent loss depending on severity of infestation. Following are the ways to check its infestation and control.

1. Grow *Striga* resistant varieties as Co-20, N-13 etc.

2. Crop rotation with trap crops as cotton, sunflower and groundnut, destroys the seeds and minimize the losses.
3. In standing crop, hand pulling when population is less or spraying 2.0 kg 2,4-D sodium salt as directed spray check its infestation and damage.

Plant Protection

Insect Pests

Shoot Fly: Insect causes damage from 1-4 week after emergence, Maggot feeds on tips resulting into wilting of central leaf. Leaf dries and gives a typical appearance of dead heart. At later stages, infested plant produce side tillers. Infestation can be avoided by sowing crop within 7-10 days of onset of monsoon. In rabi sowing end of September to first week of October, avoid shoot-fly damage. Seed treatment with Furadan at 100 g/kg seed or Furadan 3G or Phorate 10 G at sowing @ 20 kg/ha also check incidence. In case of infestation in standing crop, spray 0.025 per cent Metasystox. Repeat spraying after 15 days.

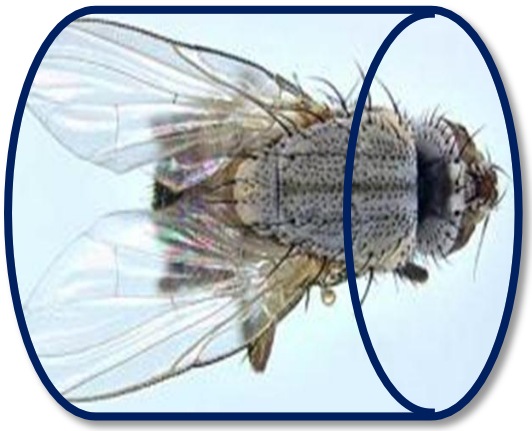

Fig: Shoot fly.

Fig: Seed treatment device.

Stem Borer: Infest crop from 15 days till maturity. Larvae initially feed on leaves. Later, the larvae bore into the main stem causing stem tunneling leading to breakage of stem. Preventive measures are to uproot and burn the stubbles of previous crop. Infestation may be checked by applying Endosulfan 4G or Malathion 10D or Furadan 3G in whorl @ 8-12 kg/ha at 20-35 days after emergence after any visual symptom of insect.

Fig: Stem borer.

Diseases

Downey Mildew: Appearance of vivid green and white stripes on leaves. Stunted growth and failure to produce head at advance stage is observed. Seed dressing with Metalaxyl (Ridomil 25) at 1.0 g/kg control infection. In field, spray of' Metalaxyl 0.01 per cent 40 days after germination check spread of Downey mildew.

Grain Moulds: This disease is caused by many fungal species. Grains infected with *Fusarium moniliforme* have white or pinkish colour, while grains infested with *Curvularia lunata* have black appearance. Discolouration of grain, reduction in grain weight leading to 75-100 per cent damage. The harvested grains are also toxic to animals. Seed treatment with Captan 4 g/kg seeds is a preventive way. In field, three sprays of Aureofungin 200 ppm + Captan 0.3 per cent from 50 per cent flowering at 10 days interval is costlier but very effective. Spraying three times Dithane M-45 and Bavistin 0.2 per cent from flowering at 10 days interval control grain mould.

Rust: Rust pustules invade the lower leaves. In susceptible varieties entire leaf tissues are destroyed by pustules. Use of clean seed, crop rotation and use of resistant varieties are preventive ways against this disease. Effective control in field could be achieved by four sprays of Dithane M-45 at 0.2 per cent at 10 days interval from 30 days after germination.

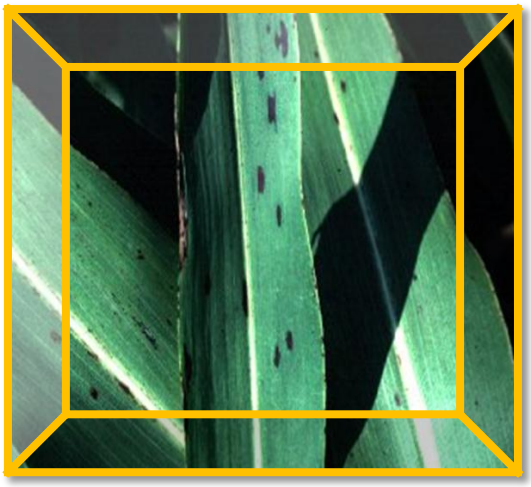

Fig: Rust.

Harvesting and Threshing

Crop should be harvested when grains are hard and having 20-25 per cent moisture. Crop may be harvested either by cutting ear head or whole plant and then ear heads are collected. Crop is threshed manually by beating with sticks or by running bullocks over heap of ear heads or by mechanical thresher after drying. Produce is cleaned and dried in sun till 10-15 per cent moisture.

Fig: Transportation of harvested produce.

Yield

Irrigated crop grown with full improved cultivation practices yield 4.5-5.0 t/ha of grain and 10-11 t/ha dry fodder. Rainfed crop provides 2.0-3.0 t/ha grain with 7.5-8.0 t/ha dry fodder.

Cropping System

Ninety five per cent of sorghum in India is rainfed. Monoculture is a common practice due to moisture stress. With the development of short duration, improved varieties double cropping is possible. Common cropping systems with sorghum are sorghum -

chickpea, sorghum - pea, sorghum - mustard, sorghum - wheat, sorghum - sunflower, sorghum - safflower, sorghum - chickpea - sorghum, sorghum - wheat - green gram, sorghum - wheat - groundnut.

Intercropping of sorghum with pulses or oil seeds, paired planting system (30/60 cm) is good. Maximum returns of soybean, green gram, pigeon pea, groundnut and safflower may be obtained in paired rows of 30/90 cm with two rows of intercrop in 90 cm space.

Sorghum Poisoning

Young plants (30-40 days stage) contain cynogenic glucoside 'Dhurrin'. Dhurrin in the stomach of animals is converted into hydrocyanic acid. Thus, when young plants (about 5 kg) of sorghum are fed to animals, it causes carcinogenic death of cow. This is known as 'prussic acid poisoning' or 'sorghum poisoning'. HCN content is more in leaves. Concentration of HCN is more in morning, and in summer. The toxic limit of HCN is 200 ppm and concentration decreases after 50 days. To overcome this problem, avoid feeding sorghum before 50 days stage. Hay and silage are generally free of HCN.

As first aid treatment affected animals may be given intravenous injection of Sodium thiosulphate to restore capability of oxygen transport of blood. Two full drenches of molasses may be given to provide extra energy to animals.

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SOYBEAN

(*Glycine max* L. Merril)

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SOYBEAN

(*Glycine max* L. Merril)

Introduction

Soybean possesses a very high nutritional value apart from the high yield potential. Soybean being the richest, cheapest and easiest source of best quality proteins and fats and having a vast multiplicity of uses as food and industrial products is called a 'wonder crop'.

Importance

Soybean contains 40 per cent high quality protein and 20 per cent oil. Soybean protein is rich in valuable amino acid lysine (5 %) which is deficient in most of the cereals. In addition, it contains a good amount of minerals, salts and vitamins (thiamine and riboflavin) and its sprouting grains contain a considerable amount of vitamin C. Vitamin A is present in the form of precursor carotene which is converted into vitamin A in the intestine.

Enriching cereal flour with soybean improves nutritive quality. Soybean contains less starch, thus, it is good for diabetic patient. Bread, chapati, milk, sweets, palav etc., can be prepared with soybean. Wheat flour fortified with soybean flour makes good quality and more nutritious chapati. Soybean is used for making high protein food for children.

Its oil is used as cooking medium and also for making vanaspati ghee. The industrial uses include soymilk, soya flour, soya cake, biscuits, varnish, paints, cosmetics and pharmaceuticals. One kilogram of bean may yield 5-6 kg of soymilk. Approximately 85 per cent of soybean produced is utilized for oil extraction, 10 per cent for seed and 5.0 per cent for food.

Soybean plant is used as fodder; forage can be made into 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 root nodules, and also through leaf fall on the ground at maturity.

Origin

Based on historical and geographical evidences eastern Asia or china is generally regarded as the origin place of soybean. It has been cultivated from pre-historic time in China. It was introduced in U.S.A. 1804 and in India during 1880.

Distribution

Soybean is one of the important crops of the world. The important soybean growing countries are U.S.A., Brazil, China, Argentina and India. Production of soybean in India is restricted mainly to Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh and Gujarat.

Classification

Soybean is a member of the family Leguminoseae, sub family Papilionoideae and the genus *Glycine*.

Climatic Requirement

Soybean is cultivated in warm and moist climate and grown in monsoon season from June-October. Temperature of 15-32 °C is required for its germination. Optimum temperature required for its growth and yield is 30-33 °C. If temperature is below 10 °C, crop growth is retarded. Similarly, if temperatures are above 38 °C, crop growth is also retarded. Day temperatures of 25 °C are good for its flowering. Crop can be grown in areas receiving 600-650 mm rainfall. Rainfall during maturity deteriorates the grain quality. Cloudy weather prolongs vegetative phase. The crop is generally cultivated at an attitude of 1,200-2,000 meter.

Soil Requirement

Soybean is grown on variety of soils ranging from light to black cotton soils in different pockets of India. Well drained fertile loams soils are ideal for its cultivation. Soils should be loose and well aerated. Highly compacted soils are harmful for root nodule development. Crop is sensitive to both saline and acidic conditions and can be grown with in pH range of 6.0-7.5. In acidic soils liming has to be done to raise the pH to about seven. Water logging is injurious to the crop.

Fig: Soil Requirement.

Varieties

The varieties recommended for cultivation are Bragg, Lee, Clark, Hardee, Improved Pelicon, Punjab-1, Ankur, Alankar, Shilajeet, PK-262, K-30, KHSB-2, Monetto and KB-79.

Land Preparation

Land should be leveled and be free from crop stubbles. One deep ploughing with mould board plough followed by two harrowings and planking are sufficient for soybean.

Sowing

Time of Sowing

Sowing of soybean soon after onset of monsoon rains is best as compared to its earlier or later sowings. There should be optimum moisture at the time of sowing. Sowing during June to July months seems to be the best.

Seed Rate

Seed rate depends upon size of the seed, test weight, spacing and method of sowing. Generally 60-70 kg seeds are required/ha. If sowing is delayed due to any reason, the seed rate must be increased by 25 per cent.

Fig: Soybean seeds.

Spacing

Crop is sown at row to row spacing of 45-60 cm in north and 30-45 cm in central and south India. At the time of thinning plant to plant spacing is kept at 5.0 cm.

Fig: Soybean crop field.

Method of Sowing

The sowing should be done in lines with the help of seed drill or behind the plough. The seed should be sown at 2-3 cm in depth in heavy and 4-5 cm in light soils.

Nutrient Management

For obtaining good yields of soybean 15-20 tons of farm yard manure or compost per hectare should be applied. Like other leguminous crops, requirement of nitrogen is substantially fulfilled from symbiotic nitrogen fixation through Rhizobium. Seed treatment with rhizobium not only enhances the yield but enriches the soil also. Rhizobium inoculation can fix 150 kg N/ha in soybean. An application of 20 kg nitrogen per hectare as a starter dose is sufficient to meet the nitrogen requirement of the crop in the initial stage.

Soybean requires relatively large quantity of phosphorus. Phosphorus is taken up by soybean plant throughout the growing season. The period of great demand starts just before the pod formation till ten days prior to seed development. A dose of 60-80 kg P_2O_5/ha is generally recommended for the crop.

Soybean also requires a relatively large amount of potassium. The rate of potassium uptake climbs to a peak during the period of rapid vegetative growth then slows down about the time bean begins to form. Application of 50-60 kg K_2O/ha is sufficient to meet the requirement of soybean crop. The fertilizers should preferably be placed, at sowing time, about 5-7 cm away from the seed at a depth of 5-7 cm from seed level.

Water Management

During kharif season, soybean crop generally does not require any irrigation. However, if there is a long spell of drought irrigations are found beneficial. Flowering and pod filling stages are most critical stages at which moisture stress severely damages crop yield. Check basin or border strip method is most popularly used for irrigating soybean. During excessive rains proper drainage is also equally important.

Weed Management

Soybean, being a rainy season crop, is heavily infested with many grassy as well as broad leaf weeds. The most common weeds infesting the soybean crop are *Dactyloctenium aegyptium, eleusine indica, Sorghum halepense, Cyperus rotandus* and *Cynodon dactylon* among grassy weeds and *Celosia argentia, Digitaria sp., Trienthema partulactrum, Tribulus terristris* and *Phyllanthus niruri* among broad leaf weeds.

Crop is sensitive to weed competition, particularly in early growth phases. The most critical period for crop weed interference is initial 30-45 days. Weeds emerging after this period are suppressed by smothering action of crop. Yield loss in soybean may range from 25-70 per cent depending upon intensity and infestation of weeds. Besides yield loss, quality is also adversely affected.

Weeds in soybean can be controlled by using khurpi or hand hoe. Generally two weedings, one at 20-25 days after sowing and other at 35-40 days after sowing keeps most of the weeds under control. Timely availability of labour and time consuming are main difficulties of hand weeding.

Fig: Intercultural operation.

Herbicidal weed control has been found efficient and economical in soybean. Pre-plant application of Fluchloralin or Trifluralin @ 0.5-1.0 kg/ha or pre-emergence application of Alachlor (1.0-2.0 kg/ha) or Butachlor (2.0 kg/ha) or Metolachlor (1.5-2.0 kg/ha) or Pendimethalin (1.0 kg/ha) or Oxadiazon (0.5-1.0 kg/ha) and post-emergence application of Sethoxydim (0.25-0.50 kg/ha) or Fluazitop-p (0.15-0.25 kg/ha) found to be effective in controlling weeds.

Plant Protection

Insect Pests

Stem Fly: It is causes 15-20 per cent reduction in yield. The larvae generally bore into the stem of soybean plant. The infected plants show partly dried and drooping leaves. Apply Thimmet 10 per cent granules @ 10 kg/ha in soil before sowing.

Gridle Beetle: It may cause 50-60 per cent loss in crop yield. The beetle makes tunnels in stem. It can be controlled by applying 0.07 per cent Endosulfan or Monocrotophos 0.4 per

cent.

Bihar Hairy Caterpillar: Caterpillar feed on leaf epidermis. It causes heavy damage in soybean. This insect can be controlled by dusting 4.0 per cent Endosulfan dust @ 25 kg/ha at early stages and by spraying 0.07 per cent Endosulfan or 0.4 per cent Monocrotophs.

Diseases

Seedling Rot: This is a fungal disease. The disease results in poor seedling emergence because of seed rotting. The seed treatment with Thiram at 3.0 g/kg of seeds is beneficial.

Pod Blight: This is also a fungal disease. The pods of affected plant turns yellowish green and later on dry up. The grain becomes shriveled and mould. Use of resistant varieties, sowing of crop in rotation and spray of 0.5 per cent Zineb can control the disease.

Yellow Mosaic: It is a viral disease and transmitted by white fly (*Bemisia tabaci*). The disease is dangerous and widely spreads. The affected plant looks yellowish. Growing of resistant varieties such as Shilajit, removal of infected plants and burning them reduces the damage. Spray Metasystox 0.2 per cent at 10-15 days interval controls the vector effectively.

Harvesting and Threshing

The maturity period ranges from 90 to 140 days depending on varieties and season. At maturity the leaves turn yellow and drop. The pods dry out quickly and the seed in pod is hard and dough. The moisture content in grain should not be more than I2-14 per cent. Preferably the crop should be harvested in the morning to avoid losses due to shattering. Harvesting is done by uprooting the plants or by cutting with sickle. Crop is threshed by beating with sticks or by bullock or tractor thresher or by mechanical soybean thresher. The grain should be dried in the sun to bring the moisture to 10-12 per cent.

Fig: Green pods.

Fig: Matured pods.

Fig: Mechanical harvester.

Yield

By adopting improved technology, improved varieties of soybean yield 30-35 quintals of grain per hectare.

Cropping System

The crop sequences generally observed with soybean are soybean - wheat, soybean - potato, soybean - bengal gram, soybean - sunflower and soybean - potato - wheat. Soybean is a remunerative ideal inter crop. The most important intercropping systems are maize + soybean, pigeopea + soybean, cotton + soybean, sorghum + soybean, groundnut + soybean, sesame + soybean, ragi + soybean and sugarcane + soybean.

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BENGAL GRAM

(*Cicer arietinum* L.)

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BENGAL GRAM

(*Cicer arietinum* L.)

Introduction

Bengal gram is commonly known as gram or chick pea or channa. It is the most important winter season pulse crop of India. The scientific name *Cicer arietinum* has been derived from Roman word. Romans used to call it *Cicer* because of the resemblance of the seed to the head of a 'ram'. The word *arietinum* originated from the word aries which also means 'ram'.

Fig: Bengal gram plant with pod and grain.

Importance

Gram being an important source of protein and calories is also rich in minerals and vitamins. Gram contains 23 per cent protein, 63.5 per cent carbohydrate, 5.3 per cent fat. It is also rich in vitamin A and C, phosphorus, calcium, magnesium and iron.

Gram is mainly used for human consumption as well as for animal feeds. It is utilized as whole grain, dal (decorticated dry split cotyledons) and flour (powdered dal). Gram based foods are prepared using a wide range of recipes like soaked, sprouted, fermented, boiled, roasted, salted or unsalted, parched, fried, flour, steamed as well as green foliage and grain as vegetables are the important forms in which it is consumed by the people. The gram flour is used for preparing various types of sweets, oil fried items and also used for bathing. Gram is considered to have medicinal effects such as for blood purification, germinated seeds are recommended to cure scurvy, malic and oxalic acids collected from green leaves are prescribed for intestinal troubles. Soaked grain and husk are fed to horses and cattle as concentrate and roughage, respectively. The straw of gram is an excellent fodder for cattle.

Fig: Green pods and grains.

Fig: Sprouted grains.

Fig: Fried gram dal.

Fig: Laddoo .

Fig: Sev.

Origin

The gram is said to be one of the oldest pulses known and cultivated from ancient times both in Asia and Europe. Vavilov (1926, 1949-50) designated two primary centers of

origin, southwest Asia and Mediterranean, a secondary one, Ethiopia. There are linguistic indications that the large-seeded, cream coloured gram reached India two centuries ago, apparently through Afghanistan, as its Hindi name Kabuli channa, an illusion to the Afghanistan capital Kabul.

Distribution

Gram is one of the important pulse crops of the world. The important gram growing countries are India, Pakistan, Mexico, Turkey, Burma and Ethiopia. In India, Madhya Pradesh, Rajasthan, Uttar Pradesh, Maharashtra, Haryana, Gujarat and Bihar are main gram growing states.

Classification

Gram belongs to family Leguminoseae (Fabaceae). The genus *Cicer* has 43 species. The Indian grams have been classified in two broad categories.

1. **Desi or Brown Gram** (*Cicer arietinum* L.)**:** It is most widely grown group. The colour of seed ranges from yellow to brown. The seed size is usually small. Plants are small with good branching ability.

2. **Kabuli or White Gram** (*Cicer kabulium*)**:** Plants of this group have poor yield potential than desi type. Grains are bold and attractive and usually white in colour. Plants are tall and erect with moderate branching ability.

Fig: Desi gram.

Fig: Kabuli gram.

Climatic Requirement

In India, gram is cultivated in winter season. In temperate countries, it is mainly cultivated in spring and summer seasons because of the availability of favourable temperature in these seasons. It requires cool climate for its growth and development and high temperature for maturity. The optimum temperature for its growth ranges from 15 to 25 °C. Low temperature at the time of germination reduces the germination percentage. Severe cold and frosts are injurious for its growth and development. Frost at the time of flowering causes flower drop. Heavy rains at the time of germination, flowering and hailstorm at and

after flowering cause severe damage to the crop. Gram requires cloud free days for its normal growth.

Being leguminous crop, gram needs less rainfall. The deep-rooted system makes it a preferred crop in dry tracts receiving an annual rainfall of 600-1000 mm. Water logging at any stage of growth may destroy the crop.

Soil Requirement

Gram is able to grow on a wide range of soils. It is commonly believed to be a hardy crop. This can be grown on marginal soils which are not suitable for crops such as wheat. The soils in major production areas range from sandy to sandy loam to deep black cotton soils. Gram thrives best on deep loams or silt clay loams free from excessive salts. However, too light and too heavy soils are not good for the gram because on light soils with low moisture retention capacity, growth of gram is retarded and on heavy soils having high moisture retention capacity, vegetative growth is abundant which restrict the light penetration in crop canopy; fruiting is retarded and makes the crop prone to diseases. The soil should be near neutral in reaction; though a pH range 6-8 is favourable for growth of gram. The soil should be well drained.

Fig: Soil Requirement.

Varieties

1. **Desi or Brown Gram Varieties:** Radhey, Type-3, Pant G-114, Pusa-209, Pusa-408, etc.
2. **Kabuli or White Gram Varieties:** L-550, K-5, ICCC-32, etc.

Land Preparation

Gram needs cloddy and rough land for good aeration in the root zone. This could be achieved by deep ploughing followed by harrowing. In rainfed areas where gram is grown with conserved moisture, deep tillage at the start of the rainy season is found beneficial as it opens up the ground, ensures greater conservation of moisture and reduces physiological wilt, particularly on soils that tend to develop hard pans in the root zone.

Fig: Land preparation.

Sowing

Time of Sowing

Sowing of chickpea under rainfed conditions is mainly determined by availability of conserved moisture in the seeding zone. In such areas, sowing should be done earlier in the first fortnight of October. In case, adequate moisture is available in the seeding zone, sowing in the second fortnight ensure better crop.

Seed Rate

The seed rate is determined by growth habit of plant and seed size. A seed rate of 50-75 kg/ha has been found sufficient for desi varieties and 75-100 kg/ha for kabuli types.

Seed Treatment

Seeds should be inoculated with *Rhizobium* and P-solubilizer cultures each @ 375 g/ha.

Spacing

A row spacing of 30 cm with a plant spacing of 10-12 cm is optimum for sowing of gram under normal conditions.

Method of Sowing

In dry lands, seeds should be placed by traditional plough sole at the depth where soil moisture is adequate for germination. Pora method using country plough or using seed drills is common for sowing of gram at the depth of 10-12 cm from the soil surface in sandy loam and loamy soils. In situations where the soil moisture for germination is not limited, a depth of 5-7 cm seems to be ideal for the emergence of gram.

Fig: Bullock drawn seed drill.

Fig: Tractor drawn seed drill.

Fig: Seedling stage.

Fig: Vegetative stage.

Fig: Reproductive stage.

Nutrient Management

Manures

Farm yard manure (FYM) is used at 12-15 t/ha. FYM is spread on the ground and ploughed down deep with a soil turning plough 10-20 days before sowing, so that proper

decomposition of the applied manure takes place in the soil.

Fertilizers

1. Nitrogen: Gram being a leguminous crop meets its major nitrogen requirement (about 75 %) meets through the process of symbiotic nitrogen fixation. However, soils with low organic matter and poor nitrogen supply may require 15-20 kg N/ha as starter dose, which can meet plant requirement before the formation of nodules.

2. Phosphorus: The responses of gram to phosphorus are conspicuous. In general, the responses to applied P ranging from 40 to 60 kg P_2O_5/ha have been positive.

3. Potassium: The responses to K are generally small and seldom significant because of the higher K status of the Indian soils. In soils deficient in K, application of 20 kg K_2O/ha is recommended.

4. Micro Nutrients: Among the micro nutrients, zinc and iron play an important role in gram production. Application of 25 kg $ZnSo_4$/ha at the time of sowing along with the macro nutrients is recommended. The effect of Fe is more pronounced in the presence of Zn. One spray of two per cent $FeSo_4$ solution 30 days after sowing is recommended for improving the productivity of gram.

Water Management

Gram is mainly grown under rainfed conditions. It has a deep tap root system and can make an efficient use of the profile-stored water. Although water requirements of the gram are relatively low, it often suffers from periodic water deficits owing to low and uncertain rains in the rabi season. Supplemental irrigation to release the crop from soil moisture stress at critical stages of crop growth has been found to result in substantial yield increases in gram. The late flowering and pod setting stages appear to be the most sensitive to soil moisture stress.

The care in irrigation is needed because of the high sensitivity of gram to lack of soil aeration. Proper land leveling and the use of ridges or narrow flat beds for the purpose of uniform distribution of irrigation water and avoiding water logging is required for optimum plant growth and development and for getting higher yields of gram.

Weed Management

The gram crop is sensitive to weed competition than many other crops. The first 4-6 weeks are most critical for weed competition and the reduction is grain yield may vary 40 to 90 per cent depending on the intensity and type of weed flora.

About 60 weed species are reported to infest gram fields. Among annuals, *Chenopodium album, Melilotus indica, Lathyrus aphaca, Medicago sp., Trichodesma indicum* and among perennials *Convolvolus arvensis* are common weeds in gram fields. *Chenopodiun album* is the most important weed of gram in India.

Weeding by mechanical methods includes the use of hand chisel (khurpi), hand hoe, wheel hoe, etc. Since the competition is more in the initial growth stage, two hand weedings

(3 to 4 weeks and 6 to 8 weeks after sowing) should be done. Under the conditions where weeds reappear following late rains or delayed irrigation, a third weeding may also be needed around 9 to 12 weeks after sowing. In view of the limitations of mechanical methods of weed control, chemical control merits appropriate consideration. Pre-emergence application of Prometryn @ 0.50 kg/ha or Alachlor @ 1.50 kg/ha and post-emergence application of Methabenzthiazuron @ 1.50 kg/ha found to be effective in controlling weeds.

Plant Protection

Insect Pests

Gram has relatively a few insect-pests when compared with most other semi-tropical leguminous crops because;

1. The plants are covered with glandular hair which exude acid-droplets containing high concentration of malic acid, so insects appeared to be deterred by this very acidic (pH 1.3) exudate and,
2. As this crop is normally sown before or just after the winter in almost all areas of the world in which it is of importance, it grows during the period when insect activity and population are at a minimum.

Gram Pod Borer: The gram pod borer is the most serious pest of gram and causes the yield reduction up to the extent of 75 per cent. The control measures are as follows.

- Use of resistant varieties such as ICC 506, ICC 6863, PDE 2, AKG 33, Pant CE 1, BG 256, etc.
- Early sowing in north and central India (15-30 October).
- Intercropping gram with mustard, wheat, safflower and barley.
- Use of insecticides, spray of Endosulfan (0.07 %) or Monocrotophos (0.04 %) or Chloropyriphos (0.05 %) solution. Use of neem based bio-pesticides @ 5.0 per cent solution.
- For biological control, use of NPV and *Bacilluis thurigiensis* are found to be effective.

Fig: Gram pod borer.

Gram Cutworm: The gram cutworm is a serious pest in low-lying areas where fields are clody. Dusting Endosulfan @ 20 kg/ha or mixing of Endosulfan in the soil @ 20-25 kg/ha is effective in controlling the pest.

Termites: Soil and seed treatment with Chloropyriphos is effective against termites. Maintaining the optimum soil moisture reduces the infestation of termites as the attack of termites is severe in dry soils.

Diseases

Blight: It is the most serious disease of gram between the latitudes 30° and 45° where relatively low temperature (15-25 °C) prevails during the crop season. Diseased debris and infected seeds are the main source of inoculum. Control measures include;

- Use resistant varieties namely, BG 261, BG 280 and H 75-35 (Gaurav).
- Removal and destruction of dead debris.
- Crop rotation.
- Deep sowing.
- Intercropping gram with wheat, barley and mustard.
- Advancing the sowing date in autumn.
- Seed treatment with Thiram or Captan (0.25%) or with Bavistin + Thiram combination @ 250 g/q of seed.
- Foliar spray – four protective sprays with Captan or Zineb @ 2.5 kg/ha at 10-15 days interval or Bordeaux mixtures spray.

Fusarium Wilt: It is prevalent in the entire gram growing areas of India. The young growing tips of diseased plants become limp and drooping. The leaves start withering due to inadequate water supply and excessive transpiration. On splitting open the taproot lengthwise, dark-brown fungus streaks can be seen in the root near the pith region. The pathogen enters the root system and xylem vessels, thereby reducing water supply to the plant.

As far as possible, early sowing of gram should not be taken before third week of October. Deep planting of about 8-10 cm deep in the light soils reduces the wilt incidence. Resistant varieties such as ICC 202, ICC 391, Pant G 114, Pusa 209 and C 235 should be grown. Seed treatment with Bavistin (25 %) + TMTD (50 %) @250 g/q of seed reduces the incidence of wilt.

Dry Root Rot: The taproot on pulling out is found to be devoid of bark and lateral roots. The dead root is dry and brittle towards the tip. Black sclerotic bodies of the fungus can be seen on the main root below the bark. Early sowing of early maturing cultivars with timely irrigation minimizes the disease. Seed should be treated with Captan or Thiram or PCNB @ 2.5 g/kg seed.

Harvesting and Threshing

Harvesting at correct time is essential to get good quality grains and higher yield. The crop should be harvested at physiological maturity or at full maturity (7 days after physiological maturity). The moisture content in grain at harvest should be around 20 per cent. Harvesting is done manually either by plucking out by hand or by cutting down the plants with sickle.

The harvested plants should be allowed to dry in the sun for about five to six days on

threshing floor. The threshing is done either by beating the plants with sticks or by trampling under the feet of bullocks or tractor tyres. The threshed grains should be cleaned by winnower and again dry for a week to reduce the moisture.

Yield

The average yield under rainfed conditions is about 7-8 q/ha. Under ideal conditions, a good crop of desi varieties gives about 20-25 q/ha whereas, kabuli varieties gives about 25-35 q/ha.

Cropping System

Crop rotation of gram with pearl millet, sorghum, maize, sesame, rice, etc. is more common in India. Mixed cropping of gram with other cool season crop is quite common. The common crop mixtures include; gram + wheat, gram + barley, gram + linseed, gram + rapeseed/mustard, gram + safflower, gram + rabi sorghum.

Gram proved an economic intercrop with rabi sorghum. Intercropping of gram between two rows of sugarcane to improve the land use efficiency during the early phase of sugarcane growth is common. Relay cropping of gram in standing crop of rice is practiced by the farmers in northeastern rice fallow areas to make use of soil moisture, which is critical for good stand establishment of gram in these areas.

Fig: Intercropping of gram with mustard.

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RED GRAM

(*Cajanus cajan* L. Millsp.)

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RED GRAM

(*Cajanus cajan* L. Millsp.)

Introduction

Red gram is commonly known as pigeon pea or tur or arhar and is a very old crop of this country. It is the second most important pulse crop after bengal gram. Red gram is a backbone of nutritional security of our country. It supplements the important component of protein particularly to Indian population where their diet is based on cereal itself. It is like other pulse is considered a subsidiary crop. It is often grown on marginal lands and is usually intercropped with other crops. As a crop of secondary importance, it receives little or no purchased inputs. However, farmers in some red gram growing areas are growing more sole crops of red gram and the crop is increasing gaining status as a cash crop.

Fig: Red gram plant.

Importance

Red gram is rich source of protein (22.3 %) and also rich in iron, iodine and the essential amino acids like lycine, tyrocene, cystine and arginine.

Red gram is mainly used as dal for preparing curries, sweets, etc. Green pods are used for extracting grains for vegetable purpose.

Fig: Green pods.

Fig: Grains.

Fig: Tur dal.

Fig: Sambar.

Fig: Dal fry.

Fig: Holige (Sweet).

Green leaves of the plants may be used as fodder. The outer covering of its seed together with part of the kernel provides a valuable feed for milch cattle. The husk of pods and leaves obtained during threshing constitute a cattle feed. Woody parts of the plant are used for various purposes such as fuel, thatch and basket making.

Red gram being a leguminous plant is capable of fixing atmospheric nitrogen and thereby restores lot of nitrogen in the soil. Its deep root system helps in extracting the nutrients and moisture from deeper soil layers. Deeper root system also help in breaking the plough pans and help in improving soil structure. Extensive ground cover of red gram prevents soil from wind and water erosion, encourages infiltration, minimizes sedimentation and smoothers weeds. It is also grown on mountain slopes to utilize the poor soils and protect it from erosion.

Origin

Red gram is the most widely grown crop in the country and has been under cultivation for over three thousand years. It has been reported to occur in wild state in the upper region of Nile river and the coastal districts of Angola in Africa. Therefore, Africa may be its original place and from where it might have been introduced to India. However, according to Vavilov (1951), India is the origin place of Red gram.

Distribution

India is the major red gram growing country in the world. Other regions where red gram is grown are South East Asia, Africa and the America. In India, it is extensively cultivated in the states of Maharashtra, Uttar Pradesh, Madhya Pradesh, Gujarat, Karnataka and Andhra Pradesh.

Classification

Red gram being a leguminous crop belongs to family Leguminoseae (Fabaceae). Cultivated red gram plants may be classified into two groups.

***Cajanus cajan variety bicolor*:** Mostly late Maturing varieties are included in this group. Plants are tall, bushy with yellow flower, pods dark coloured containing four or five seeds. It is cultivated extensively in northern India.

***Cajanus cajan variety flavus*:** Early maturing varieties of comparatively smaller plants, yellow flower and pods containing, only two or three seed included in this group. It is mainly grown in Deccan and southern India.

Climatic Requirement

Red gram is mainly grown in tropical and sub-tropical climate. Cool and bright sunny days during flowering and ripening are required for setting of pods. Crop is raised in areas having 20-30 °C temperature during *kharif* season and 17-22 °C during winter. It is highly susceptible even to light frost. Though, it can tolerate heavy rains provided water logging does not take place. It has the capacity to tolerate moisture stress to great extent because of its deep root system.

Soil Requirement

Red gram requires light textured, well drained soil. Though, it is grown on a wide range of soils ranging from sandy to clay. Soil should be neutral in reaction and well drained. Production of this crop varies greatly depending upon the depths and moisture holding capacity of soil. Red gram is susceptible to salinity as compared to other crops. Similarly fields where red gram has been grown for few seasons should be avoided as the crop may suffer due to a buildup of nematodes and increased incidence of soil borne diseases.

Fig: Soil Requirement.

Varieties

Several varieties of red gram have been developed. At present emphasis is being laid on the development of short duration high yielding varieties permitting second crop of rabi crops in the winter. These varieties mature in about 130-180 days. Earlier longer duration varieties taking 240-300 days to maturity were grown, occupying the field for whole of the year.

Late Maturing Varieties: Bahar, Gwalior-3, etc.

Medium Maturing Varieties: Laxmi, Mukta, TTB 7, Hyderabad 3C, etc.

Short Maturing Varieties: BDN-1, CO-3, Prabhat, Pusa Ageti, Pusa 74, Pusa 84, UPAS 120, ICPL 87, ICPL 151, TT6, etc.

Hybrids: ICPH 8, COH-1, COH-2, PPH 4, etc.

Land Preparation

Red gram being a deep rooted crop responds well to proper tilth. Deep ploughing to a depth of 15 cm is sufficient. Harrowing followed by cross operation by cultivator/desi plough and cross planking is sufficient to get the good tilth.

Fig: Land preparation.

Sowing

Time of Sowing

Red gram is a traditionally kharif crop sown in June-July with the onset of monsoon in various agro-climatic zones of India.

Seed Rate

Depending upon the size of seed and spacing, 15-25 kg seeds/ha is sufficient. For intercropping/mixed cropping system, red gram seeds of 7-10 kg/ha is necessary.

Seed Treatment

Seeds should be inoculated with *Rhizobium* and P-solubilizer cultures each @ 375g/ha.

Spacing

Long duration varieties of red gram are tall, spreading and occupy the field for about 240-300 days. These varieties are planted at wider row spacing of 90-120 cm and about 30 cm in between plants particularly under rainfed conditions. Under irrigated conditions, early maturing varieties are more popular as they fit well in double cropping systems. These varieties are planted at a row spacing of 50-75 cm and plant to plant spacing of 15-20 cm.

Method of Sowing

Red gram is generally broadcasted. Optimum, depth for seeding is 4-5 cm. Sowing in rows may be done behind the desi plough or in the furrows opened by tractor. Red gram is very susceptible to water-logging, particularly during seedling stage. Under such situations, crop should be sown on ridges.

Fig: Seedling stage.

Fig: Vegetative stage.

Fig: Reproductive stage.

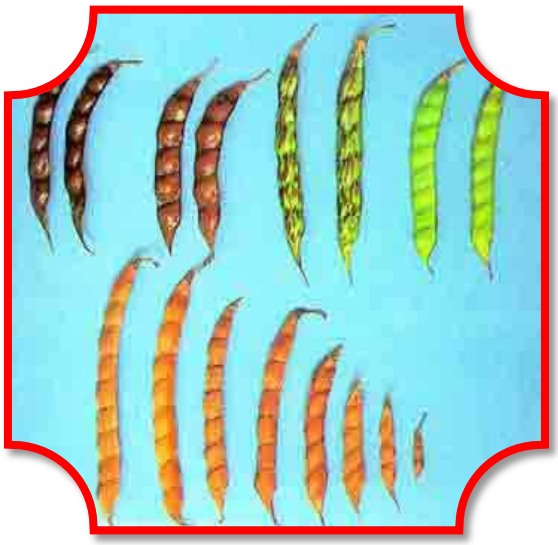

Fig: Types of pods.

Nutrient Management

Red gram requires heavy doses of the nutrients, hence care should be taken that the crop does not suffer due to lack of nutrients.

Manures

Farm yard manure of 7-10 t/ha is necessary for red gram crop. It should be incorporated 15-20 days before sowing for better decomposition in the soil.

Fertilizers

Nitrogen: Being a legume, it does not require much nitrogenous fertilizers. However, there is general agreement that a starter dose of 10-30 kg N/ha gives positive response in most of the soils depending upon the initial N status of the soil.

Phosphorus: In India, responses of red gram to phosphorus are generally positive. Phosphorus is necessary for root and nodule development. Application of 50-60 kg P_2O_5/ha is necessary for red gram crop.

Potassium: Red gram normally does not respond to potassium application unless grown on the soils low in available potassium. 20-30 kg K_2O/ha may be supplied in potassium deficit soils.

Micro nutrients: Most of red gram cultivars show susceptibility to zinc deficiency. Application of zinc sulphate at the rate of 20-25 kg/ha at the time of sowing or foliar spray of 0.5 per cent Zinc sulphate with 0.25 per cent lime is effective in controlling zinc deficiency.

Water Management

Red gram is generally cultivated under rainfed situation. The intensively managed red gram systems that involve short-duration red gram have a higher water requirement because they are grown at high densities. The water use is in the range of 55-60 cm. Branching and pod filling stages are considered as critical stages for moisture stress.

Weed Management

Among the pulses, red gram is the only crop that has a characteristically slow initial growth rate. This makes red gram less competitive with weeds. Weeds grow profusely in the rainy season due to the favorable moisture conditions and, if not timely controlled, can cause up to 90 per cent reduction in seed yield. Some of the common weeds associated with red gram are *Cyperus rotundus*, *Digitaria* sp., *Dectyloctenium aegyptium*, *Setaria glauca*, *Amaranthus* sp., *Celosia argentea*, *Commelina benghalensis*, *Phyllanthus niruri* and *Euphorbia* sp.

Timely weed control is also important. The first 60 days is very critical in the life cycle of the plants. Hand weeding twice at 25-30 and 45-60 days after sowing control the

weeds. Pre-emergence herbicides can control weeds for the first 30-40 days. Application of Alachlor, Metolachlor or Pendimethalin at 1.0 kg a.i./ha effectively control germinating seedlings of weeds and keeps the field free from the weeds for the first 50 days. A hand weeding at 10-15 days after pre-emergence herbicide application keep fields generally weed free.

Plant Protection

Insect Pests

Pod Borer: The young larva of this insect enter the pod and feed the developing grains. It is the most serious pest of red gram and causes on average 10-80 per cent damage every year. It may be controlled by spraying of 0.07 per cent Endosulfan or 0.04 per cent Monocrotophos.

Pod Fly: It is a most serious pest of red gram in north India. Damage varies from 20-60 per every year. Spraying the crop with 0.04 per cent Monocrotophos or 0.03 per cent Dimethoate emulsion has proved effective in controlling the insects.

Pod Bug: The adults and nymph of this insect suck the sap from the leaves, buds, flowers and pods. Pods become shrivel and deformed. It can be controlled by spraying of 0.04 per cent Monocrotophos or 0.03 per cent Dimethoate or by dusting 4.0 per cent Endosulfan.

Diseases

Wilt: The leaves of the affected plants become yellowish in colour followed by dropping and finally whole plants dries up. Being a soil-borne disease, its chemical control is not possible. However, some precautionary measures such as collecting and burning the plant trashes left after harvesting, following a 3-4 years crop rotation and mixed cropping with sorghum and selection of disease resistant varieties of red gram may be helpful in reducing the incidence of this disease.

Stem Rot: The affected plants show formation of brown to dark brown lesions on the stem near the soil surface. Selection of disease resistant varieties and cultivation of red gram on well drained fields may be taken as precautionary measures.

Leaf Spots: There are several types of spots on the leaves and petioles of affected plants. These leaves start drying and in severe cases defoliation may take place. Spraying of Dithane M-45 of 0.3 per cent concentration may be helpful in controlling the disease.

Sterility Mosaic: This disease is caused by sterility mosaic virus. It is transmitted from one plant to another by vector. The affected plants become pale green in colour and the size of leaves is reduced. Diseased plants fail to flower and no yield is obtained from such plants. Suitable control measure has not so far been worked out. However, repeated sprayings of systemic insecticide such as Metasystox etc. is recommended to control the mites.

Harvesting and Threshing

Red gram is an indeterminate growth type and thereby the growth is continued with reproductive phase. The best time for harvesting of the crop is when over 75 per cent of the pods turn brown. Harvesting may be done with the help of sickle or cutting blade. After

harvesting, plants are left in the sun for drying. Threshing may be done by beating the pods with sticks. Threshing may also be done with the help of small threshers. After threshing, grain should be cleaned and dried in the sun so that moisture content is reduced to around 10-11 per cent.

Fig: Matured pods.

Fig: Threshing.

Fig: Stover.

Yield

With the adoption of improved varieties and production technology yields of 25-30 q/ha can be obtained. In intercropping system, 2-3 q/ha of red gram yield may be obtained in addition to main crop yield.

Cropping System

The practice of inter cropping of red gram with companion crops like sorghum, maize, ragi, groundnut, black gram, green gram, soybean, turmeric, etc. is very common. Being deep rooted, the crop is very well suited for inter cropping and mixed cropping with the shallow rooted crops.

The crop is generally grown with wide row spacing. However, the initial growth is quite slow and the grand growth period starts after 60-70 days of sowing. A lot of inter-row spaces, therefore, remain vacant during the early stages and get infested by weeds. The space between the rows could be profitably utilized by growing short duration crops such as cowpea, green gram, black gram, etc.

Fig: Intercropping system.

Crop rotations adopted with short duration varieties are red gram - wheat, red gram - potato, red gram - wheat - mung bean, red gram - sugarcane, maize - red gram, etc.

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GROUNDNUT

(*Arachis hypogaea* L.)

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Study Questions

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GROUNDNUT

(*Arachis hypogaea* L.)

Introduction

Groundnut is an important oil seed crop. It is also known as pea nut, earth nut and monkey nut. Among the oil seed crops, groundnut has first place in India.

Fig: Groundnut plant.

Fig: Parts of groundnut plant.

Importance

Groundnut kernels contain about 45 per cent oil and 25 per cent protein. The biological value of groundnut protein is among the highest of the vegetable proteins, and which is about 1.3 times higher than meat, 2.5 times higher than eggs and 8.0 times higher than fruits. Groundnuts are rich source of vitamin B and E. They are rich source of thiamin, riboflavin and nicotinic acid. With regard to minerals, phosphorus, calcium and iron are present in significant amount.

Fig: Groundnut pods and kernels.

The oil is extensively used for cooking purposes. Besides being an important source of vegetable oil, it is also used as an important source of food, nutrition, feed and fodder. The kernels are consumed either roasted or fried and salted. Groundnut milk, butter, curd and chatni are prepared from raw kernels. Groundnut is also being used for candies and confections. The cake flour blends easily with wheat and other flours and consequently used by bakers, ice cream manufacturers, confectioners and candy makers.

Fig: Groundnut Oil.

Fig: Masala groundnut.

Fig: Salted groundnut.

Fig: Groundnut Chikkies (Candies).

Fig: Groundnut Burfi.

Groundnut has got numerous industrial uses. The oil is also used for preparing vanaspati ghee. Low quality oil is used for making soaps. Groundnut oil is used in beauty-aids, shaving cream, cold cream, etc. It is used for medical aids such as plasters, ointments, etc. The groundnut cake powder is used as laundry starch and in the manufacture of paper, gummed tapes and plastics. Activated carbon is prepared from groundnut shells. It is a good foreign exchange earner.

Fig: Groundnut shells.

The oilcake obtained after the extraction of the oil is a valuable organic manure and animal feed. It contains 7-8 per cent nitrogen, 1.5 per cent phosphorus and 1.5 per cent potash. It can be used as a nutritive cattle feed. Groundnut haulms make a very palatable fodder to cattle when fed in green state. It may be fed in the form of hay after drying or after converting it into silage. The haulms are rich in nutrition containing about 8-11 per cent protein. Groundnut being a legume crop builds up the soil fertility by fixing atmospheric nitrogen through the root nodules and also an efficient cover crop for lands exposed to soil erosion.

Origin

Groundnut crop appears to have originated or evolved in Brazil in South America, where closely related ancestors have been identified.

Distribution

Groundnut is grown on a large scale in almost all the tropical and sub-tropical counties of the world. The most important groundnut growing countries are India, China, Sudan, Nigeria, Senegal, Zaire and U.S.A. In India, it is mostly confined to the southern Indian states, viz., Andhra Pradesh, Gujarat, Tamil Nadu, Karnataka and Maharashtra.

Classification

Groundnut belongs to the Leguminoseae family and the genus *Arachis* and the species *hypogaea*. All the cultivated groundnuts have been divided into two groups.

1. Erect or Bunch Type: These include *Arachis hypogaea* subspecies *fastigiata*. Seed dormancy usually absent, foliage is light green in colour and matures early.

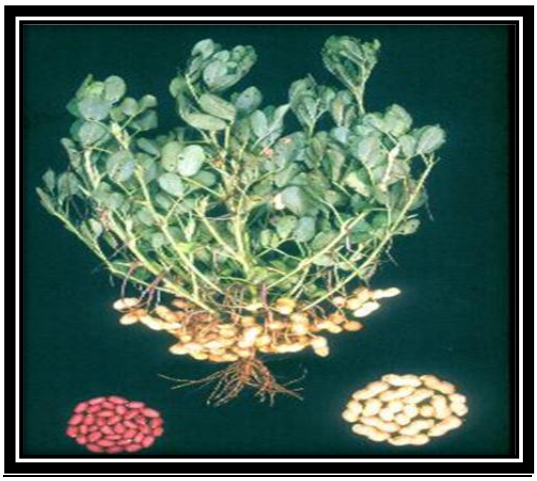

Fig: Spanish bunch type.

2. Semi-Spreading and Spreading Types: These include *Arachis hypogaea* subspecies *procumbens*. Seed dormancy usually present, foliage is dark green in colour and matures late.

Fig: Virginia runner type.

Fig: Virginia spreading type.

Climatic Requirement

Groundnut is essentially a tropical plant. It requires a long and warm growing season. The optimum temperature for vegetative growth of groundnut is from 27-30 ^{o}C. Lower temperature is not suitable for its proper development. During ripening period it requires about a month of warm and dry weather. Groundnut has been found to grow and yield well in areas receiving 500-1,250 mm of well distributed rainfall.

Soil Requirement

Groundnut thrives best in well drained sandy and sandy loam soils, as light soil helps in easy penetration of pegs and their development and also harvesting. Clay or heavy soils are not suitable for this crop. Groundnut gives good yields in the soil with pH between 6.0-6.5.

Fig: Soil Requirement.

Fig: Groundnut seedling.

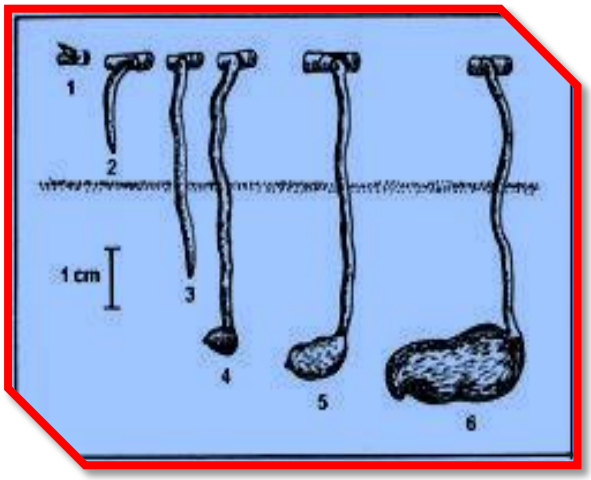

Fig: Stages of pod development.

Varieties

There are three types of varieties in groundnut, bunch types with erect plant habit, spreading and semi-spreading types. Important groundnut varieties include M-13, JL-24, VRI-2, ICGS-11, TMV-2, BG-3, M-335, RG-141, TKG-19A, B-95, DRG-12, VRI-3, DH-8, Somnath, Jawan, etc.

Fig: Different types of groundnut kernels.

Land Preparation

Although groundnut is a deep rooted crop but looking to its underground pod forming habit, deep ploughing should be avoided. Because deep ploughing encourages development of pods in deeper layers of soil which makes harvesting difficult. One ploughing with soil turning plough followed by two harrowings would be sufficient to achieve a good surface tilth up to 12-18 cm depth. One or two summer cultivations will minimize weeds and insect pests to a great extent in problem areas.

Fig: Land preparation.

Sowing

Time of Sowing

1. Kharif: The crop is sown from second fortnight of June to first fortnight of July depending upon the onset of monsoon.
2. Rabi: Crop is sown from September to December depending upon the harvest of rice.
3. Summer: The crop is sown from the second fortnight of December to first week of February depending upon the temperature.
4. Spring: Crop is sown from second fortnight of February to first week of March after harvest of toria and potato.

Groundnut suffers from yield reduction due to delayed sowing and it is more pronounced in rabi season as compared to kharif season.

Seed Rate

For bunch types 80-100 kg of seeds per hectare would be enough and 60-80 kg for spreading types. The exact seed requirement varies with seed size and row spacing.

Spacing

In bunch types, the row to row distance is kept 30-40 cm and in spreading types 45-60 cm. Plant to plant distance would be 15 and 20 cm for bunch and spreading types respectively.

Method of Sowing

Seeds should be sown after shelling pods, not the pods as such since it results in delayed and partial germination. After shelling, the damaged seeds should be rejected before sowing.

Conventional Method

Groundnut is generally sown in flat beds. In Saurashtra region of Gujarat, set-furrow system of groundnut cultivation is still a practice by the farmers. In set-furrow system farmers use same furrow (90 cm) year after year for groundnut cultivation.

Improved techniques

1. Criss-Cross Pattern: In this method, total seed lot is divided into two equal halves; first half of the seed is sown in one direction adopting recommended row to row spacing and then remaining half in perpendicular to first direction by adopting same row spacing. It maintains optimum plant population because of uniform distribution of seed.

2. Paired Row: In this system, two pairs of rows are spaced at 45/60 cm with a spacing of 22.5/30 cm within the pair.

3. Broad Bed and Furrow Method: This method is useful for high rainfall areas having deep vertisol where drainage of excess water is a problem. The moisture, thus stored in the furrows, could be utilized effectively.

Fig: Polythene mulching in broad bed and furrow method.

Sowing Implements

Bullock drawn seed drill and sowing behind the country plough are the traditional implements generally used by the farmers. These implements can maintain only row to row spacing. Improved tractor drawn groundnut seed drill can maintain both row and plant spacing.

Depth of Sowing

Generally 2.5 to 5.0 cm is found optimum. If the seed is sown in deep (5 cm), germination will be badly affected.

Nutrient Management

Groundnut being a legume and an oil seed crop has greater requirement for phosphorus and sulphur. Phosphorus is a constituent of enzymes, phospholipids and proteins while sulphur is a constituent of S containing amino acids and helps in fatty acid synthesis. Calcium is another important mineral for groundnut production and has pronounced effect on proper development of pods and kernels. Just like other legumes, groundnut meets the major part of its nitrogen requirement through the nitrogen fixation.

Well decomposed farm yard manure or compost at 5-10 tones may be added per hectare about 15-20 days before sowing. An application of 20-40 kg nitrogen per hectare as a starter dose is given to meet the nitrogen requirement of the crop in the initial stage. Nitrogen is to be applied through ammonium sulphate than urea as it supplies sulphur in addition to nitrogen. Since groundnut is a legume crop seed inoculation with rhizobium @ 375 g/ha is highly beneficial. It is necessary to supply about 50-60 kg P_2O_5 and 30-40 kg K_2O/ha to meet the requirement of the crop. Phosphorus should be applied preferably through super phosphate as it supplies sulphur in addition to phosphorus. The fertilizers should be placed at the time of sowing about 4-5 cm in the side of the seed and 4-5 cm below the seed level.

Calcium and sulphur should be supplied each @ 40 kg/ha. Application of gypsum at the rate of 125 kg/ha meets the required quantity of S and Ca. In zinc deficiency areas apply $ZnSO_4$ @ 15-20 kg/ha to the soil or spray 0.50 per cent $ZnSO_4$ and 0.25 per cent lime. In iron deficiency areas apply $FeSO_4$ @ 10 kg/ha to the soil or spray 0.15 per cent $FeSO_4$ and 0.80 per cent lime.

Water Management

Irrigation: Maintenance of optimum soil moisture at critical growth stages is the key factor for releasing higher yields. Early vegetative, growth, flowering, pegging and pod formation are considered as critical stages, of which peak flowering and pod formation stages are the most crucial. Imposing drought of 20 days, after 15-20 days of sowing (with pre-sowing irrigation) followed by releasing water stress providing two irrigations at five days interval helps in the development of deeper root system, synchronized flowering, higher biomass production and higher pod yield. Irrigation should be stopped one week before harvest so that the quality of seeds does not deteriorate.

Use of sprinkler and drip irrigation methods are becoming popular since water requirement in these methods is about-half and the water use efficiency is also quite high but the only drawback is the high initial cost involved.

Drainage: Good drainage should be provided for realizing good yields of groundnut. Present practice of flood irrigation aggravates problem and also makes it difficult for the penetration of pegs into the soil. Groundnut needs aeration in the rooting and pegging zones. Inadequate aeration results in abnormal respiration which in turn inhibits root growth and retards metabolic functions. Besides, the plants become chlorotic due to deficiency of N and or S in coarse textured soil or Fe in calcareous soil in oxygen deficient environment.

Weed Management

Weed infestation in groundnut is one of the main factors for loss in yields. Erect and bunch types suffer more than spreading types. Similarly, Kharif groundnut is affected more than rabi-summer groundnut. The weed competition at early stage of groundnut is maximum because of initial slow growth but it is relatively low at later stages where complete ground cover is attained by groundnut canopy. The critical period of crop-weed competition was reported to be between 30 and 45 days after sowing. The major weeds generally found in groundnut fields are: *Cynodon dactylon, Dactyloctenium aegyptium, Digitaria sanguinalis, Sorghum halepense,* (among monocots) and *Amaranthus viridis, Celosia argentea, Euphorbia hirta, Tridex procumbens, Abutilon indicum, Phylanthus niruri and Chenopodium album* (among dicots).

Cultural method of weed control is a common practice in groundnut. Generally, one hand weeding or hoeing at 30 days after sowing (DAS) or two weedings or hoeing at 15 DAS and 35 DAS control weed but it is time consuming, expensive and tedious. Care should be taken so that soil should not be disturbed at pod formation stage. Weeds can also be effectively controlled by use of herbicides. Pre-emergence application of Alachlor (1.5 kg/ha) or Fluchloralin (1.5 kg/ha) or Pendimethalin (1.0 kg/ha) control the weeds effectively.

Fig: Groundnut crop in the field.

Plant Protection

Insect Pests

Leaf Miner/Aphids/Thrips: For controlling these insects spray Dimethoate at 200-250 ml/ha.

White Grub: Incidence of white grub population in the field may be checked by mixing Thimet (10 %) granules in the soil before sowing at the rate of 15 kg/ha.

Red Hairy Caterpillar: Spraying of Endosulphan at 350 ml/ha reduces the infestation of red hairy caterpillar.

Fig: Aphids.

Fig: White grub.

Fig: Red hairy caterpillar.

Diseases

Leaf Spot: Small dark brown circular spots appear on the leaves and if the attack is severe, defoliation occurs and the stem remains which is commonly called as tikka disease. For controlling this disease grow tolerant varieties like TMV-6 AND TMV-10, treat the seeds with Thiram @ 3 g/kg of seeds, uproot and burn the debris of affected plants, spray Bavistin at 0.05 per cent + Dithane M-45 0.2 per cent at 2-3 weeks interval.

Collar Rot/Stem Rot: Seed treatment with Thiram 5 g or Dithane M-45 3 g or Bavistin 2 g/kg seed, uproot and burn the debris of affected plants.

Fig: Leaf spot.

Harvesting and Threshing

It is necessary to harvest the pods at the right time for obtaining higher yields of pods and oil. Nut takes two months to attain full development. The important symptoms of maturity are yellowing of foliage, shedding of leaves, hardening and toughness of pods and dark tannin discolouration inside the shell. A fully matured pod is difficult to split easily with finger pressure.

Apart from pod loss during harvest, pre-mature or delayed harvest affects the quality and viability of the seeds. In general, spreading varieties are harvested between 140-145 days, the semi spreading between 120-135 days and bunch types between 90-110 days after sowing. Irrigations, if given to the crop, must be stopped at least 8-10 days before harvest.

The bunch and semi-spreading types are generally harvested by uprooting either by hand, bullock drawn blade harrows or by tractor-drawn diggers, while the spreading types are harvested by digging out the plants with the help of khurpi or spade or bullock drawn harrows. Leave the harvested crop in small heaps for 2-3 days for curing. Stripping of pods is done manually or by using comb type hand stripper or pedal-operated stripper. Pods should be dried, in sunlight for 3-4 days by spreading in a thin layer on a threshing floor. The proper drying of the produce may be judged by shaking the pods which should give rattling sound, when a kernel is pressed between the thumb and index finger, it should easily split into two cotyledons and when the surface of the kernel is rubbed hard a portion of the testa should come off.

Yield

By adopting the improved practices, it is possible to obtain pods of 15-20 q/ha from bunch varieties and 20-30 q/ha from spreading varieties. The yield of an irrigated crop in summer is more than the rainfed kharif crop. The higher yields in summer irrigated crops are due to controlled moisture, bright sunshine, better utilization of nutrients and less pests and disease incidence. The yield of haulms is usually 2.0 to 2.5 times to that of pod yield.

Cropping System

Groundnut is grown in rotation with rice, wheat, barley, sunflower, safflower, chick pea, pea, horse gram, etc. The most promising intercropping systems are, intercropping of groundnut with pigeon pea followed by sunflower and pearl millet.

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RAPE SEED AND MUSTARD

(*Brassica* spp.)

CONTENTS

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RAPE SEED AND MUSTARD

(*Brassica* spp.)

Introduction

Rape seed and mustard are the major rabi oilseed crops of India. They occupy a prominent place being next in importance to groundnut. Sarson and toria (lahi) are commonly known as rape seed while rai or raya or laha or raiya as mustard.

Fig: Mustard plant parts.

Fig: View of mustard field.

Importance

The seed contains oil varies from 37 to 49 per cent. The seed and oil are used as condiment in the preparation of pickles and for flavouring curries and vegetables. The oil is mainly used for cooking and frying in northern India. Oil is also used in preparing

vegetable ghee, hair oil, medicines, soap, lubricating oil, greases and in tanning industries. The seed and oil have a peculiar pungency. This pungency in oil is due to presence of a glucoside sinigrin. The leaves of young plants are used as green vegetable commonly called sarson ka saag as they supply enough sulphur and minerals in the diet.

Fig: Mustard seeds.

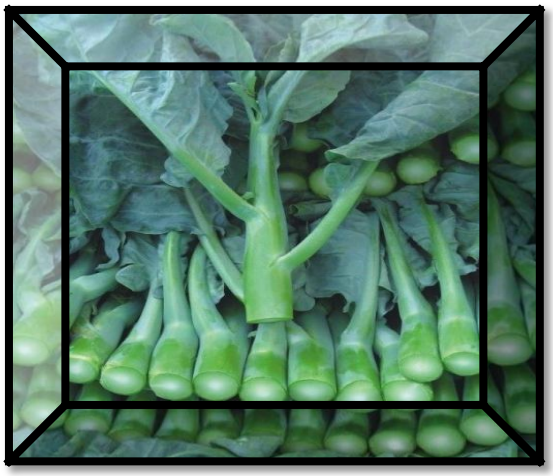

Fig: Mustard leaf used as vegetable.

Green stems and leaves are a good source of green fodder for cattle. The oil cake left after extraction is utilized as cattle feed and manure. The oil cake contains 25-30 per cent crude protein, 5.0 per cent nitrogen, 1.8-2.0 per cent phosphorus and 1.0- 1.2 per cent potassium. However, due to its pungency and less palatability animals can consume only small amounts.

Origin

The earliest written records of rape seed and mustard are found in ancient Sanskrit writings form 2,000 to 1,500 B.C. Rai is originated in China and from there it was introduced to India. From India it spread to Afghanistan via Punjab. According to Vavilov (1926) the place of origin of Rape seed is eastern Afghanistan and adjoining parts of India and Pakistan. Yellow sarson to be the oldest of the various rapes and mustards grown in India.

Distribution

The important rape seed and mustard growing countries of the world are India, Canada, China, France, Germany, Pakistan, Poland and Sweden. The leading states in India producing mustard are Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Punjab and Gujarat.

Classification

Rape seed and mustard belong to Cruciferae family and genus *Brassica*. Classification of rape seed and mustard is as follows.

Indian Group	International Name	Botanical Name	Common Name	Local Name
Sarson	Indian Colza, Colza, Rape	*B. campestris* var. yellow sarson	Turnip Rape	Yellow Sarson
		B. campestris var. brown sarson	Turnip Rape	Brown Sarson
Toria	Rape	*B. campestris* var. yellow toria	Indian Rape	Yellow Toria
		B. campestris var. black toria	Indian Rape	Black Toria or Lahi
Rai	Mustard	*B. juncea*	Indian Mustard	Rai or Raya or Laha
		B. juncea var. *rugosa*	Rugosa	Pahari Rai
		B. nigra	Black mustard	Banarsi Rai

The main distinguishing characteristics of rape seed and mustard are given below.

Character	Rape seed (Sarson/Toria/Lahi)	Mustard (Rai, Raya, Laha)
Plant height	45-150 cm	90-200 cm
Leaves	Sessile, leaf lamina clasps the stalk partially or completely	Leaves stalked and do not clasp the stalk
Siliquae (Pod)	Short and thicker	Long and slender
Pollination	Cross pollinated	Self-pollinated
Seed coat	Smooth	Rough

Climatic Requirement

Rape seed and mustard are cultivated in rabi season. Crop requires cool, dry and clear weather with temperature of 18-25 °C for its growth and development. Growth of crop ceases if temperature falls below 3 °C and above 35-40 °C. Long day with adequate sunshine are ideal for its good production. Crop need fairly good soil moisture and can be grown in areas receiving 350-450 mm annual rainfall. High rainfall, high humidity and cloudy atmosphere at flowering increases incidence of aphids and other diseases and at the same time pollination is adversely affected as movement of honey bees is restricted because of rains. The crops of the group are also susceptible to frost and water logging.

Soil Requirement

Rape seed and mustard are capable of growing under a wide range of soil conditions ranging from sandy loam to clay loam but thrive best on light loam soils. Soil having neutral pH (6.5-7.5) are ideal for their proper growth and development but can be grown on moderately saline conditions.

Fig: Soil Requirement.

Varieties

Important varieties of rape seed and mustard recommended for cultivation are as follows.

1. Toria: T-9, T-36, M-27, BR-29, Bhagirathi, Krishna, Jowahar Toria-1, Panhali, RH-68, TS-29 and KBS-3.
2. Mustard: Varuna (T-59), Shekhar, Kranti, Pusa bold, Prakash, RLM-514, RL-18, Datan-67, Laxmi, Rajat, Rohini, Sanjukta, Asesh and TM-2.
3. Brown Sarson: BSH-1, Pusa Kalyani, BS-70 and KBS-3.
4. Yellow Sarson: YS-24, K-88, Pusa Gold, NDYS-921, Rajendra Sarson-1, Subinoy and YS-923.

Land Preparation

Seeds of the crop of this group are very small; hence cultivation requires a clean and fine seed bed. The land should be well prepared first by one deep ploughing with soil turning plough followed by two cross harrowings. Clods should be broken by planking the field after ploughing. Care should be taken to see that weeds and stubbles are well removed from the field and the soil contains adequate moisture to ensure good germination. Under rainfed conditions moisture may be conserved by harrowing after every rain along with contour bunding and other water conservation measures.

Fig: Land preparation.

Sowing

Time of Sowing

The rate of development of oil in seed is greatly influenced by the variation in atmospheric temperature, humidity and other biotic factors. Hence, sowing either too early or too late has been reported to be harmful. Toria should be sown from the mid to the last week of September. If sowing is delayed, there is great danger of attack of aphids on this crop. Sowing of sarson and rai must be completed in the first fortnight of October.

Seed Rate

Pure crop of rape seed and mustard can be sown with 5-6 kg seeds/ha. If crop are sown as mixed or intercropped with other crops seed rate of 1.5-2.0 kg/ha is sufficient depending upon the row ratio.

Spacing

Generally toria is sown in rows of 30 cm apart while sarson and rai are sown in rows of 45 cm apart. Thinning is done three weeks after sowing to maintain a plant to plant distance of 10-15 cm.

Method of Sowing

In irrigated conditions sowing is done with seed-cum-fertilizer drill. Fertilizer should be drilled at 7-10 cm deep and seeds are placed at 3-4 cm. The crop can also be sown by country plough by pora method (putting seeds behind the plough through funnel tube) or ridge seeder.

Fig: A view of mustard field.

Nutrient Management

Apply well decomposed farm yard manure or compost at 10 t/ha at the time of land preparation. Under irrigated condition, apply 60-90 kg nitrogen, 60 kg phosphorus and 40 kg potassium per hectare. For rainfed crop use only half the dose of recommended nutrients. Half quantity of total nitrogen and full amount of phosphorus and potassium is applied at the time of sowing. Remaining half quantity of nitrogen should be applied at 30 days after sowing.

Sulphur also plays an important role in oilseed crops. Apply of 20-40 kg sulphur through elemental sulphur 21 days before sowing or through gypsum at the time of sowing. If no sulphur fertilizer source is available nitrogen should be preferably be applied through ammonium sulphate and phosphorus through single super phosphate. If zinc deficiency, apply 5-10 kg Zinc sulphate.

Water Management

Rape seed and mustard are usually raised as rainfed on the conserved soil moisture. Hence, efforts should be made to conserve as much water as possible by bunding and leveling the field before the monsoon and ploughing during the monsoon season, bulky organic manures are applied to the soil to improve moisture storage capacity of soil and evaporation losses of moisture are minimized by the use of mulching or intercultivation. Crops do respond to irrigation as well. There should not be deficiency of moisture at pre-flowering and pod filling stage. The total water requirement of these crops is 400 mm. About 3-4 irrigations are required in light soils and 2-3 irrigations in heavy soils.

Weed Management

The most common weeds which grow in rape seed and mustard are *Chenopodium album, Conyolvulus arvensis, Meliotus alba, Cynodon dactylon, Physalis minima, Cirsium arvense* and *Cyperus rotundus*. Weeds are negative factor in crop production. About 25-30 per cent loss is caused by weeds in rape seed and mustard. To avoid nutrient, moisture and space competition, crops should be kept weed free up to 40-50 days stage. Thereafter weed growth is automatically suppressed by smothering effect of crop.

Weeds may be controlled by one intercultural operation with khurpi or hand hoe is very beneficial. This, besides creating soil mulch and thus reducing moisture loss through evaporation. Pre-plant incorporation of Fluchloralin at 0.75-1.0 kg/ha or pre emergence application of Pendimethalin 0.5-1.5 kg or Oxyflurofen 0.2-0.5 kg or Oxadiazone 1.0-1.5 kg effectively control the weeds.

Plant Protection

Insect Pests

Mustard Saw Fly: The larvae of mustard saw fly feed on leaves and make holes. In case of severe infestation entire leaf lamina is eaten. The female of this insect have saw like ovipositor thus called saw fly. Infestation may be controlled by dusting Endosulfan dust (4 %) or Quinolphos (1.5 %) or Malathion (5 %) or Methyl parathion (2 %) at 20-25 kg/ha in morning. Spray of Monocrotophos at 0.2 per cent also takes care of this insect.

Aphid: Both nymph and adult infest the crop by sucking the cell sap from leaves, stalk and inflorescence and siliquae. Infestation is more severe under cloudy conditions and cause severe damage if occur at flowering or pod formation. It is controlled by dusting the crop with Methyl parathion (2 %) or Malathion (5 %) at 20-25 kg/ha or spraying of Phosphomiden (0.05 %) ml or Endosulfan 35 EC or Malathion 50 EC (0.2 %) or Monocrotophos (0.05 %).

Painted Bug: The nymph and adult suck the cell sap from leaves and top stem. Dusting the crop with Endosulfan (4 %) or Quinalphos (1.5 %) or Malathion (5 %) at 20-25 kg/ha or spray with Monocrotophos AT 0.2 per cent checks the infestation.

Diseases

Blight: The disease is identified by appearance of concentric black spots on leaves, stalk and pods. To control the disease spray Ridomil (0.2 %), Mencozeb or Captafal or Zineb (0.4 %).

Downey Mildew: The leaves of infected plant have yellow, irregular spots on upper side and whitish spots on lower side. Use of clean and healthy seeds for sowing, prevent infestation. Spraying of Dithane M-45 or Metalaxyl followed by Mancozeb (0.2 %) decreases spread of disease.

Powdery Mildew: Symptoms of disease are deposition of greyish white powder in leaves. On increase infestation white powdery growth changes to dark grey and black and leaves develop small-big lesions resulting to death of leaf. Infestation of disease is more under cloudy conditions. It is controlled by applying 20 kg Sulphur dust or spraying of wettable Sulphur (0.5 %).

White Blister: Leaves, stalk and floral parts have white raised blisters resulting into deformation of inflorescence. To prevent infection, use of healthy seed is necessary. Adoption of crop rotation to break continuity of disease checks its spread. Two sprayings with Zineb (0.2 %) at 10 days interval check its further infestation and spread.

Harvesting and Threshing

When crop attained maturity, the colour of leaves, stem and siliquae turn yellowish-brown. Seeds are dark and produce rattling sound on shaking. Too early harvesting produces wrinkled and small seeds of low viability with low oil content. Late harvesting, results in loss of grains by shattering. Crop should be harvested in the morning to avoid shattering. Crop is harvested with the help of serrated sickle leaving 5-10 cm. The harvested crop should be stacked for 5-7 days before threshing. Plants are threshed by beating the pods with wooden sticks or by running bullocks or tractor. Crop can also be threshed by threshers. Winnowing is done in slow blowing wind or by winnowers. Cleaned grains should be dried well to 8-10 per cent moisture before it is stored.

Fig: Immature siliquae.

Fig: Matured siliquae.

Fig: Mustard field.

Fig: Mechanical harvester.

Yield

With the use of improved varieties, agronomical and plant protection techniques, yield of 15-20 q/ha of rape seed and 20-25 q/ha of mustard under irrigated conditions and 10-15 and 15-20 q/ha respectively under rainfed conditions may be obtained.

Cropping System

Crop is generally grown as pure crop in irrigated condition and in conserved soil moisture. The crop can also be grown after kharif crop if adequate moisture is available. The cropping sequences generally followed are sorghum - mustard, maize - mustard, pearl miller - mustard, green gram/cow pea/black gram - mustard, cluster bean - mustard, soybean - mustard, rice - mustard and jute - rape seed. Profitable intercropping systems are mustard + chickpea, mustard + barley, mustard + potato, mustard + lentil and mustard + wheat.

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SUNFLOWER

(*Helianthus annuus* L.)

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SUNFLOWER

(*Helianthus annuus* L.)

Fig: Sunflower.

Introduction

Sunflower popularly known as 'Surajmukhi' is a familiar plant in India. It is grown in India as an ornamental plant since ancient times. But as an oilseed crop, it was introduced in 1969 only. Commercial cultivation of this crop in India was started in 1972. Today, sunflower is considered as a potential oilseed crop in India. It stands third among annual oil seeds grown in the world. No other crop in our country has gained as much popularity as sunflower because of its wide adaptability, short duration, photo insensitivity, drought tolerant, high yield potential, besides high quality oil.

Fig: Sunflower.

Importance

Sunflower has got 45-50 per cent good quality oil and possesses good odour which can be used for a variety of cooking purposes like any other edible oil. Among the vegetable oils, sunflower oil is considered as most suitable for human consumption because of high level of linoleic acid (67 %) which helps in washing out cholesterol deposition in the coronary arteries of the heart and thus is good for heart patients. This characteristic has made sunflower oil nutritionally better than groundnut or mustard oil. Thus, the major use of sunflower oil is as cooking oil.

Fig: Sunflower oil.

Use of sunflower oil for industrial purposes is not very common. It is used to some extent in paints, varnishes and plastics because of good semi-drying properties. This is also used in the manufacture of hydrogenated oil, soaps, detergents and cosmetics. The sunflower kernels can be eaten raw or roasted. Sunflower oil cake contains 40-44 per cent high quality protein. It is ideally suited for poultry and livestock rations. Sunflower hulls are used as roughage in animal food, litter, fuel and making insulation board. After harvesting, stalks and capitulum may be used for fuel purpose.

Origin

Sunflower probably originated in the South-West America. In India, the sunflower was introduced from Russia in 1969. Today, sunflower is one of the most important oilseed crops not only in India but at Global level also.

Distribution

The major sunflower producing countries of the world are Russia, Argentina stands next to Russia. Other main sunflower growing countries are China, U.S.A., Spain France, Romania, Turkey, Hungry, Bulgaria, India, Australia, South Africa and Yugoslavia.

In India, sunflower as an oilseed crop was introduced in 1969 in Karnataka. However, large scale cultivation of sunflower was started in 1972 with the introduction of

open-pollinated varieties of Russian (U.S.S.R.). Until mid-80's, the cultivation of sunflower remained confined to southern states of Karnataka, Tamil Nadu, Maharashtra and Andhra Pradesh. Owing to the short duration nature of the crop and development of hybrids, sunflower gained popularity in northern states and could be fitted in various cropping systems. This made sunflower an important spring season crop in the states of Punjab, Haryana, Uttar Pradesh, Madhya Pradesh and Rajasthan.

Classification

The sunflower belongs to the family Compositae and the genus *Helianthus*. The genus *Helianthus* is derived from the Greek word *heliouas* meaning ‘sun’ and *anthos* meaning 'flower'. There are about 264 species in *Helianthus* genus. Commercial varieties grown for seed are considered to be *Helianthus annuus* var. *macrocarpus*.

Climatic Requirement

Sunflower is a plant of temperate zone but varieties adapted to a wide range of environments have been developed. Sunflower is grown from 40 °S to 55 °N but major production is between latitudes 20 and 60 °N and 20-40 °S. It can be grown to an attitude of 2,500 m above mean sea level, but gives highest oil yield below 1,500 m. Sunflower grows well within a temperature range of 20-25 °C. Temperatures affect the rate of development as prolonged high temperatures reduces the time of maturity. In general, temperatures above 25 °C at flowering or below 16 °C reduce seed yield and its oil content.

Fig: Climatic requirement of sunflower.

Sunflower is considered to be drought tolerant but oil yield is substantially reduced if plants are stressed at peak growth period and flowering. Evenly distributed rainfall of 500 to 700 mm over the growing period and ceasing just before flowering and seed filling is ideal for good harvest. High humidity accompanied with cloudy weather and rainfall at the time of flowering results in poor seed set. Sunflower plant is susceptible to damage by

lodging due to winds particularly when irrigated because of its height. Sunflower at seedling stage is highly susceptible to hail.

Soil Requirement

Sunflower can be grown on a wide range of soils but soils with good drainage are best suited. It grows well on neutral to moderately alkaline soils, with a pH range of 6.5 to 8.0 but acidic soils are not suitable. Poor drainage conditions are unsuited because it increases susceptibility to fungal disease and lodging.

Fig: Soil Requirement.

Varieties

Sunflower cultivation in India was started in 1972 with the introduction of open pollinated varieties from U.S.S.R. Release of early maturing variety Morden in 1978 and the first hybrid BSH-1 in 1979 helped in reviving interest in sunflower. During the last 20 years, many open pollinated varieties have been developed which have broadened the varietal base. Besides, morden, several open pollinated varieties such as Surya, CO-1, CO-2, S-5-56, EC-68414 and TANU-SUF-9 have been released in many states. Some of the important hybrids include BSH-1, KBSH-1, KBSH-41, APSH-1, APSH-11, MFSH-1 and MFSH-17.

Fig: Big Smile.

Fig: Autumn Beauty.

Fig: Holiday.

Fig: Ikarus.

Fig: Moon Bright.

Fig: Moulin Rogue.

Fig: Pacino.

Fig: Ring of Fire.

Fig: Sonja.

Fig: Soraya.

Fig: Sun Beam.

Fig: The Joker.

Fig: Valentine.

Fig: Teddy Bear.

Land Preparation

Sunflower requires well pulverized and weed free land. The first ploughing should be done by the mould board plough and subsequently 1-2 ploughings could be done by local plough followed by planking. When the plants attain knee high stage earthing should be done along the rows. This provides safe guard against lodging which is likely to occur at heading sage if winds of high velocity blow.

Fig: Land preparation.

Sowing

Time of Sowing

Sunflower, being a photo and thermo insensitive could be grown throughout the year in India. With the exception of freezing temperatures, the sowing of sunflower can be done in any month of the year. The optimum time of sowing of sunflower is June-July for kharif, September-October for rabi and December-January for spring season. It takes about 80-90 days in kharif, 105-130 days in rabi and 100-110 days in spring season.

Seed Rate

Seed rate of 5-8 kg/ha for hybrids and 8-10 kg for dwarf genotypes are sufficient to ensure good crop stand. Sunflower seed loses its viability at a faster rate; hence one should not use older seed for sowing unless it is supported by germination test.

Fig: Sunflower seeds.

Spacing

Sunflower should be sown in lines with 45 cm for short duration and dwarf genotypes and 60 cm for hybrids. After 10-12 days of germination, extra seedlings should be uprooted to provide a space of 20-30 cm between plants in rows.

Method of Sowing

Seed should normally be sown at 3-4 cm depth, depending on the moisture status of the seed bed for better stand. Sunflower is generally sown on flat beds but to ensure germination sowing on ridges prepared at desired distance followed by irrigations recommended. On flat beds sowing can be done either behind desi plough or with seed drill. However, dibbling of 2-3 seeds per hill is recommended for maintaining optimum population, particularly for ridge sowing.

Fig: Germination stage.

Fig: Seedling stage.

Fig: Flowering stage.

Fig: Flowering stage.

Fig: Sunflower field.

Nutrient Management

Sunflower is an exhaustive crop and responds well to nitrogen, phosphorus and potassium. Hence, for obtaining higher yields adequate supply of plant nutrients for sunflower is most essential. Nitrogen is essential for vegetative growth but to improve the seed size, its proper filling and to increase oil content liberal supply of phosphorus is essential. Potash also helps in grain filling and disease resistance.

Application of 10 t/ha of well decomposed farm yard manure or compost is essential for getting good crop. In addition, a dose of 60-80 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha has been found optimum for sunflower. Half quantity of N and whole of P_2O_5 and K_2O should be applied as basal dose at the time of sowing and remaining dose of N should be top dressed at 30 days of sowing. Being an oil seed crop sunflower requires sulphur @ 25-30 kg/ha which can be supplied through ammonium sulphate, super phosphate and gypsum. Among micronutrients, boron has shown its favourable effect on the seed yield of

sunflower. Spraying of 0.2 per cent Borax to capitulum on ray floret stage or dusting of 2-5 kg Borax/ha increases the seed yield.

Water Management

Sunflower is considered to be drought tolerant, however, it responds well to irrigation. Sunflower seeds have thick hulls and imbibe water at a slow rate. It is therefore, necessary to ensure sufficient moisture for proper germination at the time of sowing. Pre-sowing irrigation is necessary for rabi and spring crops to get uniform germination and better stand. The most critical stages for moisture stress are bud formation, buttoning, flowering, seed setting and seed development. When crop is fully dependent on irrigation, water required by sunflower varies between 600-750 mm. Plants are most vulnerable to lodging at seed filling stage because of heavy capitulum. Hence, irrigation should be avoided at the time of high wind velocity as plants are easily uprooted in wet soils.

Fig: Sprinkler irrigation.

Weed Management

Sunflower is sown in wider rows (45-60 cm) which provides enough opportunity to weeds to establish. They cause enormous loss to sunflower crop as they compete for nutrients, moisture and light. Weed free conditions up to 45-60 days after sowing results in better yield performance. Sunflower smothers the weeds at later stage due to rapid growth. Hence, weeds emerging after this period do not pose serious problem. The prominent weed flora encounters with sunflower crop comprises of *Trianthma portulacastrum, Digera arvensis, Phyllanthus niruri* under dicot weeds and *Cyprus rotundus* and *Cynodon dactylon* under monocot weeds. However, weed flora may vary from region to region depending upon climate, soil type and cropping pattern.

Depending upon the intensity and frequency of weed infestation, two hand hoeings at 20 and 40 days after sowing controls the weeds effectively. Pre-planting application of Fluchloralin or pre-emergence application of Pendimethalin @1.25 kg/ha have been found effective in controlling weeds in sunflower crop.

Pollination

Poor seed setting is yet another constraint to limit the productivity of sunflower. The protandrous and self-incompatible nature of sunflower favours cross pollination and is predominantly brought about by insects. The pollination is largely done by honey bees and although other insects like bumble bees also play a role. As sunflower is highly cross pollinated crop, sufficient number or pollinators are necessary for better pollination of all the florets in capitulum to ensure higher seed set and yield. The introduction of bee-hives into the field at an appropriate time can help in seed setting in sunflower. Supplementing the natural pollination with hand pollination results in higher yield. The practice of hand pollination should be done for ten days at anthesis stage early in the morning on alternate days. For this purpose flowers should be rubbed gently with hand covered with soft cloth. This would help pollens to reach all the female flowers and result in higher fertilization.

Fig: Pollination.

Plant Protection

Insect Pests

Bihar Hairy Caterpillar: The crop is damaged by young larvae which feed gregariously on the undersurface of the leaves. In later stage, caterpillar defoliates the complete plants. The insects can be controlled by spraying Endosulfan 35 E.C. at 0.2 per cent or Dimethoate 30 E.C. 0.1 per cent.

Capitulum Borer: The insect directly damages the developing seeds and causes enormous loss to yield. Two sprays of Endosulfan (0.05 %) at 25 and 40 days after sowing is advisable for the effective management of capitulum borer.

Root Weevil: Damage is caused by both grubs and adults. The adults of the insect feed on foliage whereas grubs feed on roots which cause mortality of the plants. Soil application of

insecticide at the time of last ploughing helps to control the pest. Any of the Chlorinated hydrocarbons e.g. Lindane (3.5 kg a.i./ha), Heptachlor (1.5 kg), Dieldrin (1.0 kg) or Toxaphane (0.25 kg) may be used to control this pest.

Diseases

Alternaria Leaf Blight: It is a destructive disease cause reduction in seed and oil yield. Mancozeb at the rate of 0.30 per cent sprayed at 7-10 days interval is effective in controlling this disease.

Fig: Alternaria Leaf Blight.

Rust: Reddish brown pustules appear on the lower surface of the young leaves and later spread over entire vegetative surface. Dusting of elemental sulphur at 15 kg/ha or spraying of any Organosulphurs (Zineb 0.4 %), Mancozeb (0.15 %), Ziram 0.15 %) are highly effective in managing the disease. Sunflower hybrids viz. MSFH-1, 6, 8, 9, 10, BSH-1, VSF-1 and 2 are fairly resistant to rust in India.

Fig: Rust.

Charcoal Rot: The disease incidence, increases due to low soil moisture at flowering accompanied by high temperatures above 30 °C for prolong period. Seed treatment with Thiram at 2-4 g/kg seed helps in minimizing seed borne inoculum.

Head Rot: Kharif crop is more susceptible to the infection. At first brown irregular water soaked spots appear on the surface of the head near the stalk and gradually spread to the head causing rot of the head. This can be controlled by spraying Mancozeb at 0.2 per cent during head emergence.

Fig: Head Rot.

Birds

Sunflower heads attract the birds especially parrots due to the attractive colour. They start damaging the heads just after seed setting. They feed on seeds and make the heads empty, if not taken care. Hence, the crop should be protected for about 20 to 30 days depending upon the duration of seed setting and maturity. Manual scaring of the birds by making sound or noise, use of tape recorder, radio, dolls, coloured shining tapes as light reflecting and covering the crop by nets are most effective methods. However, application of 5.0 per cent Malathion on individual flowers after seed setting is also suggested.

Harvesting and Threshing

Harvesting of sunflower crop at its optimum stage of maturity is very important to minimize field losses and to get best quality seed with higher viability. Delay in harvesting causes field losses as sunflower is very prone to bird damage. Rainfall at maturity causes rotting of capitulum which results in fungi attack and discoloration of seed.

Generally, maturity of sunflower is judged by visual observation of colour of capitulum and seed as well. Sunflower is harvested when colour of the capitulum turns to lemon yellow. When seed turns to darker in colour, its coat also becomes hard and seed easily removed from capitulum at this stage, if seed is pressed with fingers, kernel remains intact whereas in case of immature seed, kernel is smashed on pressing. Measurement of moisture content in seed is a scientific way to judging sunflower maturity. At the time of harvesting seed moisture content, should not exceed 15 per cent. Harvesting of sunflower is done mostly by sickles. At the time of harvesting, capitulum is separated from stem and left for sun-drying. Threshing is done by beating the centre of the head with a stick or with thresher. After threshing, cleaning of seeds should be done by separating foreign materials

by sieving and winnowing. Further, sun drying of the seed is desirable before storage and the moisture in seed should not exceed 10 per cent.

Fig: Maturing stage.

Fig: Maturity stage.

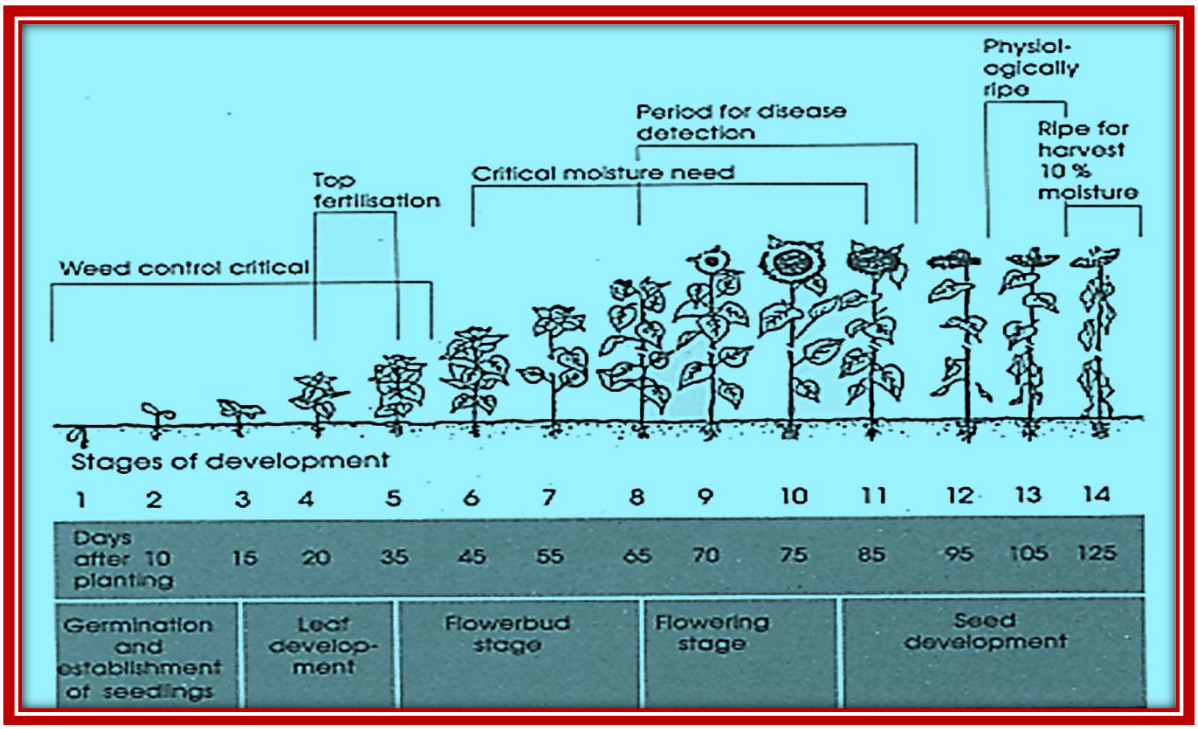

Fig: Sunflower growth stages.

Yield

A good crop of sunflower raised properly and nursed appropriately yields 15-20 q/ha under rainfed condition and 25-30 q/ha under irrigated condition.

Cropping System

Sunflower crop is grown in rotation with several crops. Some of the important crop rotations are maize - sunflower, maize - potato - sunflower, paddy - sunflower, sunflower - safflower and pigeon pea - sunflower.

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FODDER CROPS

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FODDER CROPS

Introduction

The agricultural prosperity in India is intimately bound up with domestic animals maintained by the agriculturists. Malnutrition and under feeding to the cattle lowers the national wealth and productivity. By supplying nutritious feeds, milk yield in milch animals and efficiency in draught animals could be enhanced considerably. There is an urgent need to enhance the fodder resources. The fodder resources can be improved by the adoption of better techniques of fodder production, introduction of nutritious exotic types of fodder, development of grassland farming, improving grazing grounds, etc. As there is population pressure of land, it is essential to intensify efforts towards production of high yielding forage crops per unit area.

Forage crops comprises mostly of grasses and legumes. Mixing of legume and non-legume fodder crops should be regularized in the ratio of 40:60. Forages are rich source of calcium, phosphorus, minerals and vitamin A. Feeding of good quality forages leads to maintenance of animals, normal reproduction, and production of liberal amount of milk and butter fat. Further, forages are the cheapest source of nutrients for dairy animals. Harvest of forage crops at right time ensures more of digestible proteins, increased palatability and less wastage of fodder. All cereal crops, grasses and legumes cut at the stage of flowering are most suitable as forage feeds.

Fig: Fodder Crops.

Classification

Forage crops refer to vegetative matter, fresh or preserved, utilized as feed for animals. It includes fodder, hay, silage and pastures.

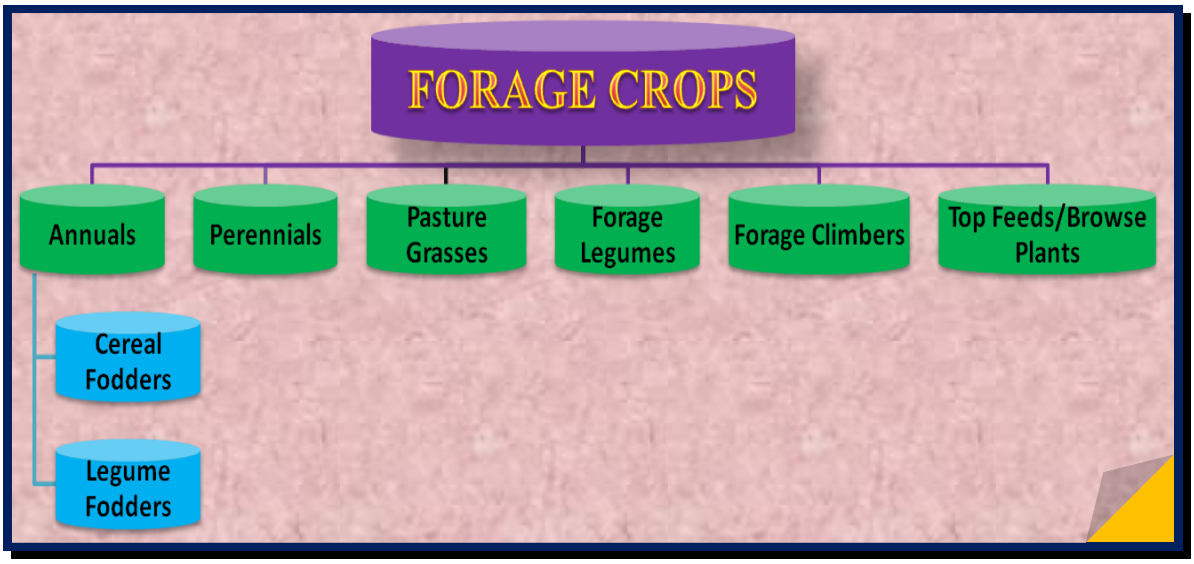

Fig: Classification of Forage Crops.

a) Annuals

i) Cereal Fodders

1. Maize : *Zea mays*
2. Jowar : *Sorghum bicolar*
3. Bajra : *Pennisetum typhoides*
4. Barley : *Hardium vulgare*
5. Oats : *Avena sativa*
6. Mustard : *Brassica oleracea*
7. Deenabandhu : *Pennisetum pedicillatum*

Fig: Maize.

Fig: Sorghum.

Fig: Bajra.

Fig: Barley.

Fig: Oats.

Fig: Mustard.

ii) Legume Fodders

1. Cowpea : *Vigna unguiculata/V. sinensis*
2. Horse gram : *Dolichos biflorus*
3. Lucerne/Alfa alfa : *Medicago sativa*
4. Cluster bean/Guar : *Cyamopsis tetragonaloba*
5. Berseem : *Trifolium alexandrium*
6. Rice bean : *Phaseolus calcaratus*
7. Lupins : *Lupinus lupins*

Fig: Horse Gram.

Fig: Cowpea.

Fig: Lucerne.

Fig: Cluster bean.

Fig: Berseem.

b) Perennials

1. Rhodes : *Chloris gayana*
2. Green panic : *Panicum maximum cv trichoglume*
3. Guinea : *Panicum maximum*
4. Setaria : *Setaria anceps*
5. Para : *Bracharia mutica*
6. Napier : *Pennisetum purpureum*
7. Signal : *Bracharia brizantha*
8. Sudan : *Sorghum sudanensis*

Fig: Panicum.

c) Pasture Grasses

1. Anjan : *Cenchrus ciliaris*
2. Dawalu : *Chrysopogon fulvis*
3. Marvel : *Dicantheum annulatum*
4. Pavan : *Sehima nervosum*
5. Spear : *Heteropogon contentus*
6. Dhallis : *Paspalum notatum*

d) Forage Legumes

1. Stylo : *Stylosanthes hamata*
2. Glysine : *Glysine weightii*
3. Centro : *Centrosema pubescence*
4. Calapo : *Calapogonium muconoides*
5. Glysine : *Glysine weightii*
6. Green leaf : *Desmodium intortum*
7. Silver leaf : *Desmodium unicatum*

Fig: Stylo.

e) Forage Climbers

1. Winged bean : *Psorocarpus tetragonoloba*
2. Velvet bean : *Styzolobium deerengianum*
3. Dolichos : *Dolichos lablab*

f) Top Feeds/Browse Plants

1. Agase : *Sesbania grandiflora*
2. Sesbania/Shevri : *S. aegyptica*
3. Subabul : *Leucana leucocephala*
4. Mulberry : *Morus alba*
5. Erythrina/Harivana : *Erythrina indica*

Fig: Agase.

Fig: Subabul.

Fig: Mulberry.

The cultivation practices of some important fodder crops are given below.

Cultivation practices of important fodder crops

Crop	Varieties	Seed Rate/ha	FYM/ Compost (t/ha)		N:P_2O_5:K_20 (kg/ha)		Spacing (cm)	Clippings (Cuttings) (Days)		No. of Clips (Cuttings)/ Year		Green Forage Yield (t/ha/Year)	
			R	I	R	I		First	Subse-quent	R	I	R	I
Hybrid Napier	NB-21, BH-18, BH-4, CO-1, Pusa Giant, IGFRI-31 (Swethiha-1), IGFRI-6, IGFRI-7, IGFRI-10 (Yeshwant)	20,000	10	20	150:90:60	180:120:80	90x60	60-80	40-50	3-4	6-8	45-60	130-150
Guinea	-	75,000	-	25	-	200:50:25	60x45	60-70	30-35	-	5-6	35-40	90-100
Green Panic	-	1,00,000	-	10	-	150:25:25	45x30	40-45	30	6-8	10-12	35-40	90-100
Rhodes	-	1,00,000	-	10	-	150:100:50	60x30	50-60	20-25	-	12	30-40	80-90
Para	-	27,250	-	10	-	150:75:40	60x60	75	25-30	-	10	-	125-150
Congo Signal	-	75,000	-	10	-	100:60:40	45x30	60	40-45	-	6	30-35	60-75
Sudan	-	20,000	-	10	-	62:62:37	25x25	75	40-50	-	4-5	-	80-85

Contd…

Crop	Varieties	Seed Rate/ha	FYM/ Compost (t/ha)		N:P_2O_5:K_20 (kg/ha)		Spacing (cm)	Clippings (Cuttings) (Days)		No. of Clips (Cuttings)/ Year		Green Forage Yield (t/ha/Year)	
			R	I	R	I		First	Subse-quent	R	I	R	I
Anjan	CAZRI-75 (Marvar Anjan), IGFRI-3108 (Bundel Anjan)	5 kg	-	5	40-60:30:0	-	45x30	60-75	40-60	3-5	-	25-30	-
Fodder Sorghum	GS-3, GS-20, S-1049, M.P. Chari, Rajasthan Chari-1 (RC-1), Pusa Chari-69, Jawahar Chari-69 (JC-69), Meethi Sudan (SSG 59-3), Pioneer hybrid	50	5	10	50:25:25	80:40:40	30	60-70	40	-	2-4	25-30	50-70
Fodder Maize	-	100	5	10	100:50:25	150:75:50	30	70	-	-	-	45-50	65-70

Contd…

Crop	Varieties	Seed Rate/ha	FYM/ Compost (t/ha)		N:P_2O_5:K_20 (kg/ha)		Spacing (cm)	Clippings (Cuttings) (Days)		No. of Clips (Cuttings)/ Year		Green Forage Yield (t/ha/Year)	
			R	I	R	I		First	Subse-quent	R	I	R	I
Lucerne	T-9, Ananda-2, Sirsa-9, R.L.-88	10	-	10	-	25:50:25	30	50-60	25-30	-	10-11	-	75-85
Berseem	Pusa Giant, IGFRI-S-99-1, IGFRI-S-54, UPB-101, T-526, BL-1	25-40	-	10	-	20:60:30	15	45-50	25-30		6-8	-	100

Note: R – Rainfed; I – Irrigated

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