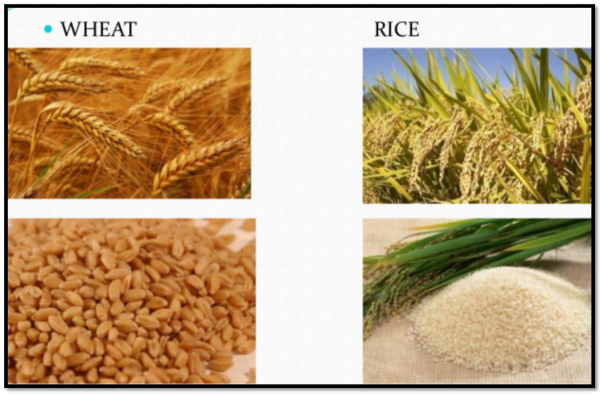
AGR 211 (2+1): Crop Production Technology-I

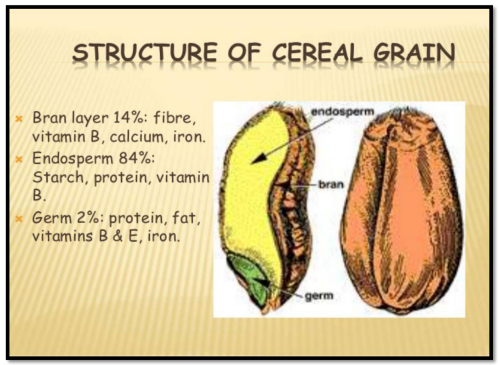
Lecture-1

Introduction and importance of cereal crops



Cereal?

- Cereals are the grasses belongs to Gramineae/ Poaceae family grown for their edible grains which composed of endosperm, germ and bran are called as **cereals.**
- The word cereals has been derived from **'Ceres'**, name of a Roman Goddess, means **'Giver of Grains'.**



Importance of cereals

- Cereals such as rice, wheat and maize are the important staple food crops in many areas of the world.
- Approximately 50% of the world's calories are provided by **rice, wheat and maize**, but in many parts of **Africa** and **Asia**, people rely mainly on **sorghum** or **millet.**
- **Maize, sorghum** and **barley** are important sources of **livestock feed**, and **barley** and **rice** are used in the **brewing industry.**
- Grains of **oats** in particular, have been shown to contain chemical compounds that help to reduce the chance of certain types of **cancer** and **coronary heart disease.**

- Cereals are the major source of carbohydrates, protein and minerals.
- Cereals can be found living in a wide range of altitudes (edge of the sea to 1000's of feet above sea level), temperatures (equatorial belt to arctic and Antarctic regions), moisture conditions, soil types and salinity concentrations.
- Cereals are also used to produce animal feed, oils, starch, flour, sugar, syrup, processed foods, malt, alcoholic beverages, gluten and renewable energy.

Average nutritional composition of Cereals

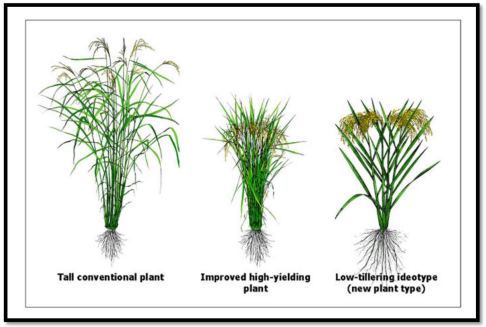
Protein	Fat	Carbohydrates	Vitamins	Minerals	Water
7-15%	2-7%	70-77%	0.5% B	1% Ca & Fe	12%

Nutritive value of cereals

- Useful amount of protein (gluten) – growth.
- Small amount of unsaturated fat.
- Lot of carbohydrates, cellulose, starch, energy.
- Vitamin B group for nerves and energy.
- Phosphorous and calcium for bones and iron for the blood.
- Very little water so they are easy to store.

Reasons for low yield of traditional varieties

- Poor genetic yield potential of the varieties of different crops.
- Weak and tall straw, susceptible to lodging under heavy fertilizer application.
- Inefficient leaf arrangement responsible for poor photosynthetic activity and less utilization of Solar energy.
- Many associated attributes like unsynchronized, susceptibility towards the attack of pests and diseases.



In recent years due to all round efforts of agricultural scientists it has been possible to cultivate HYVs of cereal crops which are often been termed as **"NEW PLANT TYPES (NPT's)".**

CHARACTERS OF NPT's :

1. Morphologically dwarf in growth habit with hard and stiff straw.
2. Erect and dark green leaves remaining active for longer duration.
3. Agronomically highly responsive to heavy fertilizer application
4. Physiologically be well equipped for more dry matter production and high yields.
5. Adaptable under different agro climatic conditions and are shorter growing duration.

Important features of such NPT's of cereals in grain crops

1. DWARFNESS:

- NPT's are dwarf in nature due to **NORIN in wheat and DEE-GEE-WOO-GEN in rice** dwarf genes.
- NPT's are short, stiff, not more than knee height but could take more fertilizers without lodging.

Norin 10, the donor of the dwarfing gene which saved millions of lives

2. EFFICIANT LEAF ARRANGEMENT:

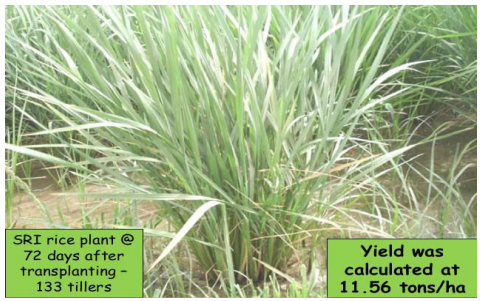
- NPTs are **narrow, thick, erect and dark green color** with optimum LAI composed of properly arranged leaves, which remain active for longer period after flowering due to high sunlight interception they play important role in supporting grain formation resulting into more number of fertile grains per ear head.

3. SYNCHRONOUS TILLERING:

The growth and development of NPTs are more or less rhythmic i.e.,

- high germination %
- formation of all tillers at a time (during a specific period) and timely maturity of all the tillers.

❖ So, they have highest synchronized coefficient as regards to the development and maturity of grains of different ears of a plant.



4. LOW FLORET STERILITY:

- Traditional tall varieties under heavy fertilizer application produce more sterile florets.
- NPT's have a very low floret sterility % due to synchronized tillering into uniform ear head formation supported by longer physiological activity of leaves at maturity.
- Low floret sterility an in NPT's has also been attributed due to increased activities of roots at grain formation stage.

5. SHORTER GROWTH DURATION:

- NPT's have shorter duration than traditional varieties.
- At High N application longer growth duration and at low N application, short duration variety is preferred for obtaining higher dry matter production as well as more grain production efficiency i.e., grain yield/unit area/unit time.
- These short duration varieties can fit very well in under high cropping intensity programmes like multiple and relay cropping.

6. ADAPTABILITY TO DIFFERENT CROP SEASONS

- All most all NPT's are photo insensitive and completely resistant to fluctuations in day length.
- They can be grown under all crop seasons provided inputs like fertilizers and irrigations are adequately made available, so higher yields can be obtained.
- However, some of the NPTs are thermo-sensitive and are affected by variation in temperature during season.

7. ABSENCE OF SEED DORMANCY:

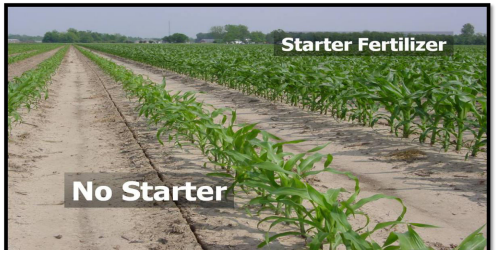
- NPTs have no dormancy i.e. they do not require any rest period, called dormancy period.
- Freshly harvested seed can be used for sowing.
- This character is useful in seed multiplication programmes of HYVs, within a short span of time.
- This along with photo insensitivity makes them quite suitable for
- adaptation under high intensity cropping programmes.

8. EFFECTIVE TRANSLOCATION OF FOOD MATERIAL FROM PLANTS TO GRAIN

- NPTs have higher potentiality to absorb and assimilate nutrient from soil throughout the growth duration which in combination with higher photosynthetic activities enable them for higher dry matter production.
- The built in efficient plant mechanism in NPT's coupled with fewer organs respiring at flowering stage permit more efficient use of respiration for growth and grain production.
- After flowering, this enables effective translocation of accumulated food materials of straw for grain formation.

9. RESPONSIVE TO HEAVY FERTILISER APPLICATIONS:

- NPT's possess the trait of high responsiveness towards fertilizer application.
- Their optimum N requirement is 2 ½ -3 times more than the requirement is so called improved local varieties similarly, the P & K requirement of NPT's are also 1 ½ -2 times more in comparison to local types.
- NPT's require about 100-120 kg N, 50-70 kg P_2O_5 and 40-60 kg K_2O/ha under optimum conditions of soil moisture status.



10. LODGING RESISTANCE:

- NPT's are generally dwarf in growth habit with strong and stiff stem which provides them considerable resistance against plant lodging.
- Because of incorporation of dwarfing genes in NPT's, they possess the trait of high responsiveness towards heavy fertilizer application without lodging.

11. YIELDING POTENTIALITY:

- The NPT's are known for their HY potential.
- NPT's are capable of yielding 2-3 times more grain yield in comparison to local tall improved types.
- This is probably due to their altered morphology which results into efficient utilization of water, nutrients and radiation and increased metabolic activities with high dry matter production.
- Their grain to straw ratio is approximately about 1:1.

12. DISEASE SUSCEPTIBILITY:

- The only drawback associated with NPT's is the disease susceptibility with luxuriant vegetative growth; the varieties offer scope for insect pests and diseases. However, attempts are being made to develop disease resistant NPT's.

Eg : Rice - BPH resistant varieties: MTU-2067, MTU-2077 and MTU-4870.
Wheat ----- Rust resistant varieties ----- Sonalika.

Rice

Oryza sativa L.

Introduction

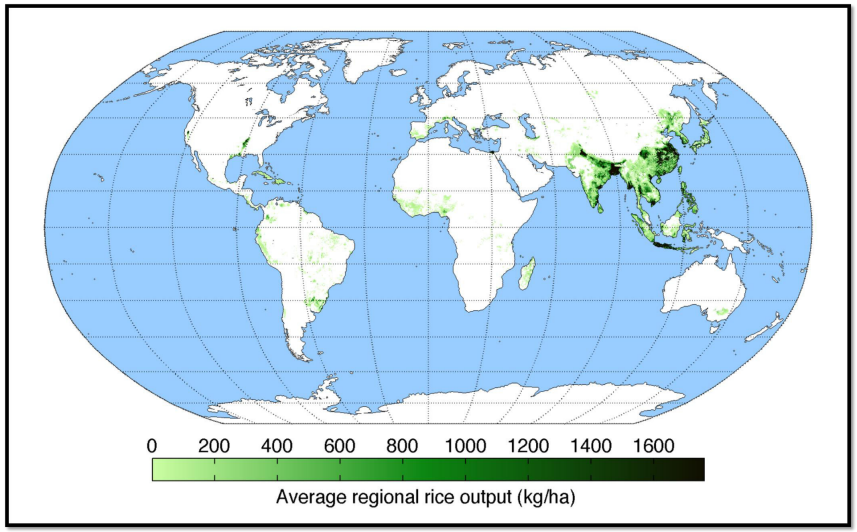
- Rice is the 3rd highest worldwide production of cereal crop after corn and wheat.
- World wide rice is grown with an area of **161.1 m.ha.** with the production of **488 million metric tons** (2017-18).
- Asian countries accounts for 85% share in the world rice production.
- **China** stands 1st in world rice production followed by **India.**

World wide production of cereal grain in 2017-18
(million metric tons)

Sl.No.	Crops	Production (million metric tons)
1	Corn	1033.74
2	Rice (milled)	488.6
3	Wheat	757.92
4	Barley	144.26
5	Oats	23.51
6	Rye	12.38

World wide production of rice in 2017-18 (million metric tons)

Sl. No.	Counties	Production (million metric tons)
1	China	144.95
2	India	110.15
3	Indonesia	36.86
4	Bangladesh	34.58
5	Vietnam	27.40
6	Thailand	19.20
7	Myanmar/Burma	12.65
8	Philippines	11.69
9	Brazil	8.38
10	Japan	7.78



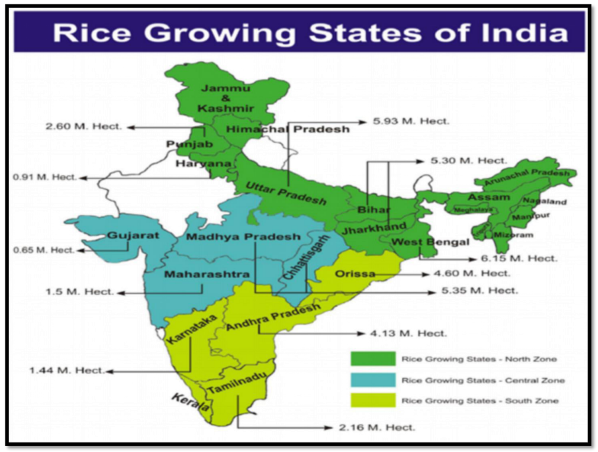
Indian Rice Scenario

- Area - 43.19 million hectare
  production – 110.15 million metric tons (2017-18).

- It accounts for - 43% of total food grain production
  - 55% of the total cereal production
  - 24% of gross cropped area of the country

- Out of total rice area, 93% is cultivated in *kharif* season

- The area is roughly **3 times** more in *kharif* than in rabi.



➢East and central India accounts for 70% of rice area.

Rice growing states of India (2016-17)

Sl. No.	Name of the state	Area (m.ha)	Production (million tons)	Productivity (kg/ha)	% share of rice production
1	West Bengal	5.00	15.74	2600	15%
2	U.P.	5.90	12.50	2300	13%
3	Punjab	2.80	11.82	2500	10%

➢ These states accounts for 75% of total rice production in India

Origin and distribution of Rice

- The genus *Oryza* includes 24 species in which 22 are wild and 2 are cultivated i.e
- ***Oryza sativa*** (grown in asia and world wide)
- ***Oryza glaberrima*** (grown in west africa (nigeria))

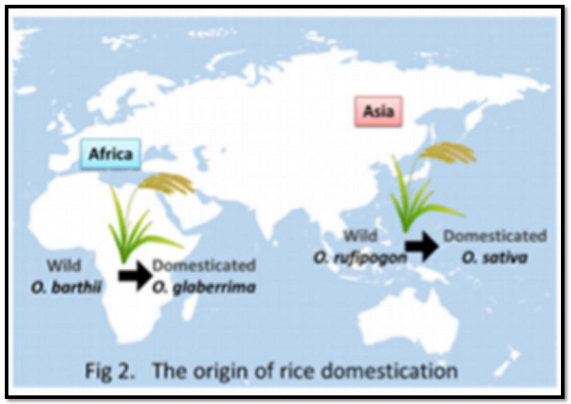
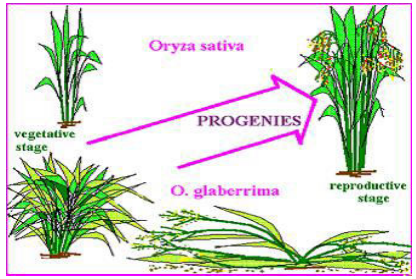


Fig 2. The origin of rice domestication

Characteristics of Asian and African rice species

Oryza sativa (Asian rice)	*Oryza glaberrima* (African rice)
High yield potential, but low adaptation to rainfed uplands	Low yield but a rich reservoir of genes for resistence to biotic and abiotic stress
It has replaced *O. glaberrima* over much of the rice cultivated area	Almost totally abondoned by farmers
Very popular across globe	Less known than asian rice
Originated earlier	Originate after asian rice

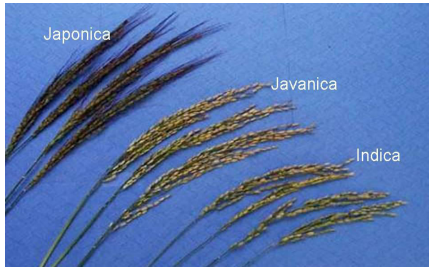


The *Sativa* species varieties in the world are grouped in to **three sub species**

1. Indica: Rice grown in **tropical and subtropical** (Southern Asia, including Sri Lanka, India, Thailand, Vietnam and Southern China) belong to the indica sub species

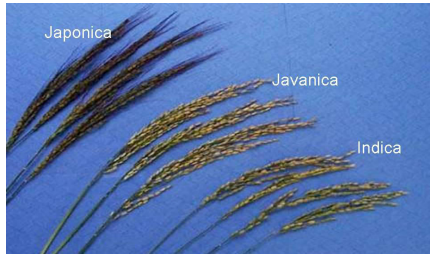
2. Japonica: The varieties developed in **Japan** belong to this sub species

3. Javanica: These varieties are mainly found in **Indonesia**



Characteristics features of indica, japonica and javanica

Characters	Indica	Japonica	Javanica
Growing climate	Hot climate (tropical and sub tropical) *viz*., southern asia including srilanka, india, china etc.	Temperate climate *viz*., japan portugal, spain etc.	Grown only in indonesia
Leaves	Very broad to narrow pale green	Narrow, dark green	Broad, very stiff, light green
Grain size	Long to short, slender, somewhat flat	Short, roundish	Long, broad and very thick grains
Tillering	Profuse	Medium	low



Characters	Indica	Japonica	Javanica
Height	Tall to intermediate	Dwarf	Tall
Hairs on leaves and glumes	Present	Present, dense	Present but are very long
Awns	Awnless or short and smooth	Awned or awnless	awned
Cooking quality	Less sticky and fluffy after cooking	More glutinous (sticky)	sticky
Yield	Medium yield	Higher yield	Lower yield

Origin of rice

- Origin of rice is still contradictory and in debate
- Cultivated species *Oryza sativa* is thought to have originated in South & SE tropical Asia.
- De Candolle (1886) and Watt (1892) opinioned that south India was the place where cultivated rice originated.
- Vavilov (1926) suggested that India and Burma should be regarded as the centre of origin of cultivated rice.

Rice ecosystems

Rice ecosystem is broadly classified in to 4 types

1. Irrigated ecosystems
2. Rainfed lowlands
3. Rainfed uplands
4. Deep water rice/flood prone

1. Irrigated ecosystems

- It accounts for 49.50% of the total area under rice crop in the country.
- This system is followed in regions of assured water supply
- In this system fields are bunded and soils are puddled.
- Seedlings are transplanted in soft mud under impounded water
- Water stagnation is continuous throughout the crop growth
- Raising nursery is indispensible
- Average yield is 4-5t/ha

Major problem:

Yield instability and environment Degradation due to inefficient irrigation and nutrient use

2. Rainfed low lands

- Practiced in areas with rainfall of >1000 mm and scope for irrigation is limited.
- Fields are bunded to store rain water and puddled.
- Seedlings are transplanted in standing water (30-90 cm depth).
- Field are not artificially irrigated.
- It is followed in **heavy rainfall hilly regions.**

This ecosystem is further classified in to 3 types

Shallow water : < 50 cm

Semi deep water : 50-100 cm

Deep water : > 100 cm

3. Rainfed upland ecosystem

- It accounts for 13.5% of the total area under rice crop in the country
- The areas lies in eastern zone comprising of Assam, West Bengal, north eastern hilly region etc.
- Upland rice is mostly grown as direct seeded.
- Fields are unbunded and rain water is not stored
- It is followed in assured rainfall tracts without irrigation

Constraints:

Productivity is very low <1.00 t/ha due to uncertainty of available water, light textured and unfertile soil, poor nutrition balance, weed problem

4. Deep water rice

- It accounts for 11.4% of the total area under rice crop in the country.
- It is followed in an area of very heavy rainfall regions (>2000 mm)
- Rice seeds are broad casted before the occurrence of rainfall with suitable tolerant varieties
- Very heavy rainfall leads to flooding of land to a height of 1- 5m
- This stagnated water is used for fish farming
- Yield is <1.5 t/ha and variable

Soil and climatic requirements

- Rice can be grown in all types of soils
- Rice being a semi aquatic crop grows best under submerged condition.
- Soils with good WHC and good amount of clay and organic matter are ideal for rice cultivation.
- Clay or clay loam is most suitable for rice cultivation.
- Rice plant is able to tolerate a wide range of soil reaction, It grows well in soils having a pH ranges between **5.5 to 6.5 pH.**
- It can be grown on alkali soils also after treating them with gypsum.
- Rice can be grown mild salinity (EC up to 0.75 ds/m). However it can also withstand the acidity up to pH 4.00.

Climatic condition

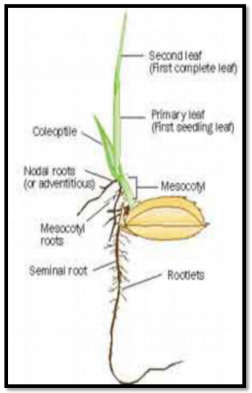
- Rice is a short day plant
- Among various climatic factors, solar radiation, temperature, rainfall and relative humidity plays a major role in rice production.

Rice crop is being cultivated under widely varying climatic conditions as detailed below:

- Latitude : 45° N – 40° S
- Altitude : Mean Sea Level to 3000 m MSL
- RH : 35 – 100%
- Rainfall : 500mm to 5000mm
- Temperature : 20° -35° C, night temp: 15-20° is favourable
- Day length : 9 hrs. optimum
- Light : 400 cal/cm2/day is the minimum requirement.

Botanical description of rice

Roots:



- Rice form a fibrous root system consisting of seminal, nodal and lateral roots.

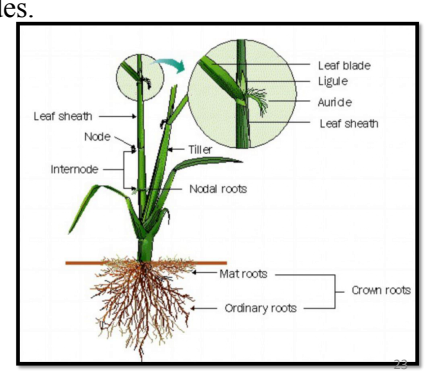
Seminal Roots: Shortly after germination embryonic roots appear from coleorhiza which may die later.

Nodal roots: also called as secondary roots which arises from first node of coleoptile

Lateral roots: these roots are called as adventitious fibrous roots which develops from coleoptile.

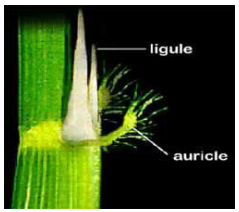
Stem:

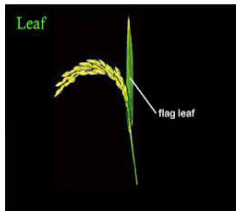
- The stem of rice is called as Culm/ haulm.
- The **culm** is made up of a series of **nodes** and **internodes**
- The stem of rice is generally erect, cylindrical and hollow at the internodes and solid at the nodes.



Leaf:

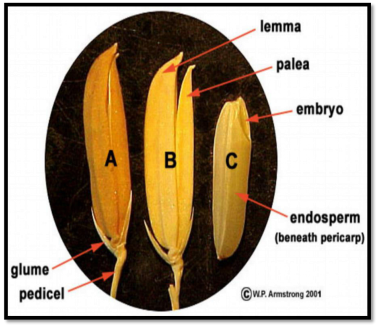
- The node or nodal region of the culm will bear a **leaf.**
- Leaves are borne alternately on the culm in opposite directions. One leaf is produced at each node.
- The topmost leaf below the panicle is the **flag leaf**.
- The flag leaf contributes largely to the filling of grains because it supplies photosynthetic products, mainly to the panicle.
- Most leaves possess small, paired ear-like appendages on either side of the base of the blade - called **auricles**.
- **ligule** a papery membrane at the inside juncture between the leaf sheath and the blade



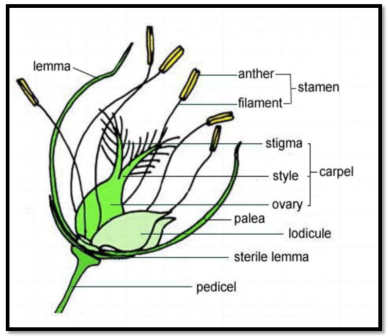


Inflorescence:

- Inflorescence of the rice is called as **panicle**.
- Panicle consists of more number of spikelet
- Spikelet consists of two hard glumes called Lemma and Palea
- Lemma and palea leter harden to become Hull or Husk

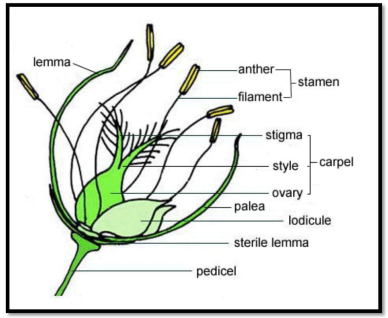


- The spikelet/ floret consists of 6 long stamens and a short pistil and at the base two transparent structure called Lodicules.



Pollination:

- Rice is a self pollinated crop
- On full growth of spikelt, lodicules attains turgidity and push the lemma and palea to open the stamens out of glumes.
- Later, anthers shed the pollen directly on stigma which facilitates self pollination.



- After pollination, grain enters milking stage and then become hard to form a grain.
- The grain of rice is called as **Caryopsis.**

Growth stages of rice

Growth stages of rice is divided in to three types *viz*.,

1. Vegetative stage: it is divided in to 3 sub stages

a. Seedling (sowing to transplanting)

b. Active vegetative stage (Transplanting to maximum tillering stage)

c. Vegetative lag phase (Maximum tillering to panicle initiation)

2. Reproduction stage (PI to flowering)

3. Ripening stage (Flowering to harvest)

a. Seedling stage:

- Germination to transplanting. Seed germinating to time when young plants becomes independent of food reserve of the seed i.e. nursery stage.
- The seedlings are transplanted to the main field from nursery at 20-25 days.

b. Active Vegetative Stage (Transplanting to Max. tillering stage):

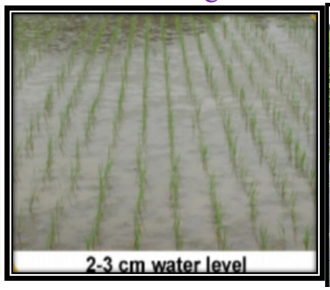
This includes sub stages *viz*.,

a) Recovery stage

b) Rooting stage

c) Maximum tillering stage

- The transplanted seedlings requires about 9 days to recover from the shock of uprooting during transplanting after which new roots appear. It is also known as recovering and rooting stage.



c) Maximum tillering stage:

- After recover from transplanting shock, plants start establishing roots, once roots established tillers develop rapidly and increases to a maximum number.
- Tiller height and straw weight also increases during this stage.
- Plants attain maximum tillering stage at 25-30 days after transplanting.

C. Vegetative lag phase (Maximum tillering to panicle initiation):

It includes sub stages

(i) Effective tillering stage

- During this stage weak tillers begin to die; each strong tiller bears a panicle primordium.
- The number of these potential productive (ear bearing) tillers come to be fixed at this stage which is known as **"Effective tillering stage".**


(ii) Non effective tillering stage

- Tillers that develop subsequently do not bear panicles and die ultimately. This is the **"non effective tillering stage".**

- Plants reaches panicle initiation stage after **30 days after maximum tillering.**


2. Reproductive stage (PI to Flowering): 30 DAS from PI

- Panicle initiation stage- beginning of reproductive stage.
- Internodes elongation and booting stage- After panicle initiation internal auxin concentration accelerates and elongates of internodes.

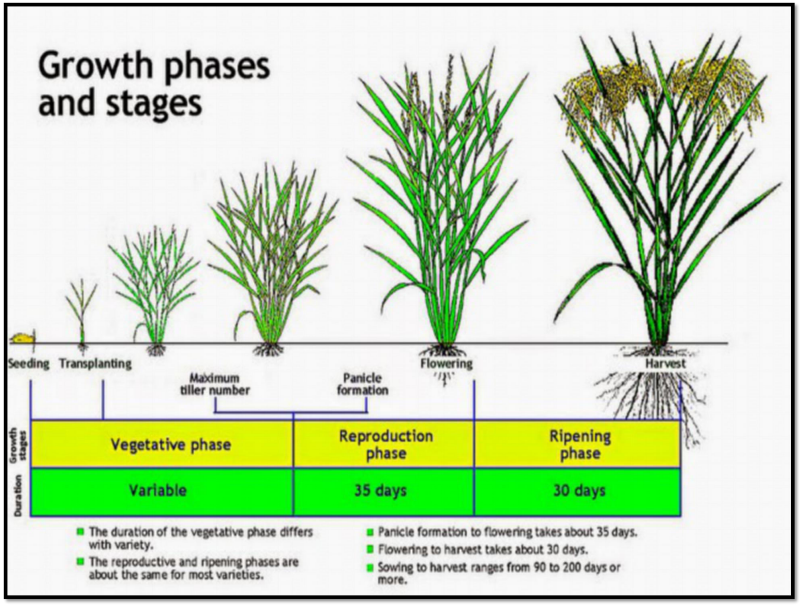

- Heading stage: 15 days after booting- emergence of panicle and flowering.
- Flowering: 20-25 days after booting- continues until the spikelets in the panicle bloom. Followed by **pollination and fertilization.**


3. Ripening State (Flowering to harvest): 30 Days from flowering

This includes the sub stages of grain *viz*.,

- Milking stage: 7-12 days after anthesis, the water content of the grain turn milky in consistency
- Dough stage: the grains turn into soft dough stage and later turns into hard dough stage 2-3 weeks after maturity stage.
- Maturity stage: Grains turn hard and free from greenish

Milking Dough Maturity



- During vegetative growth period, a relatively small amount of water is needed.
- Therefore, shortage at this period does not greatly affect the yield, except at the recovering and rooting stages.
- Stages after panicle primordial development, especially booting, heading and flowering stages need sufficient water.

Seasons of rice cultivation

Crop Season	Local name	Sowing time	Harvest time
Kharif	Aus/Autumn (West Bengal, Bihar)	May - June	Sept – Oct.
Rabi	Aman or Aghani	June - July	Nov - Dec
Summer or Spring	Boro (West Bengal)	Nov - Dec	March - April

Tamil Nadu rice growing season	
Kuruvai	June -July
Samba	Aug - September
Late Samba / Thaladi	Sep -October
Navarai	Dec -January

Classification of rice

Rice can be classified on the basis of

- Duration of crop
- Location of growing the crop
- Availability of water
- Grain length
- Season

Duration of crop

- Early duration : 90-110 days
- Medium duration : 125-140 days
- Late duration : > 150 days

Location of growing the crop:

- Upland
- Low land
- Mid land

Availability of water:

- Irrigated
- Drill sown (rainfed)
- Flooded
- Deep water

Grain length:

- Coarse
- Medium
- Fine
- Superfine

Season:

- Aus/Autumn (Kharif)
- Aman (rabi/winter)
- Boro (Summer)

Systems of cultivation/ Method of cultivation

- Transplanted irrigated rice
- Direct seeded rice (DSR)
- System of rice intensification (SRI)
- Aerobic rice cultivation

Transplanted irrigated rice

Important cultivation practices of transplanted rice includes

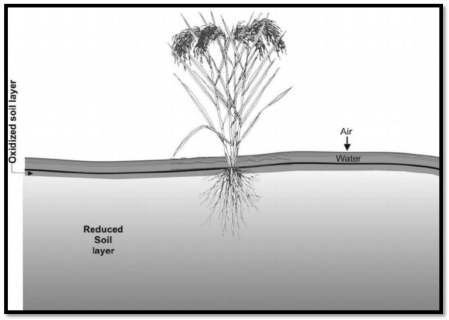
- **Nursery Management**
- **Puddling**
- **Transplanting of seedlings**
- **Nutrient management**
- **Weed management**
- **Water management**

Puddling

- Mechanical manipulation of the soil at high moisture regime (standing water) which reduces deep percolation loss of water is termed as PUDDLING.
- Puddling of the soil results in the reduction of macro pore space (break down of soil aggregates) and transforming the upper soil layer into a fine soft mud or puddle.
- It can be done by ploughs, tiller or tractor drawn implements depending upon their availability and soil conditions.

Objectives of Puddling

1. To obtain a soft soil layer for the seedlings to establish themselves faster.
2. Suppression of weeds.
3. To mix organic matter with the soil.
4. To create an impervious sub soil layer for reducing deep percolation & leaching losses of water and nutrients.
5. To facilitate easy transplantation.



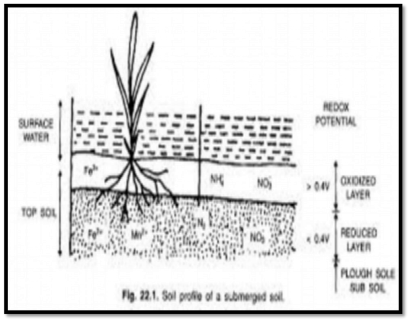
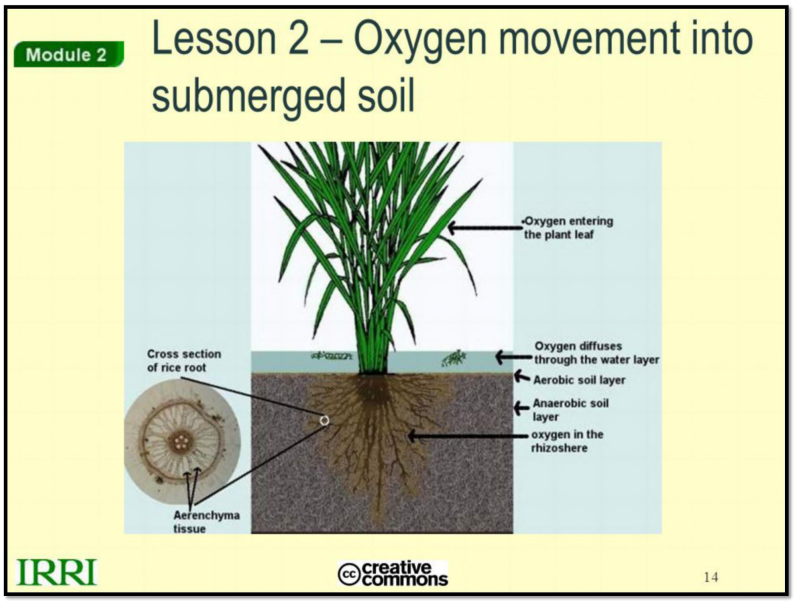


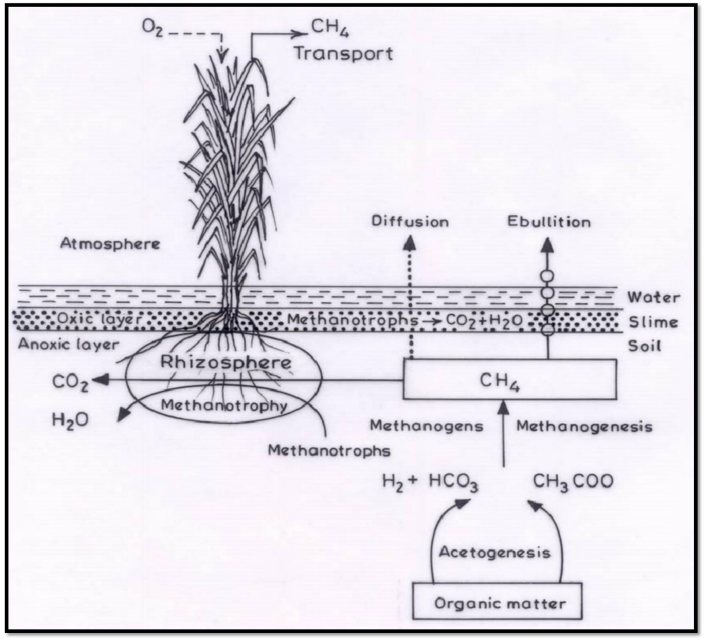
Fig. 22.1. Soil profile of a submerged soil.



- Increase in the supply of availability of N
- Increase in the availability of P, Si & Mo
- Decrease in the concentration of water soluble Zn & Cu
- Generation of Co_2, Methane (CH_4) & toxic reduction products such as organic acids and H_2S.

Sequential chemical changes that occur during submergence and puddling in rice

- Chemical reduction of soil, characterization of the oxidized & reduced zones and decrease in redox potential.
- Increase in pH of acid soils and a decrease in pH of sodic & calcareous soils.
- Reduction of ferric (Fe^{+3}) to Ferrous (Fe^{+2}) and Mn^{+4} to Mn^{+2}
- Reduction of NO_3 and NO_2 to N_2 and N_2O
- Reduction of SO_4^{-2} to SO_2^{2} i.e. extremely reduced conditions



Inputs for puddled transplanting rice

Seed rate: 25 kg/acre or 62.5 kg/ha

Spacing: 20 cm x 10 cm

No. of seedlings/hill: 2-3 seedlings/hill for 25-30 days aged seedlings

4-5 seedlings/hill for 35 days aged seedlings

Optimum population: 50 hills/m^2 area

Nutrients: 100:50:50 kg NPK ha^{-1}

Transplanting

- Transplanting of healthy seedlings may be done at 4-5 leaf stage or when they are about 20-25 cm in height @ 2-3 seedlings not deeper than 2-4 cm.
- Transplanting can be done in two ways.

1. Random transplanting
2. Straight row planting

Advantages of transplanting

1. A good levelling of the field is ensured.
2. Weeds are buried at the time of puddling and weed problem is reduced.
3. The plant population becomes more uniform.
4. The availability of most plant nutrients like P, Fe & K is increased and N is converted better.
5. Seedlings transplanted in soft puddle are able to establish themselves faster and start early tillering and growth.
6. Community nurseries facilitate timely transplanting.
7. The treatment of seedlings for nutrient deficiency and for plant protection against pests and diseases is facilitated before transplanting.

Community paddy nursery

Disadvantages of transplanting

1. It involves extra cost on seed bed preparation, plant protection, pulling and transplanting.
2. It needs higher amount of labour at a time when labour is in short supply.
3. It requires more quantity of water.
4. Seedlings are exposed to possible injury during handling.
5. Plants tend to grow more slowly than direct seeding because of recovery time after transplanting.
6. Harvesting is delayed.

Nutrient management

- **Recommended dosage:** 100:50:50 kg NPK ha^{-1}
- **Time of application:**

a. Basal dose: 50: 50:50 kg NPK ha^{-1}

b. Split dose: N should be applied in two stages

i)Tillering stage – 25 kg N ha^{-1}

ii) Panicle initiation stage – 25 kg ha^{-1}

Source of nutrients:

a. **FYM**
b. **Green manure**
c. **Azolla**
d. **Biofertilizers**
e. **Inorganic fertilizers (includes macro & micro nutrients)**

- Application of both organic and inorganic manures in combination found to be beneficial in improving the yield and soil fertility status in rice crop.

- **FYM + Inorganic fertilizers:**
- 10 tons of FYM ha^{-1} + 50:25:25 kg NPK ha^{-1}
- Well decomposed FYM should be applied one week prior to transplanting and should be incorporated in to the soil.

- **Green manuring + Inorganic fertilizers:**
- 5 tons of green manure ha^{-1} + 50:25:25 kg NPK ha^{-1}
- To obtain 5 ton biomass of green manure, we have to broadcast **25 kg seeds** of green manure crop *viz*., sunhemp or dhaincha per hectare
- Green manure crop should be incorporated to the soil at 45-60 days after sowing or at flowering stage, 2 weeks before transplanting.

Inorganic fertilizers alone:

100:50:50 kg NPK ha^{-1}.

Source of fertilizer:

Nitrogen – Urea, ammonium sulphate

Phosphorous – Single super phosphate (SSP), Rock phosphate.

Potassium – Muriate of potash (MOP)

- **DAP (Di-ammonium Phosphate)** is an excellent fertilizer for basal application in paddy fields.
- **Rock phosphate** can be used as a source of phosphorous in **acid soil** and it should not used in **neutral and alkaline soil.**

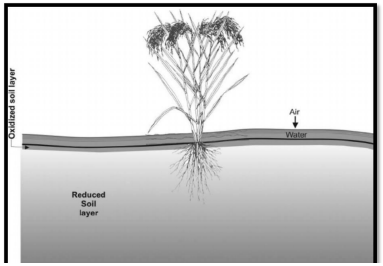
Method of application: Broadcast manually

Type of nitrogen fertilizer suitable:

- Puddling results in the conversion of the root zone of the soil from aerobic to anaerobic environment due to depletion of oxygen in the soil profile. The puddled soils develops two zones

a. **Oxidised zone:** It is the upper zone (1 – 10 mm thick) receives oxygen periodically from supply of irrigation water.

b. **Reduced zone:** It is the lower portion without oxygen.



- There are two types of nitrogen fertilizers

1. Ammonical nitrogen fertilizers: Urea, Ammonium sulphate.

2. Nitrate nitrogen fertilizer: Calcium ammonium nitrate (CAN)
   Ammonium sulphate nitrate (ASN)

- Ammonical form of fertilizers contain more nitrogen
- Less hygroscopic in nature
- Not readily available to the crops
- Takes more time for conversion in to nitrate form

Place of application of nitrogen fertilizers:

- When ammonical nitrogen fertilizers are applied to the paddy field, gets oxidised to nitrate form (NO_3^-) in the oxidised zone.
- This nitrate nitrogen in turn leaches down to the reduced zone and gets denitrified to gaseous nitrogen.
- This loss of nitrogen can be prevented by incorporating ammonical nitrogen in to the reduced zone of the soil before final puddling at 5 cm depth.

- The fertilizer containing nitrate such as CAN, ASN are more susceptible to loss of nitrogen through leaching and denitrification compared to ammonical form of nitrogen fertilizers containing no nitrate.
- The use of nitrate fertilizers should therefore be avoided in paddy.

Why ammonical nitrogen fertilizers are more suited for paddy cultivation?

- Rice is the only crop which can utilize the ammonical nitrogen.
- They are less readily available to plants than nitrate fertilizers. The ammonical nitrogen has to nitrify in the soil and be converted into nitrate before it can be taken up by plants.
- The ammonia in ammonium sulphate is fixed (adsorbed) by the soil immediately after application and it is not leached away like nitrates.
- Hence, this group of fertilizers may be used in basal application and top dressing.

How to reduce nitrogen loss in Rice?

- The efficiency of applied nitrogen in **paddy soils is nearly 40%.**
- Rest of the applied nitrogen is lost mainly through **leaching and denitrification.**
- These losses can be reduced by

(1) Delaying the nitrification process of nitrogen fertilizer by altering its granule size.

(2) Coating or treating of N fertilizer with different materials.

These are called as **slow releasing nitrogen fertilizers**

1. Use of pre-incubated urea:

- Mix urea with moist soil at the rate of **1 kg urea with 5 kg soil.** Allow this mixture to **stand in shade for 36-48 hours before applying in the field.**

2. Use of Mud balls:

- Prepare small balls of moist soil and putting urea or any other fertilisers in the centre of the ball.
- These balls can be used in the paddy fields where it is not possible to drain out the water from the field at the time of fertilizer application in standing crop

3. Use of neemseed cake:

- Finely grounded neem seed cake is mixed with urea at the rate of 15-20 per cent.
- These oil cakes delay nitrate formation from urea and thus reduces the denitrification and leaching.

3. Use of sulphur coated urea granules

4. Use of bigger urea granules.

5. Use of neem coated urea

Efficient management of N fertilizers in wetland rice

1. Proper puddling and levelling to reduce percolation loss of water and nutrients.
2. Apply right quantity at right time (i.e. split application) by right N fertilizers.
3. Deep placement of N fertilizer in reduced soils.
4. Use of slow release N or controlled release of N fertilizer.
5. Combining the concept of slow release and deep placement of N fertilizers.
6. Integrated use of organic manures (including green manures) and bio-fertilisers along with fertilizers
7. By following proper water management practices

Khaira Disease in rice (Zn deficiency)

- Zinc deficiency is the most common deficiency in wetland rice soils, next to nitrogen and phosphate deficiencies.

Reasons for Zn deficiency in lowland rice

- High pH (>7.0)
- Prolonged submergence and low redox potential
- High organic matter and bicarbonate content (HCO_3)
- High Mg : calcium ratio (absorption of Zn as $MgCO_3$ & $CaCO_3$)
- High available P
- decreased Zn uptake because of an increase in Iron (Fe), Ca, Mg, Copper (Cu), Manganese (Mn), and P after flooding.

- The deficiency of Zn is noticed in the rice crop after 2-3 weeks after transplanting.

Zn deficiency symptoms:

- uneven plant growth and poor tillering
- In the younger leaves especially base become chlorotic.
- Appearance of brown blotches and streaks on the lower leaves followed by stunted growth .
- The size of leaf blade is reduced but not leaf sheath
- white line sometimes appears along the leaf midrib

Management of Khaira disease:

- Use fertilizers that generate acidity (e.g., replace some urea with ammonium sulfate).
- Apply organic manure before seeding or transplanting or applied to the nursery seedbed a few days before transplanting.
- Drain out of water from the field periodically.
- Soil application of $ZnSO_4$ @ 8 kg ha^{-1} once after 3 crops.
- By dipping the seedlings in 2% suspension of ZnO for 15 minutes before transplanting.
- Foliar spray of Zn @1%
- Growing of varieties tolerant to Zn deficiency eg: IR8, 28, 30 & 34.

Zinc Deficiency Shown by Reduced Tillering, Chlorosis in the Leaves, and Reduced Plant Size (Mature Rice Plants Are Only about 50-80 CM High).

Iron deficiency in rice

- Iron deficiency is more common in upland, high pH and aerobic soil.
- The main reason for Fe deficiency is low concentration of iron in upland soil, coarse textured soils and lowland soil with very low organic matter content.
- Soils with the pH of more than 6.5 are likely to be deficient in available sulphur.

Deficiency symptom:

- Interveinal chlorosis of emerging leaves
- less dry matter production
- stunted growth with narrow leaves

Control measures:

- Soil application of $FeSO_4$ @ 25 kg ha^{-1}
- Foliar spray of $FeSO_4$ @ 1-3% solution

Iron toxicity

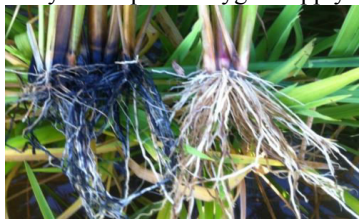
- Fe toxicity occurs on a wide range of soils, but generally in lowland rice soils with permanent flooding and in acid soils.
- Iron toxicity is caused by toxic effects of excessive iron uptake due to large concentration of iron in soil solution.
- Iron toxicity leads to **Akiochi disease in rice.**

Symptom:

- Tiny brown spots on lower leaves, starting from tip and spread towards the base of the leaf, and leaves turn from **yellow to orange brown and die.**
- Root starts rotting and turns in to black color.

Management of Iron Toxicity:

- Incorporate lime in the topsoil to raise pH in acid soils
- Apply additional K, Phosphorus, and Magnesium fertilizers
- Incorporate about 100−200 kg MnO_2 ha^{-1} in the topsoil to decrease Fe^{3+} reduction.
- Carry out midseason drainage to remove accumulated Fe^{2+} at the mid-tillering stage (25−30 days after planting/sowing)
- Drain the field and keep it free of floodwater (but moist) for about 7−10 days to improve oxygen supply during tillering



Water Management

- The water requirement of rice is not same throughout the crop period.
- It requires small quantities of water in the early stages, gradually increases its water requirement at flowering and early maturing stage and then decreases to the lowest at later stages of crop growth.
- Hence, scheduling irrigation to meet the crop water demands at different stages is very important.

- The water requirement of the rice crop varies from 150-250 cm.
- To produce **one kg of rice** on an average **5000 litre of water is required**
- Water requirement depends on - soil
  - climate,
  - season and
  - variety.
- The critical stages of rice crop for irrigation is

1. Tillering
2. Panicle initiation
3. Booting
4. Flowering
5. Milking stage

Depth of water to be maintained:

- Transplanting to panicle initiation stage 2-3 cm depth
- Panicle initiation to milking stage 5 cm depth
- Water from the rice field should be drain out once crop reaches dough stage.

Mid season drainage

- Drainage for a period of 5 to 7 days during the beginning of maximum tillering stage.
- This helps to stimulate the vigorous growth of roots and checks the development of non effective tillers by supplying oxygen in to root system.

- Moisture stress at active tillering phase - 30% yield reduction
- Moisture stress at reproductive phase - 50 - 60% yield reduction

Management of percolation losses in rice fields

This can be reduced by

1. Growing rice on clayey soil
2. Scrupulous land levelling
3. Thorough puddling
4. Shallow depth of submergence
5. Sub soil compaction

- Percolation rate of **5mm/day** is found to be favourable to for supply of dissolve oxygen , removal of harmful substances and maintenance of root activity

Weed management in transplanted puddled rice

- The critical period of crop weed competition in rice is up to 15-45 days after transplanting.
- Competition of weeds in transplanted rice causes 20-30% yield reduction.
- Integrated weed management approach is found to be better in transplanted puddled rice.

- The major weed flora in transplanted puddled rice are categorised in to mono cots, dicots and sedges

Echinochloa colona

Echinochloa crussgalli

Cyperus irria

Cyperus difformis

Integrated weed management

1. Cultural Methods:

a. Following good crop husbandry practices like

- good land preparation
- seed bed preparation
- method of sowing
- Spacing

2. Puddling of soil during transplanting to control *cynadon* and *cyperus*

3. Flooding of rice fields during crop growth period will reduces the germination of weed seeds.

4. Manual hand weeding at 20 and 50 days after transplanting

II. Chemical method: it includes application of pre and post emergence application of herbicides

Pre-emergent herbicides: 2-3 days after transplanting

1. Butachlor 5% g @12 kg acre^{-1}
2. Butachlor 50%EC @ 0.8 lt per acre (mixing with 30 kg sand and should be applied to main field)
3. Anilophos 30% EC @ 0.5 litre in 200 litre of water per acre (if intensity of *Echinochloa* is more)
4. Pyrazosulfuran ethyl 10% WP @ 100 g per acre
5. **Londax power:** Bensulfuron methyl (0.6g) + pretilachlor (0.6% g) @ 4 kg per acre

Post emergent herbicides: 3-4 leaf stage of weeds (15-20 DAT)

- 2,4-D 80% WP @ 1 kg in 200 lt of water per acre
- Propanil 35% EC @ 3 litre in 200 lt of water per acre
- Bispysibac sodium 10% SC @ 100 ml in 200 lt of water per acre

- Bispyribac sodium is a contact herbicides applied as a post emergent herbicide. It has to be applied completely on the foliage of the weeds properly or else its efficiency will be reduced

Introduction

- System of Rice Intensification (SRI) is special method of rice cultivation originally developed at Madagascar in 1983.
- It was not known outside Madagaskar till 1997. In 2000 it is introduced in India.
- In SRI method, fundamental cultivation practices remain more or less same but there is a changes in agronomic practices *viz*., nursery management, time of transplanting and management of water, nutrients and weeds.

Why System of Rice Intensification?

- Depletion of water resources.
- Stagnating rice productivity.
- Increased importance of organic agriculture.
- Increasing production costs.
- Need best utilization of family labour for small and marginal farmers.

6 basic principles of SRI

1. Young-aged seedlings
2. Careful single seedling transplanting
3. Wider spacing
4. Water management
5. Weeding
6. Compost/organic manuring.

Nursery Management

1. Field Nursery:

- For raising seedlings for one acre **40 m² area is required.**
- **40 m² area** is divided in to **4 seed bed,** each seed bed with the dimension of **1 m width x 10 m length.**

- On each seed bed, **2 to 3 cm** depth of **well decomposed FYM** should be applied uniformly.

- For raising seedling for **one acre area**, **2 kg seed is required.**
- For each seed bed, **500 g of seeds are distributed uniformly.**

- After seeds are sown in the seed bed, again **2-3 cm of FYM should be spread on the seed bed.**
- Later each seed bed should be **covered with paddy straw** and **should be irrigated with rose cans 2 times in a day for 5- 6 days to maintain optimum soil moisture condition.**

- **After 4-5 days, paddy straw should be removed from the seed bed** and **gentle irrigation should be given.**

- **After 12 days, healthy** seedlings are ready for transplanting from seed bed.

2. Tray nursery:

- If farmers found any difficulty for raising seedling in field condition, **then they can grow seedling in trays.**
- For raising seedlings for one acre area, **20-25 trays are needed.**
- The dimension of each tray is **50 cm x 20 cm.**
- Foe each trays, **80 g of seeds** should be sown.

Land preparation

- At the early stage of land preparation, deep ploughing should be done once, to loosen the soil and to remove weeds.
- Then harrowing should be done for 2-3 times for levelling and to break clods.
- Puddling should be done finally in the presence of water.

Land preparation

- At the early stage of land preparation, deep ploughing should be done once, to loosen the soil and to remove weeds.
- Then harrowing should be done for 2-3 times for levelling and to break clods.
- Puddling should be done finally in the presence of water.

- After final puddling and before transplanting, **30 cm irrigation channel** should be open for every **2 m width in the main field.**

Then, **25 cm x 25 cm or 30 cm x 30 cm square** marking should be done in the main field by using **Iron rake or by wooden marker.**

- **12 days old seedlings** from the seed bed should be uprooted very carefully in such a way that, **each seedling should be in contact with seed, roots and soil.**

- After seedling uprooting, only **one seedling should be transplanted in each hill very care fully** with out damaging the seed, roots and soil.
- Soil should be at saturated condition at transplanting (no standing water)

Nutrient Management

RDF : 100-50-50 kg NPK ha^{-1}

- **10 t of FYM or 5 t of green manure** should be applied 2-3 week before transplanting.
- At the time of transplanting, 50 % recommended N & K and full dose of P should be applied as basal dose.
- The remaining 25% of N should be applied at 30 DAT (at tillering stage).
- The remaining **25% N** and 50% of K should be applied at **60 DAT (at panicle initiation stage).**

Weed management

- The critical period of crop weed competition is **15-45 DAT.**
- Since moisture is maintained at **saturation condition** throughout the crop growth period, **intensity of weed for natural resource competition is more.**
- As compared to **chemical method of weed control**, weeding with **manually or machine operated cono-rotary weedor** is found to be **more superior and advantageous** in SRI method of rice cultivation.




- Weeding should be done by using cono-rotary weeder for five times *i.e.* 12, 24, 36, 48 and 60 DAT.


Advantages of cono-rotary weedor in SRI

- Weeding with cono-weedor helps in aeration, which helps in increasing root biomass and more nutrient and water uptake, which results in production of more number of tillers/hill (30-50 tillers/hill).
- No. of productive tillers is more in SRI method as compared to puddled transplanted rice.
- In puddled transplanted rice cultivation decaying of roots takes place after 50 DAT, which leads to lesser number of productive tillers and decreases water and nutrient uptake leading to lower test weight and more chaffy grains.

Pre-emergent herbicide: (3-5 DAT)

- **Londax power:** Bensulfuron methyl (0.6g) + pretilachlor (0.6% g) @ 4 kg per acre

Post emergent herbicide: (20 DAT)

- Bispysibac sodium 10% SC @ 100 ml in 200 lt of water per acre

Water Management

- After transplanting, field should be irrigated very lightly (maintain saturation point) for every 2-3 days throughout the crop growth period.
- Moisture should be maintained in such a way that there should not be any hair line cracks in the soil and also their should not be stagnation of water in the field.
- Alternate wetting and drying should be followed.
- In this way, we can able to save **45-50% of water.**




Plant Protection

- Incidence of pest and diseases in SRI method of rice cultivation is very less as compared to puddled transplanted method of rice cultivation.
- If any pest and diseases is found to be beyond economic threshold level suitable plant protection measure should be taken as per the suitable recommendations.

Harvesting and Yield

- In SRI method of rice cultivation, **crop will mature 10 days early** as compared to **transplanted puddled rice.**
- In SRI method of rice cultivation, their will be **increase in the yield up to 15-20%** as compared to puddled transplanted rice.

Difference between SRI and puddled rice

SRI	Puddled Transplanting
➢12 days old seedlings are transplanted	➢25-30 days old seedlings are transplanted
➢Single seedlings are transplanted/hill	➢3-4 seedlings are transplanted/hill
➢Inter and intra row spacing is followed (25x25cm)	➢Proper spacing is not followed
➢More application of organic manures	➢Less application of organic manures
➢Water is maintained at saturation point	➢5 cm height of water is allowed to stand
➢More no. of tillers and productive tillers/hill	➢Less no. of tillers and productive tillers/hill

Advantages of SRI method of rice cultivation

- Higher grain yield and straw yield (15-20%)
- Reduction in crop duration by 10 days
- Lesser seed rate (2 kg/acre)
- Savings in water requirement up to 45-50%
- More no. of productive tillers
- More use of organic manures
- Lesser chaffy grains
- Improvement in soil health through biological activity
- Reduction in methane emission

DSR: Direct seeded rice cultivation

In DSR 2 types of transplanting

1. **Direct seeded rice in wet condition**: **Drum Seeding Rice**

- Puddling is followed
- Seedlings are not raised in nursery
- Pre-germinated seeds are directly sown in the field using seed drill.
- All the other agronomic practices remain similar as that of transplanted puddled rice cultivation.

Advantages of DSR:

- This method is popularly adopted in the areas of acute labour shortage for transplanting.
- Puddling and transplanting can be completed in a single day without wasting time for nursery.
- Timely sowing is possible
- Crop matures 10 days earlier as compared to transplanted rice.
- 10-15 per cent water can be saved.
- Rice yield can be increased by 5-10%.

Inputs:

- **Seed rate – 25-30 kg/ ha.**
- Seeds should be soaked in water for 24 hr.
- The pre soaked seeds should be treated with carbendazim @ 4g/ kg seed.
- The treated seed should be filled in wet gunny bag, tied loosely and maintained in warm condition for 24 hr.
- Then the pre-germinated seeds should be filled in four drums of the drum seeder.

Land preparation:

- Puddling should be done and excess water should be removed and maintained soft muddy layer.

Water management:

- up to 10 days after seeding, water should not be stagnated and it should not dry. Soil should be maintained at saturation point. Stagnation of water immediately after sowing leads to rotting of seeds.
- After 15 days, as like in the puddled transplanted rice, water should be maintained at 2cm depth up to tillering stage and after tillering depth should be increased up to 5 cm.

Weed management:

- Weeds compete with rice seedlings in the very early stage of the crop growth and reduces the yield subsequently.
- It is necessary to go for 2 hand weeding at 20 days and 40 days after sowing.
- Application of pre-emergent herbicide at 3-5 DAS and post emergent herbicide at 15-20 DAS is found to be promising.

2. Direct seeded rice in dry condition: Aerobic rice cultivation

- Dry seeds are directly dibbled in the rows.
- Puddling is not followed
- No need of raising nursery beds
- Irrigation is provided once in 3-5 days to maintain moisture at field capacity.

- If rice grown under dry condition with assured irrigation is called as aerobic rice cultivation.

- If rice grown under dry condition without assured irrigation and completely depended on rainfall, it is called as Rainfed upland rice cultivation.

Cultivation aspects of Aerobic rice

Land preparation:

- Land is ploughed 2 to 3 times, clods were broken and levelled using harrow and soil should be in fine tilth condition.

Inputs:

- **FYM:** 10 t/ha.
- **Seed rate:** 8-10 kg/ha.
- **Fertilizers:** 100:50:50 kg NPK/ha.

Sowing:

- Dry seeds are dibbled in a row spacing of 25 cm or 30 cm.
- Line sowing could also be done using seed drill.
- After sowing, land should be irrigated uniformly to ensure enough soil moisture during germination.

Varieties/ Hybrids:

- All the varieties and hybrids growing under puddled transplanted condition are suitable for growing under aerobic condition.
- **Aerobic rice varieties:** MAS 946-1, MAS-26.

Season of sowing:

- Aerobic rice can be sown up to **end of July** for obtaining optimum yield.
- If sowing is done after **first fort night of august**, the panicle initiation stage is coincide with the low temperature during November and December, which affect the heading, flowering and pollination of the crop and resulted in poor yield because of more chaffy grains.

Water management:

- In aerobic rice cultivation, crop can be irrigated through surface irrigation or through drip.
- If surface irrigation is followed, crop should be irrigated once in 3-4 days to maintain soil moisture at field capacity.
- If irrigation is scheduled through drip, crop should be irrigate once in two days for a period of 2-3 hours.

Nutrient management:

- 10 t of FYM is applied 3 weeks prior to sowing.
- 50 % recommended N and full dose of P & K should be applied in the rows and should be mix properly before dibbling of seed.
- Remaining 50% of N should be applied at tillering and panicle initiation stage.

Micronutrient management:

- In aerobic rice cultivation **deficiency of Zn and Fe is more common.**
- Soil application of **$ZnSO_4$ @ 8 kg/acre.**
- Foliar spray of **$Fe(SO4)_2$ at 0.5%.**

Advantages of aerobic rice:

- 10-15% higher grain yield due to more number of tillers per hill (>50)
- 55-60% water saving
- Increased water productivity
- Decreased consumption of inputs like water, nutrients, energy and labour
- Less or no impact on environment by reduced methane emission.

Weed Management:

- Weed infestation is seviour during early stage of the crop in aerobic situation.
- Passing of cono-rotary weeders could be used to control weeds apart from loosening the soil in initial stage of the crop.

Pre-emergent:

- Pyrazosulfuron ethyl (10%) @ 1 g per litre of water.
- Londax power @ 10 kg/ha @ 2-3 days after sowing.

Post emergent:

- Byspiribac sodium (10%) @0.08 litre/ha at 15-20 DAS.

Targeted areas of Aerobic rice:

- Uplands
- Undulating rainfed lowlands
- Water short irrigated lowlands.

Rice production in saline and sodic soils

Saline soils: pH – 7.5 to 8.5

ESP - < 15%

Sodic soils: pH - > 8.5

ESP - > 15% (dominated with sodium carbonate and sodium bi-carbonates)


Management of saline and sodic soils

1. Soil management:

- Providing proper drainage
- Application of FYM or growing of green manure crops and incorporation in to soil
- Application of Gypsum ($CaSo_4$) based on soil test value 2 weeks prior to transplanting.
- Application of 25% extra recommended dose of nitrogen and phosphorous. (Ammonical N fertilizers are preferred)
- Soil application of $ZnSO_4$ @ 8 kg/acre


2. Crop Management:

- Planting of 30-35 days age old seedlings
- Planting of 5-6 seedlings/hill
- Planting at closer spacing 15 cm x 10 cm to maintained optimum plant population.
- Use of saline tolerant rice varieties: Prakash, Rashi, Mangala, Vikas and IR-30864


3. Water management:

- Flooding the land with fresh water once in 15 days and providing proper drainage.
- Providing proper drainage all along the field for leaching out the excess salts from the field.

Varietal development in rice

➢**TN-1 (Taichung Native)** was developed after II World War in Taiwan.

T.N.-1 = **Dee-geo-woo-gen** x **Tasai Yung Chung**

(Taichung Native) (Dwarf & N responsive) (Tall & drought resistance)

➢**Dr. T. T. Chang** brought **TN-1**, Dee-geo-woo-gen from Taiwan to IRRI, Manila.

➢First time in India, **T.N.-1** was introduced by G. V. Chalam from IRRI in 1964-65.

- Breeder **Henry M. Beachell** at IRRI, Manilla developed another rice variety **IR-8.**

IR-8 = **Dee-geo-woo-gen** x **Peta** **(from indonesia)**

- **IR-8** was introduced in **India in 1966** and **IR-8 out yielded TN-1.**

- The literally meaning of Dee-geo-woo-gen is **"Brown tipped short legged".**

- **Dr. Shastry**, developed first rice variety under Indian rice programme **"JAYA"**.

Jaya = **T. N.**-1 (from Taiwan) x **T-141** (Indian Variety)

- **Jaya Variety** out yielded T.N.-1 & IR-8 both varieties, hence it is called as **"Miracle Rice" in India**.
- **"Jagannath"** is the Mutant variety of **T-141.**
- **"Padma"** is the reverse cross product of the parent of **Jaya.**

CR-1014 = **T-90** x **Urang Urangan**

(Indica) **(Javanica)**

- **CR-1014** was released in **1988**, popular in **Orissa, AP & West Bengal,** it is super fine grain variety, suitable under **submerged condition in semi-deep water regime.**

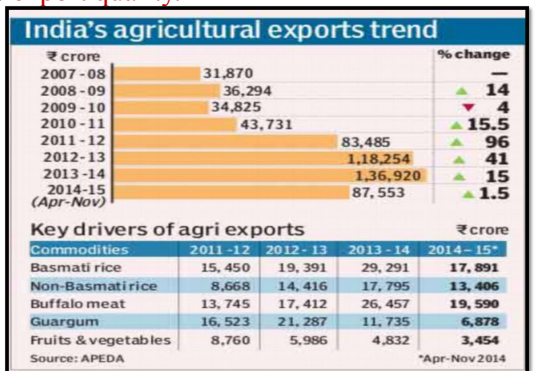
- **Pusa Basmati-1** is the world's first high yielding dwarf variety under quality rice has been developed by IARI through convergent breeding.

Aromatic (Scented) rice: (includes both basmati and non basmati varieties)

- Pusa Basmati-1, Sabarmati, Basmati-370, Basmati-385, Haryana Basmati-1.
- Basmati rice varieties are different to other rice varieties because of its **Aroma.**
- This aroma in Basmati rice is due to the presence of the chemical **2-acetyl-1-pyrroline,** which is found in basmati rice at **about 90 parts per billion.**

Non Basmati super fine rice:

- IR-64, PR-106, Gaurav & Punjab No.-1.
- Among all the agricultural produce, **Basmati rice** is the only agricultural produce which earning highest foreign returns to India due to its export quality.



Ruling rice varieties from UAS, Bangalore

Broadly rice varieties are classified in to

- Long duration varieties : 140-145 days
- Medium duration varieties : 130-135 days
- Short duration varieties : 120-125 days

Long duration rice varieties				
Name of the varieties	Duration (days)	Sowing time	Yield potential (q/acre)	Special characters
BR-2655	140-145	July	24-26	➢Resistant to blast disease
Jaya	140-145	July	22-24	➢ Tasty rice, less P&D
Mandya Vijaya	140-145	July	20-22	➢Susceptible to blast, ➢fine quality rice grain
Prakash	140-145	July	20-22	➢Saline tolerant variety

Medium duration rice varieties				
Name of the varieties	Duration (days)	Sowing time	Yield potential (q/acre)	Special characters
Tanu (KMP 101)	130-135	Ist week of August	18-20	➢More straw yield
MTU 1001	130-135	Ist week of August	18-20	➢Coarse grain
IR 20	130-135	Ist week of August	18-20	-
IR 30864	130-135	Ist week of August	18-20	-
IET 7575	130-135	Ist week of August	18-20	➢Suitable for summer season

Shorter duration rice varieties				
Name of the varieties	Duration (days)	Sowing time	Yield potential (q/acre)	Special characters
Raksha (KMP 105)	110-115	3rd week of August	18-20	-
MTU 1010	120-125	3rd week of August	18-20	-
Rasi	120-125	3rd week of August	18-20	-
Mangala	120-125	3rd week of August	18-20	Saline tolerant

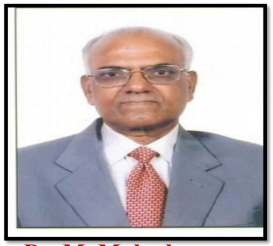
Late season rice varieties				
Name of the varieties	Duration (days)	Sowing time	Yield potential (q/acre)	Special characters
Rasi	110-115	1st week of september	18-20	-
Raksha	110-115	1st week of september	18-20	-
Mangala	110-115	1st week of september	16-18	-
Jyothi	115-120	1st week of september	18-20	Red Kernal Rice

Hybrid rice varieties				
Name of the varieties	Duration (days)	Sowing time	Yield potential (q/acre)	Special characters
KRH-2	120-125	Ist week of August	28-30	Slightly Aroma
KRH-4	130-135	Ist week of August	30-35	High yielding

Hybrid rice production


Performance of UASB KRH-4 at Darasaguppe Village, Srirangapatna Tq

- Seed rate: 6-8 kg/acre or 15-20 kg/ha
- Spacing: 15 x 15 cm
- FYM: 10 t/ha
- Green manure: 5 t/ha
- NPK: 125: 62.5: 62.5 kg/ha (*kharif*)
  150: 80: 80 kg/ha (Summer)
- In Summer season, all the rice varieties and hybrids matures 8-10 days late as compared to *kharif* season.
- However, rice yield are more in summer season as compared to *kharif* season.



Dr. M. Mahadevappa,

- popularly known as *Rice Mahadevappa* is an Indian Agricultural Scientist and Plant Breedor, renowned for developing high yielding hybrid varieties of rice.
- He is the recipient of **'Padma Bushan'** India's third highest civilian honour and various other accolades.
- Released KRH-1 & KRH-2, at national level.
- Developed **first rice male-steriles/hybrids** giving impetus to Hybrid Research in India.

Harvesting of rice:

- Turning the crop colour from green to yellow is the general symptom of maturity.
- At this stage, the grain starts maturing from top to bottom of the panicle.
- About a week prior to harvest of the crop, the water is let out from the field completely.



- For shattering varieties, crop should be harvested before panicle is fully dried.
- At the time of harvest, some of the grains at the base of the earhead will be green. If it is fully riped, the rice gets broken during milling.

- Harvesting of rice is done either manually or through combined harvester.


Yield:

- It varies from season to season, and variety to variety besides several other factors. While the average yields vary from **4-5 tons/ha for varieties and 8-10 t/ha for hybrids during kharif.**
- A minimum of **1 more tonne** can be expected during **rabi for HYV.**

Processing of rice

- Processing of rice usually involves milling and polishing.
- **Milling:** The outermost layer of rice called the **hull** is removed to make **brown rice.** Brown rice is rice with the whole kernel intact is still surrounded by all layers of bran.
- **Polishing:** removal of aleurone layer that remains on the rice. This step is called **polishing.** Polished rice is called as **White rice.**
- The bran, germ, and aleurone layers of rice contain most of the fat content found in rice and are the source of fat-soluble vitamins like vitamin E as well as many other nutrients.

Hulling/ milling percentage:

Hulling % = (weight of rice / weight of paddy grains) x 100

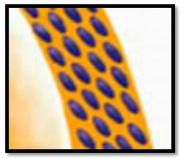
- Hulling percentage in rice is **65-75%**

By products of rice:

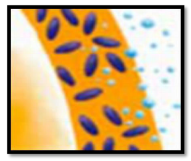
1. Husk: used as cheap fuel and bedding in poultry houses under deep litter system.

2. Rice bran: contains 12- 14% rice bran oil (Branola) prescribed for heart patients.

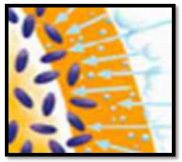
1. Raw paddy rice



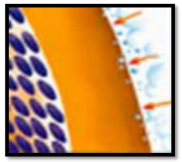
2. Vitamins and minerals in the bran.



3. Soaking in warm water, the nutrients become more soluble and move out of the bran.



4. To move these nutrients into the kernel, hot steam and air pressure are used, otherwise they would rinse out into the water.



5. Parboiled rice carries 80% of the nutrients of brown rice.

PARBOILING

- A hydrothermal treatment of rice grain immediately after drying prior to milling to prepare parboiled grains is called **parboiling.**
- The soaking of a rice grain in hot water results in swelling of the starch granules.
- Soaking in hot water weakens the granule structure by breaking the hydrogen bond which consequently provides a larger surface for the absorption of water by the starch granules. The whole process is called **gelatinization.**
- Later on, moist heating is done to provide the irreversible swelling or the fusion of the starch granules.
- Steam is used for moist heating called **steam rice.**

Advantages of parboiling

- The percentage of broken grains is reduced
- More nutritious than raw rice
- Renders more resistant to insects during storage.
- Loss of solids in gruel is less than raw rice during cooking.
- The bran from parboiled rice contains higher oil content.

Disadvantages

- Parboiled rice takes more time to cook.
- Common rice consumer may not like the flavour and colour of the par boiled rice.
- Parboiled rice may contain higher moisture content and some mycotoxins may develop.
- The milling cost of parboiled rice is higher since the shelled grains are comparatively harder.

YIELD & YIELD ESTIMATES OF RICE

- Yield of rice in a given field condition can be estimated by the following parameters

1. No. of panicles/m^2
2. Average no. of grains per panicle
3. Percentage of filled grains
4. Weight of the grain (test weight)

(Yield/m^2 = 1 x 2 x 3 x 4)

Reasons for low yield in rice

- Widely varying climatic conditions under which rice is grown.
- Inefficient utilization of applied N.
- Limited scope for optimum water management in heavy rainfall areas.
- Cloudiness and its ill effects on the photosynthetic activity of rice in monsoon (80% of the season is cloudy during kharif)
- Adverse effects of soil salinity or alkalinity
- Susceptibility to heavy incidence of pests and diseases which tend to increase under ideal crop conditions.
- Little scope for rainfed upland rice to achieve its yield potential fully due to short growing season and practically no control over time of transplantation in assured rainfall areas without irrigation facilities.
- Indiscriminate use of fertilizers.
- Monoculture rice farming
- Poor drainage

Measures to improve the yield

- Tailoring new varieties which can effectively photosynthesize even under low light intensity. Eg : IET 9354, Vijaya.
- Integrated pest and disease management practices
- Growing varieties tolerant to salinity and drought. Eg: Prakash, mangala, vijaya.
- Increasing cropping intensity through early maturing modern rice varieties.
- Adopting best agronomical practices like adjusting the date of planting in a given locality in such a way that the last 6 weeks of a variety pass through cloud free days.
- Practicing integrated weed and nutrient management practices.

Bio-fertilizer application

- The bio-fertilizer suitable for rice cultivation is **Azospirillum.**
- Azospirillum can be applied in three forms

1. Seed treatment
2. Soil application
3. Root treatment

I. Seed treatment (Direct seed rice):

1. 50 g of Jaggery should be mixed in 500 ml of water and the mixture should be boiled for 5-10 min.
2. Jaggery solution should be sprinkled on the 25 kg of the seed, later 400 g of Azospirillum should be mixed.
3. The treated seed should be dried in shade for 30 min.


Seed treatment with biofertilizer

II. Soil Application:

- 800 g of Azospirillum should be mixed with 10 kg of well decomposed FYM and 10 kg of Soil and applied to the field.

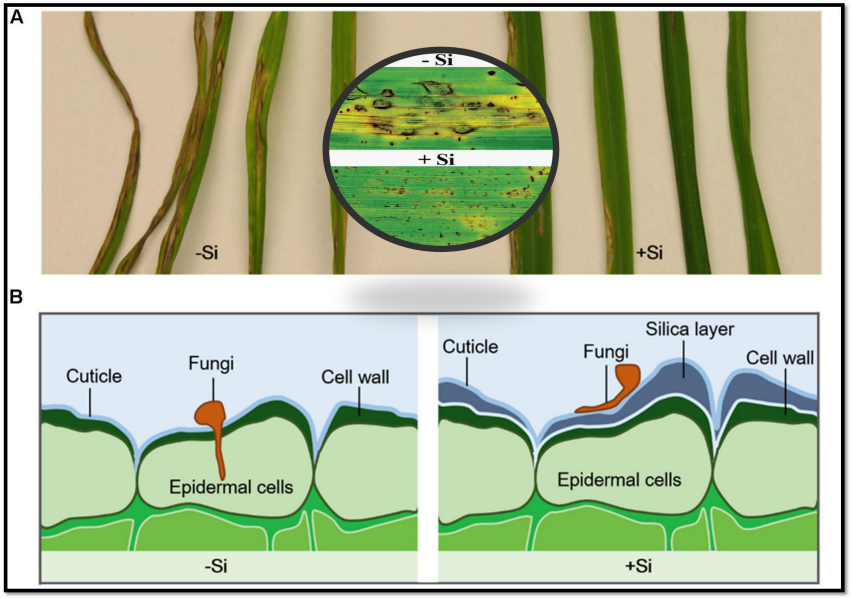

Soil application of biofertilizer

III. Root treatment:

- 6 ft length and 6 ft width of bed should be prepared and 4 inch of water should be allowed to stand.
- In this area, 400 g of Azospirillum is mixed with water and seedlings are immersed in the bed for 10-15 minutes before transplanting.

Role of silicon nutrition in Rice

- Rice is a **high silicon accumulating plant.**
- Si is a **beneficial element for plant growth** and **not a essential element** but it is **agronomically essential for improving and sustaining rice productivity.**
- Silicon is absorbed as **monosilicic acid** by rice plants in **larger quantities than the macronutrients**, for example, **silicon uptake is 108% greater than Nitrogen (N) uptake.**
- A rice crop producing a yield of **5000 kg.ha^{-1}** removes **230-470 kg Si ha $^{-1}$.**
- Si increases the **mechanical strength of the stem**, thus **reducing crop lodging.**
- Besides rice yield increase, Si has many fold advantages of **increasing nutrient availability (N, P, K, Ca, Mg, S, Zn).**
- It **decreases the nutrient toxicity (Fe, Mn, P, Al)** and **minimizing biotic and abiotic stress in plants.**
- **It reduces oxidative stress** and it help **in alleviating salt damage.**
- It will reduces the **incidence of occurrence of blast disease in rice plant.**
- **It reduces the insect attack in rice crop.**



Silicon deficiency leads to:

1. Soft and droopy leaves which cause lodging and mutual shading.
2. Reduced photosynthetic activity.
3. Reduced grain yields.
4. Increased occurrence of diseases such as blast.
5. Reduced number of panicles and filled spikelet's per panicle

- Silicon deficiency is **not very common in irrigated rice.**
- It occurs in areas with **poor soil fertility, and is common in old and degraded paddy soils.**
- It also occurs **in organic soils with small mineral Si reserves**, and in **highly weathered and leached tropical soils in the rainfed lowland and upland areas.**

Management:

- recycling of rice straw (5−6% Si) and rice husks (10% Si).
- Application of Ca silicate: 120–200 kg/ha; K silicate: 40–60 kg/ha for rapid correction.
- Foliar spray of Si @0.1-0.2% with sodium silicate improve Si nutrition.

- Maize is one of the **important cereal crops** in the world's **agricultural economy** both as **food for men and feed for animals**, because of its **higher yield potential** compared to other cereals. Hence it is called as **"Queen of Cereals".**

Classification of maize

- Classification is mainly based on the **character of the kernels** and mainly related to **type of starch (hard v/s soft) in grains.**
- It is classified in to 7 groups

1. Flint corn – *Zea mays indurata* (all hard)

- **Starchy endosperm enclosed with hard kernal.**
- Kernel size is **large with flat bottom and round at the top.**
- **High proportion of starch.**
- Colour may be white or yellow.
- This is the type **mostly grown in India.**

2. Dent corn – *Zea mays indentata* (Soft centre)

- Kernels is having both **hard and soft starches.**
- **Soft starches is in the centre of kernel** but **hard starch extends on the sides.**
- **Depression or dent in the crown on the seed** is the result of **drying and shrinkage of soft starch.**
- This type is widely grown in **USA**

3. Pop corn – *Zea mays averta* (core of soft)

- **Kernel size is small.**
- Presence of **soft endosperm at the core of the seed.**

4. Sweet corn – *Zea mays Saccharata*

- The **sugar and starch** make the **major components of the endosperm** that results in **sweet taste of kernels.**
- It is mainly grown in **USA.**
- The cobs are picked up green for **canning and table purpose.**

5. Flour corn – *Zea mays amylaceae* (all soft)

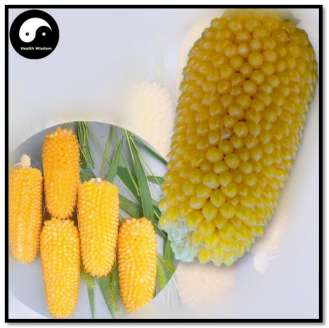
- The grain appears **flint corn.**
- The grains are composed of **soft starch** and have **little or no dent** are called as **"Soft Corn".**
- It is widely grown in **USA and South Africa.**

6. Pod corn – Zea mays tunicata (husk like glumes)

- Each kernel is enclosed in a **pod or husk in an ear.**

7. Waxy corn – *Zea mays cerabina*

- The kernel looks to have **waxy appearance and gummy starch** in them, **because of amylopectin.**
- The starch is similar to that of **Tapioca starch for making adhesive for articles.**



Origin of Maize

- **Mexico and Central America.**

CIMMYT: International Centre for the Improvement of Maize and Wheat.

- It is located at **Mexico.**

Economic importance and uses

- Most important cereal crop in the world's agriculture economy. 85% is consumed as human food.
- Green cobs are roasted and eaten by the people.
- Corn has low fibre content, more carbohydrate and most palatable.
- Widely used in preparation of cattle feed and poultry feed.
- It can be used as a green fodder. It has no HCN content.
- Can be preserved as silage.
- Food products: Corn meal, corn flakes.

- **Industrial products:** Alcohol, Corn Starch (Dextrose), glucose, corn oil, corn syrup.
- Used in canning industry, production of polymer, making paper.
- Maize grain contains

Protein – 10%

Oil – 4%

Crude fibre – 2.3%

Carbohydrate – 70%

Albuminoides – 10.4%

- Maize protein **"Zein"** is deficit in two amino acids *viz.*, **Lysine and Tryptophan.**
- Maize has a significant quantity of **Vitamin – A, nicotinic acid, riboflavin and Vitamin E.**
- Maize is **low in Calcium** but **fairly high in "P".**

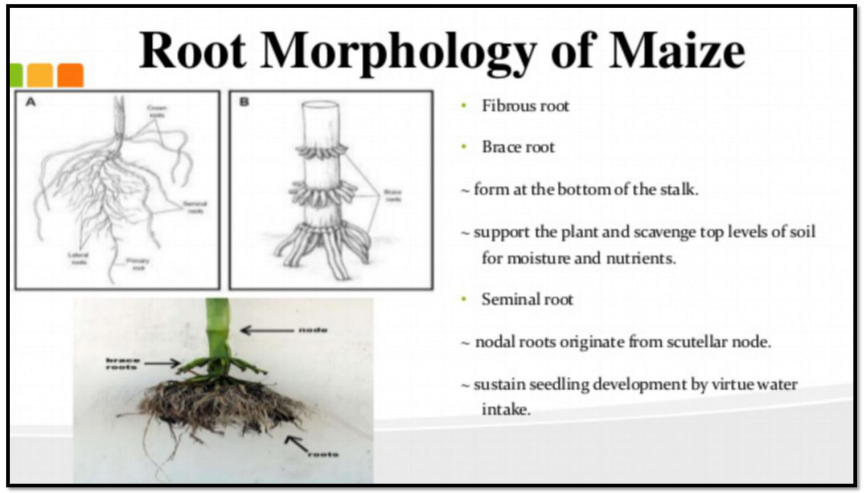
Climatic requirements

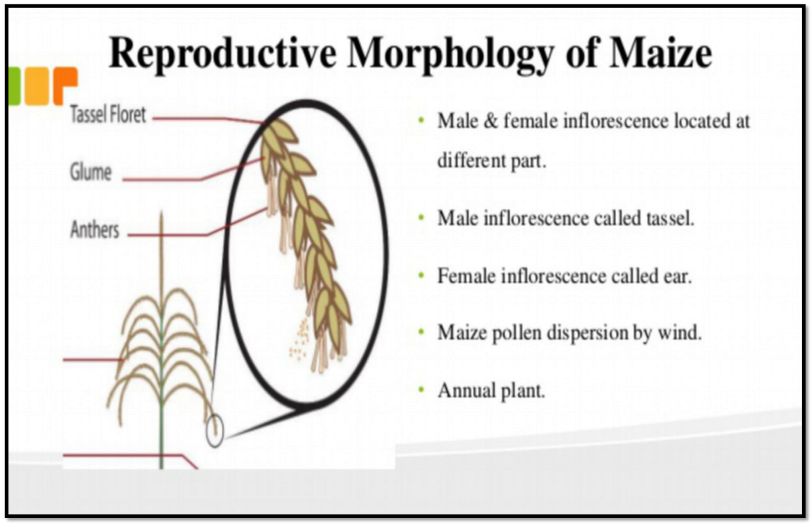
- It is essentially a **tropical crop.**
- It is a **C_4 short day plant.**
- Though it is a tropical crop, it has got **high adaptability to wider climate 55^0 N to 45^0 S.**
- It can be grown up to **2500 m above MSL.**
- Maize requires **moist and warm weather from germination to flowering.**
- Optimum temperature for germination is **21^0 C** and for growth is **32^0 C.**
- **500-750 mm** rainfall with well distributed is ideal for proper growth.

- Extremely **high temperature** and **low RH** at **flowering, desiccate the pollen resulting in poor pollen grain formation.**
- **Temp. > 35⁰ C** reduces the **pollen germination** and **temp < 15⁰ C delays silking and tasseling.**

Maize - morphology

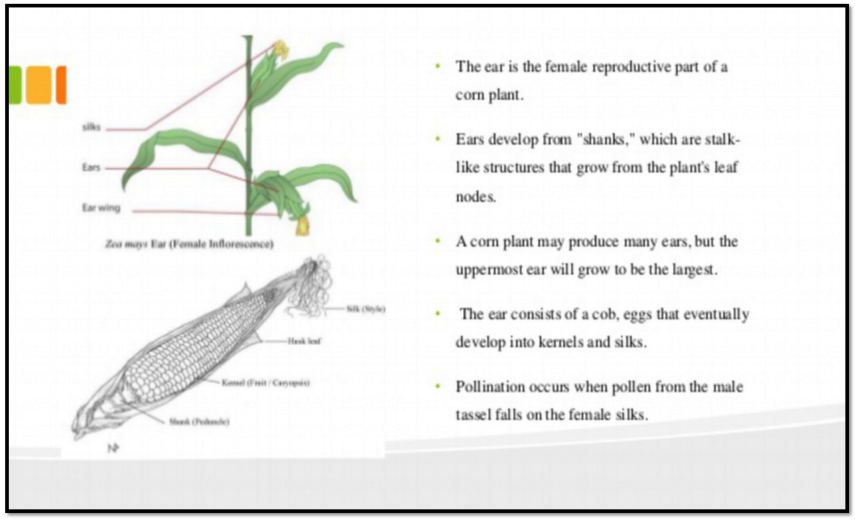
- Maize generally has **one main stem**, but some varieties can produce tillers.
- The maize stem is **round and erect**, with conspicuous nodes and internodes.
- Unlike many grasses, the **stem is solid** rather than hollow. The leaves are borne in an alternate pattern on opposite sides of the stem.





Growth stages of maize

1. Seedling stage: 1-14 days (2-3 leaves).
2. Vegetative stage: 15-39 days (knee high stage).
3. Flowering phase: 40-65 days.
4. Maturity phase: 66-95 days.
5. Ripening phase: 96-105 days.



Soil Requirements

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

Land preparation

- The crop **does not require fine tilth.**
- Field is ploughed to a **depth of 25-30 cm using mould board plough**, followed by **2-3 ploughing with desi plough or harrow.**
- **Proper drainage** should be provided in **heavy textured soils.**

Season and sowing

In India, it is grown in all the 3 season.

1. Kharif: June - July (85% of rainfed area)
2. Rabi: Oct – November (Peninsular India and Bihar)
3. Spring/ Summer: Jan – Feb (Irrigated condition)

Sowing method:

- Dibbling
- Broadcasting
- Line sowing
- Seed drilling (seeding behind plough)

❖ Maize yield are more in **rabi and spring** as compared to **kharif season.**

Seed rate: 15 kg ha^{-1}

Spacing: 60 x 30 cm

Depth of sowing: 5 cm

Varieties:

Varieties	Sowing time	Duration (days)	Yield (per ha)			
			Irrigated		Rainfed	
			Seed	Straw	Seed	Straw
Hybrid – Hema (NAH-1137)	May-June Sep-Oct Jan-Feb	110-120	90-100 q	30 t	70-80 q	20 t
Hybrid – Nithyashree (NAH-2049)	May-June Sep-Oct Jan-Feb	110-120	80-90 q	30 t	60-70 q	20 t
Composite NAC- 6004	May-June Sep-Oct Jan-Feb	115-120	60-65 q	20 t	45-50 q	15 t
Composite NAC- 6002	May-June Sep-Oct Jan-Feb	90-95	45-50 q	15 t	30-35 q	10 t

Seed treatment:

- Azospirillum or Phosphorous solubilising bacteria @ 200 g per acre of seed.
- Mancozeb @ 3g/kg seed to avoid downey mildew disease.

Gap-filling and thinning:

- Thinning should be done at 10 days after sowing in order to maintain optimum plant population and also to rough out week and disease affected plants.

Nutrient Management

- As maize is an **exhaustive crop**, fertilizer management is very important for **obtaining higher yield and maintaining soil fertility.**

FYM: 10 t ha^{-1} (Irrigated)

7.5 t ha^{-1} (rainfed)

NPK: 150:75:40 kg ha^{-1} (Irrigated)

100:50:25 kg ha^{-1} (rainfed)

- 50% N and 100% P & K should be applied at the time of sowing.
- Remaining 50% N should be applied at 30 DAS at the time of final earthing up.

- Zinc deficiency is more common in maize crop.
- Zinc deficiency in maize leads to **"White Bud"** in Maize.
- Soil application of Zinc sulphate @ 20 kg ha^{-1} 15 days prior to sowing of the crop.
- Foliar spray of 0.5% $ZnSO_4$



Water Management

- Maize is **very susceptible** to **excess water and moisture stress.**
- Water stagnation for **3 days will spoil the entire crop.**
- Maize can **tolerate heavy rains** provided **water does not stand in the field for long periods.** Therefore proper drainage is essential.
- **500-600mm of water** is required during its lifecycle.
- It should be irrigated at **least four times** *viz*., seedling stage, knee high stage, tasseling stage, silking and grain filling stage.
- **Tasseling and silking** stage are very critical.
- At this stage water shortage for **2 days reduce yield by 20%.** If it is for **6-8 days yields are reduced by 50%.**

Weed management

- Crop weed competition in maize is up to **25-30 DAS.**
- After 30 DAS weeds will be suppressed due to **shading effect of the main crop.** Hence, it is necessary to control weeds till 25-30 days.
- Inter cultivation is done in between rows at 15 and 30 DAS with small implements i.e., small blade harrow - i) to remove weeds
  ii) to stir/loose the top soil
  and iii) to give slight earthing up to maize plants
- Pre-emergent application of **Atrazine 50 % WP @ 1-1.25 kg a.i./ha (Sole crop)**
- **Pendimethalin 30% EC @ 1 kg a.i./ha (Intercrop) followed by one hand weeding at 30 DAS.**
- Post-emergent application of **2,4-D @ 0.75-1.0 kg a.i./ha** at 15-20 DAS

Cropping system in maize

I. Cropping sequence

- Maize – Potato
- Maize – Berseem
- Maize – Chick pea

II. Intercropping system (paired row maize planting)

- Maize + fieldbean
- Maize + Soybean
- Maize + Cowpea
- Maize + French bean

Harvesting and yield

- The crop comes to harvest at 120 DAS.
- The crop should be harvested when the cob sheath turns brownish, grains become hard and moisture content of 20%.
- After harvesting the cob, they should be dried under sun to reduce the moisture content to 10-12%.

Pop corn

Variety	Sowing time	Duration	Seed yield	Straw yield
Amber popcorn	May-June Sep-Oct Jan-Feb	100-110 days	35-40 q ha^{-1}	7.5-9.0 t ha^{-1}

Seed rate: 15 kg ha^{-1}

Spacing: 60 x 15 cm

FYM: 10 t ha^{-1}

NPK: 150:75:40 kg ha^{-1}

Baby corn

Variety	Sowing time	Duration	Seed yield	Straw yield
Hybrid babycorn	May-June Sep-Oct Jan-Feb	65-75 days	75-80 q ha^{-1}	30-35 t ha^{-1}

Seed rate: 40 kg ha^{-1}

Spacing: 45 x 15 cm

FYM: 10 t ha^{-1}

NPK: 150:75:40 kg ha^{-1}

❖Crop should be harvest at 40 DAS (immediately after silking)

World wide production of cereal grain in 2017-18
(million metric tons)

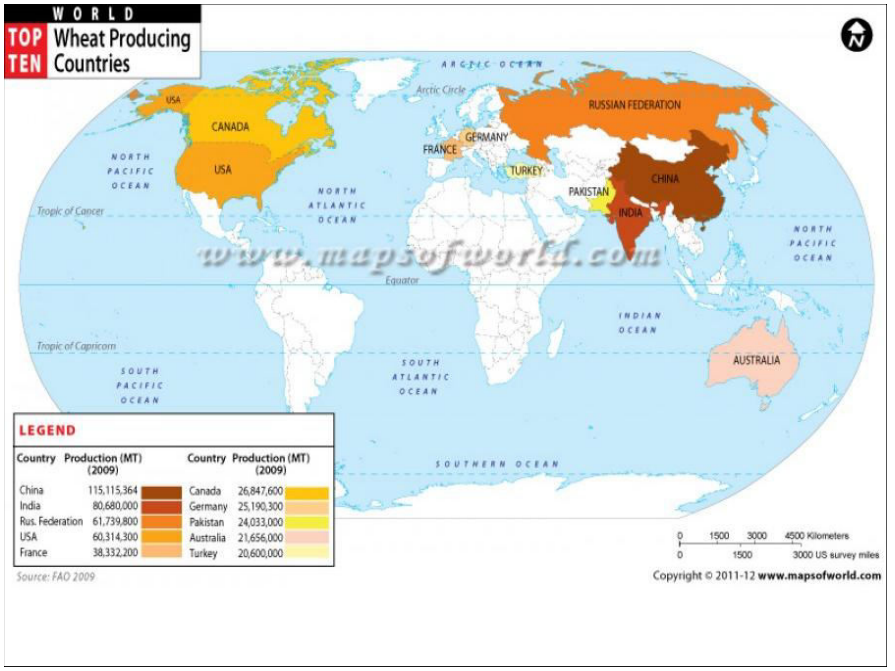
Sl.No.	Crops	Production (million metric tons)
1	Corn	1033.74
2	Wheat	757.92
3	Rice (milled)	488.6
4	Barley	144.26
5	Oats	23.51
6	Rye	12.38

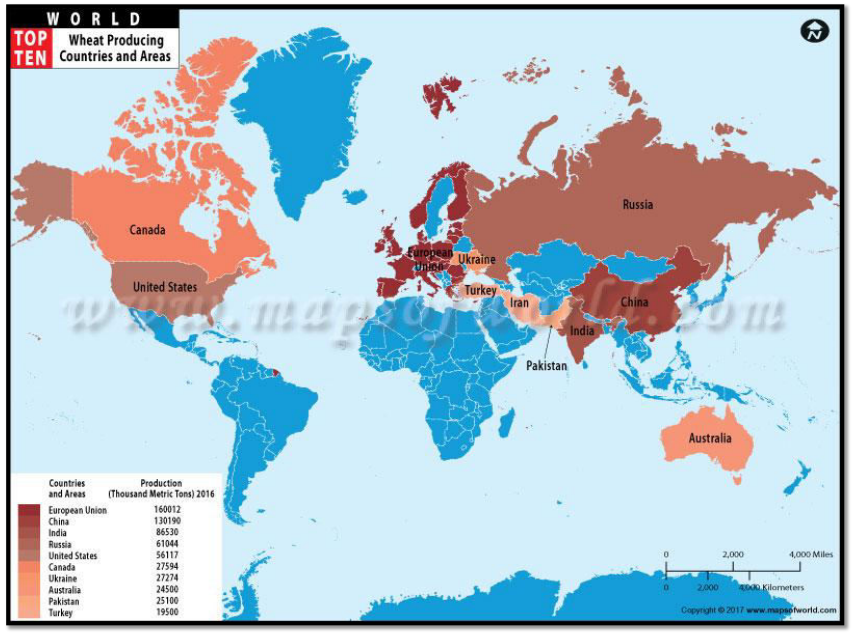
- Wheat is the **world's most widely cultivated food crop.**
- Wheat contributes **30%** towards **global food basket** after **Corn** followed by **rice.**
- It is an important **cereal food crop supplying energy** to major chunk of population in the world.

- Nutritionally, it constitute **72% of carbohydrates** and **higher protein content of 10-14%** as compared to any other cereal crops.
- It is also a rich source of **niacin, thiamine carotene and iron (5.3%).**
- The protein which is present in the wheat is called as **Gluten.**
- Gluten is responsible for **stickiness and dough formation**. Hence it is used in preparation of bread and other bakery products.

Area and distribution of wheat

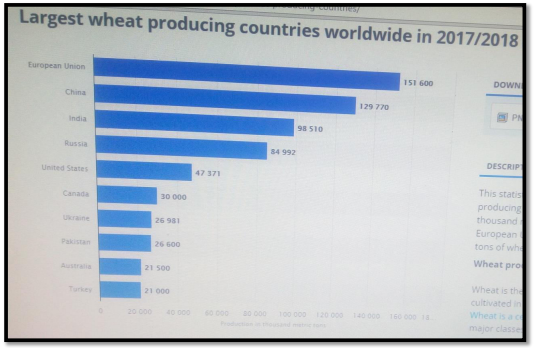
- Wheat rank second position in the world among the cereals both in area and production.
- It is a crop that primarily grown in temperate regions.
- It constitutes the staple food in at least 43 countries.
- The most important wheat growing countries are the **USSR, USA, China, India, Canada, Argentina, Australia and a number of European countries.**





World Wheat Scenario (2017-18)

Sl. No.	Countries	Area (m.ha)	Production (m.t)	Productivity (t/ha)
1	European Union	26.32	151.68	5.76
2	China	23.99	129.77	5.41
3	India	30.79	98.51	3.20
4	Russia	27.34	84.99	3.11
5	United states	15.21	47.37	3.11
	World	219.52	758.27	3.45



Indian Wheat Scenario (2017-18)

Sl. No.	States	Area (lakh hectares)	Production (lakh tons)	Productivity (kg/ha)
1	Uttar Pradesh	96	300.10	3100
2	Punjab	35	164.72	4531
3	Haryana	25	116.30	4000
4	Madhya Pradesh	33.18	76.27	1753
5	Rajasthan	24	72.14	2481
	India	**300.79**	**985.1**	**3045**

Karnataka:

Area: 0.4 lakh ha,
Production: 40 lakh tons
Productivity: 887 kg/ha

Classification of wheat

- Wheat is classified in to **three groups** based on their **chromosomes number.**

1. Diploid wheat: 2n=14

T. monococcum (Einkorn)

2. Tetraploid wheat: 2n=28

T. durum (durum/ marconi wheat)

T. dicoccum (Emmer wheat)

3. Hexaploid wheat: 2n=42

T. aestivum (Bread wheat)

T. spelta (spelt wheat)

T. vulgare

Species	Common name	% production	Uses	Distribution
Triticum aestivum	Bread wheat	87%	Chapathi & Backery	N. India, Central and S. India
Triticum durum	Durum wheat or macaroni	12%	Suji, semiya/ upma	Central & S. India
Triticum dicoccum	Emmer wheat	1 %	Upma	TN, AP, Kar, Maharastra and Gujrath

II. Wheat is also classified based on season of cultivation

1. **Winter wheat:** Which requires a **low temperature of 0 – 8^{o} c** during transition from **vegetative to reproductive phase.**

- These type of wheat should requires **30-60 days of chilling temperature.**
- These wheat are grown during **September to November in Northern hemisphere** and **harvested in early summer.**
- These type of wheat is predominantly grown in **USA.**

2. **Spring wheat:** Which **do not requires low temperatures** during transition from **vegetative to reproductive phase (3-15^{o} C).**

- This type of wheat is grown during **Late November/ December** and harvested at **late summer (April-May).**
- South Asia (India, Pakistan, Nepal, Bangladesh), North Africa, the Middle East and the lower latitudes (e.g. Sonora in Mexico).

Origin of Wheat

- **Tetraploid wheat** originated about 8000 years back between **Syria and Iraq** but,
- ***T. durum*** is domesticated in **Central Europe**
- ***T. dicoccum*** was domesticated in **South eastern Iraq.**
- **Hexaploid bread wheat** was originated in **Iran and Afganisthan** but domesticated in **North Western India.**

Soil and climatic condition

- Wheat can be grown on widely varying soils with good drainage and moisture holding capacity.
- Soils with clay loam with good water holding capacity is ideal.
- Heavy soils with poor drainage are not suitable, since wheat is sensitive to water logging.
- pH: 5.5-6.5 (can withstand slight acidity & alkalinity).

In India wheat growing areas can be mainly divided in to 5 soil types:

1. Gangetic alluvium of UP & Bihar
2. Indus Alluvium of Punjab & Haryana
3. Black soil regions of Central & Southern India comprising MP, MH & Karnataka
4. Hilly regions of the Himalaya
5. Desert soils of Rajasthan

Climatic condition:

Latitude:

- Wheat is a widely adopted crop grown in tropical, subtropical, temperate and in extreme cold tract beyond 60° N latitude.
- It can tolerate severe cold climate.
- It is a long day plant requires longer day length for flowering.
- Wheat crop takes 180 days in hills of North India ; western region and 100 days in Peninsular India for maturity

Rainfall:

- It can be grown in annual rainfall region of 300-1130 mm. In India, it is grown in the regions from 100 mm in Rajasthan to the regions of very high rainfall up to 4000 mm in humid Western Plains.

Temperature:

- In India wheat is grown during **Rabi season.**
- It requires a cooler temperature of 0 – 8° C for Winter wheat and 5 -14° C for Spring wheat during vegetative phase.
- Best wheat is produced in the regions of cool (14-15° C) and dry climate during major portion of crop life followed by warm climate (not > 25° C) during grain ripening phase. Warm and moist climate are not suitable for germination and growth.
- Excessive high temperature beyond 25° C at ripening phase may reduce grain filling and results in chaffiness.

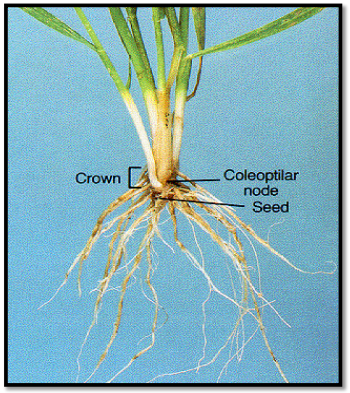
Why area and production of wheat in India is low?

- In India, wheat is grown during **rabi or winter season.**
- The **high temperatures on both ends of wheat season** restrict the cultivation of this crop in India.
- Too cooler months, high temperatures in September do not permit good tillering of the crop. They also favour root rot and seedling blight.
- **Hot summer during the grain ripening period** hastens the maturity of the crop giving inferior quality of the crop.

STAGES OF CROP GROWTH

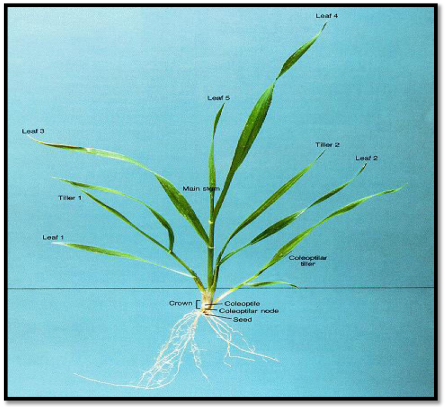
1. CRI: Crown root initiation

- **CRI takes place 15-21 DAS.** Plants at this stage are very sensitive to soil moisture stress. Hence, there is a need for adequate moisture at this stage.



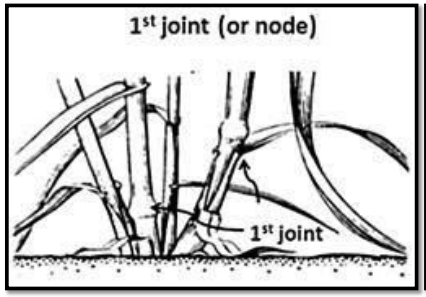
2. TILLERING:

The lateral buds at these nodes give rise to tillers. Tiller initiation takes place 4 weeks after sowing and tillers continue to emerge for another 2 or 3 weeks.



3. JOINTING STAGE :

- It represents the node production and active growth period.
- Upto this stage, the seedlings consists of a whorl of leaves.
- At this jointing stage, the stem becomes visible with distinct nodes.



4. HEADING :

- This is the stage where the internodes begin to elongate.
- Flag leaf and ear emerge towards the end of this stage.
- Adequate moisture should also be present in the soil at the heading stage.

5. Flowering and grain development :

- After heading, flowering takes place and reaches grain filling stage.
- Later it reaches to soft dough stage of the grain.
- At this stage also, the plant requires adequate moisture at dough stage.
- Awns are attached to Lemma. Green awns are photosynthetically active and contributes 15% of net photosynthesis.
- Botanically seed is called as **Kernal.**

Production Techniques

Land preparation:

- Land should be ploughed 2-3 times with the help of cultivator to bring soil to fine tilt. Later with the help of harrow field should be levelled properly.

Method of sowing:

1. Broad casting
2. Sowing behind the plough with hand
3. **Sowing behind the plough with seed drill**
4. **Dibbling**
5. **Zero tillage sowing**

Spacing:

- Irrigated condition: Dibbling 2 or 3 seeds by hand at 4-6 cm depth at a distance of 22.5 cm x 10-15 cm spacing under normal sowing and 15 -18 cm row spacing at late sowing condition.
- Rainfed condition: 30 cm row to row

Time of sowing:

- Optimum sowing time is **15th October to 15th November.**
- Early sowing with long duration Varieties – sown during october.
- For late sowing varieties with less than 100 days – end of November.

Seed Rate

- **Normal condition:** 100 kg ha^{-1}
- **Late sowing:** 125 kg ha^{-1}

Recommended varieties

- H.D. 2189
- DWR-39 (Keerthi)
- DWR-39

Manures and Fertilizers:

- **FYM:** 8 t ha-1
- **NPK:** 120:60:40 kg ha^{-1} (Irrigated timely sown crop)

  80:40:20 kg ha^{-1} (Irrigated late sown crop)

  60:30:20 kg ha^{-1} (rainfed crop)
- Half of nitrogen and full dose of P & K should be applied at the time of sowing in the rows and remaining half of N should be top dressed at first irrigation (CRI) 20-25 DAS.
- In Rainfed condition full dose of nitrogen, phosphorous and potassium should be applied at the time of sowing itself.

Water management:

- Adequate soil moisture is required for normal development of the wheat plant at all the stages of growth.
- The water require of crop is around **40-45 cm.**
- The critical stages for irrigation are

1. CRI,
2. tillering,
3. jointing,
4. flowering,
5. milking and
6. dough stage.

- Hence, 4-6 irrigation is required for obtaining better yield.

Scheduling of irrigation at normal condition

- 1irrigation: CRI at 20-25 DAS
- 2 irrigation: tillering stage at 40-45 DAS
- 3 irrigation: late jointing stage at 70-75 DAS
- 4 irrigation: flowering stage at 90-95 DAS
- 5 irrigation: dough stage at 110-115 DAS

Scheduling of irrigation at limited water supply

- If only one irrigation: CRI stage
- If only 2 irrigation: CRI and flowering stage
- If only 3 irrigation: CRI, late jointing (booting) and milking stage.
- If only 4 irrigation: CRI, late tillering, late jointing & flowering stage.

Weed management:

- Critical period of crop weed competition is up to **35-40 days.**
- ***Phalaris minor*** is a crop associated weed in wheat crop

a. Manual weeding at 20 and 40 DAS

b. Pre-emergent application of Pendimethalin @ 3.3 l/ha

c. Post emergent application:

Isoproturon 50% @1.5 kg a.i./ha

2,4-D 36% @1.5 kg a.i./ha at 30-DAS.

Phalaris minor crop associated weed in wheat

Cropping system:

I. Irrigated systems:

a. **Rice-wheat:** widely practiced in irrigated system in North western and North Eastern plains

b. **Maize-wheat:** Practiced in J&K, HP, UP, Rajasthan, MP.

c. **Cotton-wheat:** Rajasthan, Punjab, Haryana

Rainfed ecosystems:

- Majorly followed in vertisol regions of MP, Gujarath, MH & Karnataka

a. Fallow-wheat, Pearl millet-wheat, Groundnut-wheat, green gram-wheat, soybean-wheat

Mixed cropping:

Wheat+Mustard, Wheat + chickpea+linseed, wheat+ safflower, wheat+mustard

Yield:

- Crop attains maturity at **115-120 DAS.**
- Irrigated condition: **45-55 q/ha**
- Rainfed condition: **20-25 q/ha**

Description of wheat species

1. *T. dicoccum* (Emmer wheat):

- Grown in some parts of south sates like **Maharashtra, Tamil Nadu** and **Karnataka.**
- It is good for South Indian dish **"Uppumav".**
- This wheat is called **Ravva, Godhumalu** and **Samba Wheat** in South states.



2. *T. Durum* (duram/marconi wheat):

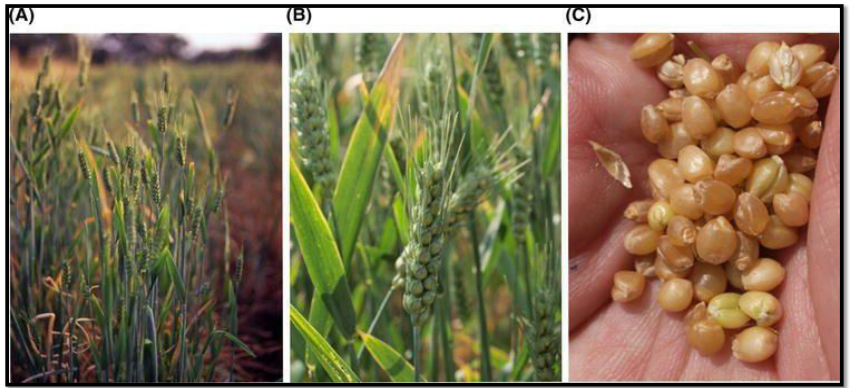
- **Very old and best wheat** for **drought condition/ under restricted irrigation**
- It is the **second most important wheat grown in country.**
- It is used for preparation of **"Suji and vermicelli"** preparation.
- It is grown in **MP, Gujarath, Rajasthan, Maharashtra & Karnataka.**


3. *T. Vulgare* (Common Bread wheat):

- Typical **tall wheat for rainfed condition** in **Indo-gangetic plains.**

4. *T. Sphero*cocc*um* (Indian dwarf wheat):

- It is also called as **"Club wheat"** in western countries.
- Grown in limited areas of **MP and UP.**
- **Very short** and **compact heads.**
- **Low productivity** and **highly susceptible to diseases**



5. *T. Aestivum* (Mexican dwarf wheat):

- Presently grown in India everywhere and called **"Bread Wheat".**
- It was evolved by **Dr. N. E. Borloug** of **Mexico at CIMMYT.**
- It covers more than **87 % of the total wheat growing area of India,** followed by **durum wheat** and **dicoccum wheat**.
- Which is good for **chapati making and bakery product**s is grown in whole of **North India and also in central and South India.**

Varietal development of Wheat

- **"Norin"** dwarf gene was isolated from **Norin series wheat varieties** and **"Nor"(Rht)** in wheat variety in **Japan.**
- **Rht** – Reduced height.
- The first such variety **"Norin-10" (dwarf gene wheat)** was brought to **USA by S.C. Salamon in 1948.**

- Using **"Norin"** genes **Dr. O. A. Vogel** developed a dwarf winter wheat variety **"Grains" in USA** and many other varieties were developed by **Dr. Norman Borloug,** Nobel laureate in **1961-62 at CIMMYT, Mexico.**
- **In 1963,** Govt. of India imported **100 kg** of Mexican wheat varieties **Sonora 63, Sonora 64** and **Lerma Rojo 64,** with the help of **Rockfeller foundation.**
- After extensive tests, huge quantities of **Lerma Rojo 64 A (single gene dwarf variety)** and **Sonora 64 (Double gene dwarf variety)** were imported in **1965-1966 from CIMMYT.**

- In **1965** both varieties were released for general cultivation in India and brought **green revolution**.
- Later, these varieties were replaced by **Kalyansona** and **Sonalika.** Later **Kalyansona** became susceptible to all **rust** and **Sonalika** to Kernal Bunt.

Sources of dwarf gene in Wheat

1. **Norin 10 (Japan)**
2. **Tom thumb (Tibet)**
3. **Olsen dwarf (South Rhodesia)**

- Later in **1970**, triple gene dwarf varieties were released.

Single gene dwarf varieties:

- Lerma Rojo 64 A, Sonalika, UP-262, WL-711, Girija.

Double gene dwarf varieties:

- Kalyansona, Sonora -64, Arjun, Janak, UP-215, HD-2204, Pratap

Triple gene dwarf varieties:

- Hira, Moti, Jawahar, Jyoti, Sangam, HD-1941, HD-1977, UP-301, UP-319.

Varieties with high Gluten content:

- HI-977, NI-5439, HW-657 and DWR-39.

Late sown varieties of wheat:

- Sonora -64, Sarbati sonora, Sonalika, Safed Lerm, UP-301, NP-830.
- The **inflorescence** of wheat is called as **Ear** or **Head**. Botanically called as **"Spike".**
- **Shelling %** in wheat is about **60%.**
- The test weight of wheat is **40g.**

Economic Importance

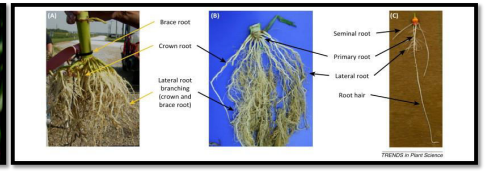
- Sorghum is also called as **Jowar/ Jwar/ Cholam/ Jola** in **India.**
- In Europe it is called as **Guinea Corn.**
- It is the **third important staple food crop** of **India** and **Asia** **and** **fifth** important cereal crop after **Rice, Wheat, Maize and Barley.**
- **Millions of people in Africa** depend on sorghum as **their staple food.**
- It is a well known **drought resistant crop**, hence grown in **arid and semi arid regions under rainfed condition**
- It is grown both on **marginal** and **rich lands**, with or without irrigation.

- Sorghum grains are well known for their **high nutritional values** due to their, Low fat (3%), high starch (>70%), high protein (10-12%), rich in Iron (>70 ppm) and Zinc (> 50 ppm), which helps in reducing the **micronutrient malnutrition globally.**
- Sorghum is deficit in Amino acids like **Arginine, Glycine, Tyrosine and Methionine.**
- Sorghum is mainly consumed as **roti and popped sorghum (India), fermented beer (Africa), Sweet syrup in condiments/breads/biscuits (USA).**
- Grains are used as industrial raw material to produce **ethanol (biofuel)** and to **ferment other liquors.**

Reasons for drought resistance in sorghum

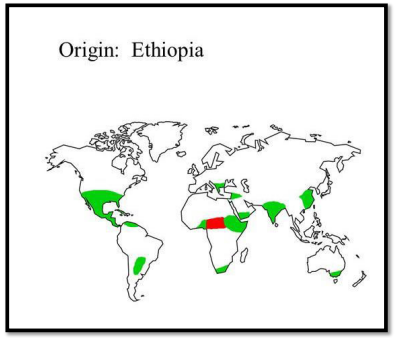
- **Slow shoot growth** till roots are well developed.
- **Higher root weight/ volume** than most other cereals **(well proliferated root system).**
- **Deeper root system** than any other cereal crop.
- **Maintain high turgor pressure** during stress by **reducing leaf osmotic potential.**
- **Produce large epicuticular waxes** **on stem and leaves** to **reduce transpiration.**
- **Roll the leaf surface under stress** by **special motor cells in leaf tissues.**





Origin of Sorghum

- **East and Central Africa (Ethiopia/ Sudan)** is regarded as the place of origin of sorghum.
- It reached **India** at around **1500 BC,** while it entered **USA** as late as **125 years back.**



Area and distribution of Sorghum

Sl. No.	Countries	Area (million hectares)	Production (million tons)	Productivity (metric tons/ha)
1	Sudan	6.30	3.74	0.59
2	Nigeria	5.80	6.55	1.13
3	India	4.83	4.95	1.03
4	Ethiopia	1.82	4.05	2.23
5	USA	2.04	9.24	4.53
	World	40.02	57.85	1.45

- India ranks **3rd in area and production** but **4th in productivity**

- The major jowar growing states in India are Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Telangana, Tamil Nadu ,Gujarat and Uttar Pradesh.

Climatic requirement of Sorghum

- It is **primarily a tropical warm weather crop** but can be grown in sub tropics and temperate regions during warm months.
- It is a **sturdy/ hardy crop** and can withstand varied climatic hazards more than any other cereal crop.
- It is successfully grown in **arid areas of UP, Rajasthan** and also in **humid regions of W. Bengal and Bihar.**
- It can not be grown beyond **40^0 N and 40^0 S.**
- It can withstand wide range of temperatures varying from **15.5^0 C to 40.5^0 C** with rainfall variations of **35-150 cm per annum.**
- This crop can be grown from **sea level to as high as 1500 m.**
- Sorghum is a **short day plant. Flowering and grain formation** starts when **day length shortens during winter.**

Soil Requirement

- Sorghum can be grown in **heavy black soils to red soils**, but comes up well in **heavy black soils.**
- Jowar does not grow well under **sandy and marshy soils.**
- The crop grows well in **neutral pH of 7.0 but it can** withstand the pH of **6.0 – 8.5** as it considerably **withstand salinity and alkalinity.**
- During *kharif* season crop grown under black soils, where as under rabi and summer season crop can be grown under sandy soils with assured irrigation facility.

Land preparation

- Deep ploughing should be done to a depth of **20-25 cm** to loose the soil.
- It should be followed by **2 to 3 ploughing** with **country plough.**
- Later **harrowing** should be done to **break the clods and to level the field.**

Seeds and Sowing:

- Sorghum is sown by various methods in different parts of the country,

1. Broadcasting,
2. Seed drilling
3. Dibbling

- For obtaining higher yield, **seeds should be sown in lines using seed drill.**

Seed rate: 12-15 kg ha^{-1}

Spacing: 45 x 15 cm

Depth of sowing: 5 cm

Time of sowing

- In India, Sorghum is grown in **all the three season.**

1. Kharif : June –July.

- In **Northern India**, sorghum is sown only in *kharif* season. Under irrigated condition first week of June is ideal, under rainfed condition, crop should be sown with onset of monsoon.
- Timely planted kharif crop escapes the damage of **shoot fly** and **midge.**

2. Rabi: Mid-September - mid-October (MH, Karnataka & AP)

3. Summer: January – February (TN, AP & some parts of Karnataka)

Varieties and hybrids

Sl. No.	*Kharif* cultivars		Rabi cultivars	
	Hybrids	Varieties	Hybrids	Varieties
1	CSH-5	SB 1066	CSH-13	M-35-1
2	CSH-9	DVS-1	CSH-15	DSV-4
3	CSH-16	DVS-2	CSH-19	DSV-5
4	CSG-17	CSV-4	-	CSV-8
5	CSH-18	CSV-11	-	CSV-14
6	CSH-21	CSV-13	-	CSV-216
7	CSH-22 (I)	CSV-15	-	

- Among all the cultivars, **CSH-1** hybrid is more suitable for **ratoon crop** and the local varieties are not at all fit for ratooning.
- This is only possible **under irrigated conditions.**

Manures & Fertilizers:

- Sorghum requires heavy doses of fertilizers because it removes nutrients in heavy amount from the soil. Manures and fertilizers both play an important role in sorghum cultivation.

FYM: 8 t ha^{-1}.

NPK: Irrigated:100: 75: 40 kg ha^{-1}

Rainfed: 65: 40: 40 kg ha^{-1}

Basal dose: 50% N & full dose of P & K

Split dose: 50% N at 30-35 days.

- In rainfed crop, entire quantity should be applied at the time of sowing.

Fe deficiency: Sorghum is more sensitive to Fe deficiency (Foliar spray of FeSO4 @ 0.5 -1%)

Zn Deficiency: 15-20 kg ha^{-1} of $ZnSO_4$ at the time of sowing.

Thinning and intercultural operation

- To maintain desirable plant population of 1,50,000 ha^{-1}, thinning should be done two times at **10-15 DAS** and at **20-25 DAS.**
- Sorghum is a **slow growing crop up to 30-40 DAS**, hence there will be more competition from the weeds and also to improve the growth intercultural operation should be carried out to **supply aeration to the roots by loosening the soil and formation of earthing up.**
- **Two intercultural operations** should be done. **First at 20 DAS** and **second at 45 DAS after split application of N (earthingup).**

Water Management

- Water requirement of sorghum is **30-35 cm.**
- Generally it is grown as **rainfed crop and drought resistant in nature** but responds well to irrigation.
- However, in case of no rains, the crop may be irrigated **once or twice to a depth of 5 cm**, especially in **heading and grain development stage.**
- Whenever the crop is irrigated, it is always useful to adopt the **ridges and furrow method.**

Critical stages of irrigations are

1. Germination (at the time of sowing)
2. Knee high stage (30-35 DAS)
3. Flag leaf stage (50-55DAS)
4. Flowering (70-75 DAS)
5. Grain formation stage (100-105DAS)

Under irrigated condition:

- In **sandy loam soils** irrigation should be given at once in **8 days,** where as in **clay loam soils** irrigation should be given at **15 days once,** in general **6 to 8 irrigation is required** for successful crop of sorghum.

Weed management

- Sorghum is a slow growing crop up to **35-40 DAS.**
- After 40 DAS weeds will be suppressed due to **shading effect of the main crop and also due to allelopathic effect**. Hence, it is necessary to control weeds till 40 days.
- Inter cultivation is done in between rows with small implements i.e., small blade harrow - i) to remove weeds

  ii) to stir/loose the top soil

  and iii) to give slight earthing up to jowar plants
- Pre-emergent application of **Atrazine 50 % WP @ 0.5-0.75 kg a.i./ha.**
- Post-emergent application of **2,4-D @ 0.75-1.0 kg a.i./ha** at 15-20 DAS

- **Striga (*Striga asiatica*)** is a **crop associated root parasitic weed** in Sorghum and damaging the crop up to **5-90%.**
- Striga is also called as **witch weed** which affects **Maize, sorghum, Sugarcane and some legume crop.**

Management of Striga Weed

- **Striga infestation is more in low fertile soils.**

1. **Deep ploughing**
2. **Growing of Trap** Crops like cotton, cowpea, groundnut, sunflower, linseed, field bean, soybean in rotation. These crops **stimulate the germination of striga seeds but not parasite leads to suicidal effect.**
3. **Grow resistant varieties:** Secrete stimuli but not parasite, Nadyal, bilichigun, N-13, Co-20, CS- 3541, RS-813
4. **Mechanical:** Hand pulling and destroying before produce flowers.
5. **Chemical:** Application of atrazin @ 1 kg ai/ha as pre emergent and 2.4-D @ 1 kg ai/ha as post emergent at 2-3 weeks after sowing.
6. Application of excessive **N and FYM**
7. **Injecting of ethylene** @ 3kg/ha in 4-6 inch layer of soil is found to be effective in inducing **80-90% of germination of striga.**

Cropping system

North India -(i) Sequence cropping

- Sorghum - Wheat
- Sorghum - Wheat- greengram
- Sorghum - Wheat – Cowpea
- Sorghum – Pea
- Sorghum - Safflower/ Sunflower

(ii) Mixed cropping

- Sorghum + Soya bean
- Sorghum + Pigeonpea
- Sorghum + Greengram/Blackgram

South India - (i) Sequences

- Sorghum- Cotton
- Sorghum - Rabi sorghum
- Sorghum -- Finger millet - Groundnut
- Groundnut - Rabi sorghum

(ii) Mixed cropping (kharif)

- Sorghum + Fingermillet
- Sorghum + pigeonpea
- Sorghum + greengram
- Sorghum + blackgram
- Sorghurn + cowpea

SORGHUM EFFECT

- It is caused due to 2 reasons

1. Nutrients removal

2. Allelochemicals

- Sorghum is an **exhaustive crop.** It removes more amounts of nutrients.
- So, two exhaustive crops like **sorghum and cotton** should not follow each other.
- Instead **pulse crop** can follow sorghum.

- **Succeeding crops** after sorghum do not thrive well due to **some toxic effect left over by the jowar crop**.
- This can be counteracted by **good manuring** of the succeeding crop with **FYM and by green manuring** or **crop rotation** or **sorghum mixed cropping.**

Ratooning of sorghum

- The **cultivation of an additional crop from the re-growth of stubbles of previous main crop after its harvest,** there by avoiding **reseeding or replanting** such as sugarcane, sorghum, fodder grasses etc.
- Hybrids of sorghum can, be **ratooned with good success.**
- Of all **CSH-l** is the best for ratooning and the **local varieties are not at all fit for ratooning.**
- This is only possible under **irrigated conditions.**

STEPS: 1. The main crop has to be harvested while the **stem is green**, leaving **30 cm stubble *above* ground level.**

2.The 2nd day after harvesting, **an irrigation has to be given to induce sprouting from the nodes.**

3.Fertilizers @ **60kgN/ ha** has to be applied – 2 stages: **1st at one week after harvest, 2nd at 30 days after ratooning.**

4. From each stubble, a number of sprouts come up. The weak sprouts have to be thinned out leaving **2 or 3 good healthy sprouts** in each stubble.

5.Maintain **sufficient moisture from boot leaf to grain hardening stage.**

6. The ear head size though **small in ratoon crop** gives equal yield to main crop as it putforths 2 or 3 sprouts.

7. Ratoon comes to harvest in **80-85 days.**

8. Plant protection measures have to be taken up **in time against pests and diseases as in planted crop.**

9. Ratooning reduces expenditure on **land preparation, sowing, fertilisers and gives more net income** when it is managed well.

Sorghum poisoning

- It is due to content of Cynogenic glucoside called **dhurriin.**
- Cynogenic glucoside is present in **young sorghum plants** which are subjected to **drought** and the crop which has utilized **large quantity of nitrogen.**
- Once plants containing **dhurrin (prussic acid)** has been consumed by the animals the **toxin rapidly enters the blood stream** and is transported throughout the body of the animals.
- The animal **suffocated and causes death.** This is called as **"Sorghum poisoning".**

- Dhurrin content is maximum at **30 days of the crop** and at that stage leaves contain maximum dhurrin content of **48 mg/100g fresh weight.** Stem has **6.5 mg/100 of fresh weight**. Roots have **0.05 mg/100g fresh weight.**

Management of sorghum poisoning

- Sorghum when grown for fodder **should not be harvested before flowering.**
- **P, K and S** supply reduces dhurrin content under drought.
- **Give irrigation under stress condition.**
- If it is inevitable to use, **it should be dried**, dried dhurrin escapes in gaseous form.
- **Give molasses to animals** when dhurrin poisonous.
- Intravenous injection of **sodium thiosulphate** will restore the oxygen supply to animals and prevents the death.

Harvesting and yield

- Harvesting of sorghum is done when the **grains attains physiological maturity.**
- Crop comes to harvest, when the crop attains **120 days after sowing.**

Yield:

Irrigated condition: Grain yield: **40-50 q ha^{-1}**

Fodder yield: **100-125 q ha^{-1}**

Rainfed condition: Grain yield: **20-25 q ha^{-1}**

Fodder yield: **50-70 q ha^{-1}**

- Millets are a group of highly variable small-seeded grasses, widely grown around the world as **cereal crops** for fodder and human food.
- **Millets are classified in to 2 types**

1. Coarse millets: Sorghum & Bajra

2. Small millets:

- **Finger millet:** *Eleusine coracana* (L.) Gaertn. – **Ragi**
- **Fox tail millet:** *Setaria italica* (L.) Beauv – **Navane**
- **Kodo millet:** *Paspalum scrobiculatum* (L.) – **Haraka**
- **Little millet:** *Panicum sumatrense* – **Same**
- **Proso millet:** *Panicum miliaceum* (L.) – **Baragu**
- **Barn yard millet:** *Echinochloa frumentacea* – **udalu**

Importance of minor millets

- Minor millets are **important staple food crops in semi arid tropics of Asia and Africa.**
- **India is the largest producer of many kinds of millets**, which are often referred as **coarse cereals.**
- Nutritionally the grains are rich in **proteins, minerals and vitamins** and comparable or even superior to major cereals.
- Finger millet is the richest source of **calcium (300-350 mg/100 gram grain)** and other small millets are good source of **phosphorus and iron** too.
- The protein content range from **7-12%** and fat content varies from **1.3-4.7%.**

- The millet protein has **well balanced amino acid profile** and good source of **methionine, cystine and lysine**.
- Millets are the **rich source of fiber** as compared to any other cereal crop.
- Realizing the nutrient composition of these grains they are considered as **nutria-cereals (Nutritious grains).**
- Unlike other cereals, grains of small millets are **practically devoid of store pests besides retaining viability for long periods even under poor storage conditions.** So they are referred as **famine reserves.**

UNIQUE CHARACTERS OF MINOR MILLETS

1. Wider adaptability – high temperature, salinity.
2. Short duration.
3. Fast growing – intensive cropping system as catch, relay crop & sole.
4. Resistance to pests and diseases.
5. Less water requirement.
6. Resistance to drought and variations in the climatic abnormalities.
7. Wide range of Photoperiodism.
8. Higher nutritional values.
9. Less potential to yield.
10. Long shelf life.

Nutrient composition of millets and cereals (per 100 g grain)

Food grain	Protein (g)	CHO (g)	Fat (g)	Crude fibre (g)	Mineral matter (g)	Ca (mg)	P (mg)	Fe (mg)
Millets								
Finger millet	7.3	72.0	1.3	**3.6**	**2.7**	**344**	**283**	**3.9**
Kodo millet	8.3	65.0	1.4	**9.0**	**2.6**	27	**188**	**12.0**
Proso millet	**12.5**	70.4	3.1	**7.2**	**1.9**	14	**206**	**10.0**
Foxtail millet	**12.3**	60.9	4.3	**8.0**	**3.3**	31	**290**	**5.0**
Little millet	7.7	67.0	4.7	**7.6**	**1.5**	17	**220**	**6.0**
Barn yard millet	6.2	65.5	2.2	**9.8**	**4.4**	11	**280**	**15.0**
Cereals								
Wheat	11.8	71.2	1.5	1.2	1.5	41	306	5.3
Rice	6.8	78.2	0.5	0.2	0.6	45	160	-

FACTORS INFLUENCING LOW CONSUMPTION

1. **Lack of regular supply of small millets** largely due to limited demand by urban population.
2. Availability of cheap preferred cereals such as **wheat & rice**.
3. **Higher social prestige** associated with consumption rice & wheat.
4. **Marketing channels are not well developed for small millets** due to distance between remote producing areas and major consuming centres.
5. Most food aid projects include other cereals, more readily available in the market, rather than small millets.
6. Increased production though higher yields has led to decrease in area under small millets in **favour of cash crops.**

➢ The ICAR in New Delhi established the following **6 crop specific lead centres** with the help of the **International Development centre, Canada in 1978-79** for the improvement of small millets.

1. For Ragi – Bangalore.
2. For Prosomillet at Dholi in Bihar
3. For Kodomillet at Dindori in Madhyapradesh.
4. For Foxtail millet at Nandyal in Andhra Pradesh.
5. For Little millet at Semiliguda in Orissa.
6. For Barnyard millet at Almora in Uttar Pradesh.

Origin and distribution

Crop	Origin	Distribution
Fox tail millet	China	➢India, China, easten Europe, Southern parts of USSR and some parts of Africa and America ➢In India, Navane is cultivated on a limited area in AP, KA, MH,TN,RJ,MP,UP and North eastern states
Kodo millet	Indigenous to Indian sub continent	➢MP, Chattisgarh, MH, UP, GJ and TN.
Little millet	India	➢It is a grown in India and Srilanka. ➢It India it is grown in Tamilnadu, Andhra Pradesh, Karnataka, MP and UP
Proso millet	India	➢Grown extensively in India, Japan, China, Egypt, Arabia and Western Europe ➢ India largely grown in MP, Eastern UP, Bihar, TN, Maharastra, AP and Karnataka
Barn yard millet	India	➢Grown in India, China, Japan, Malaysia and east Indies and some extent in Africa and USA. ➢ In India grown in MP, UP, TN, AP, Karnataka, Maharashtra and Bihar.

Soil and climatic requirement

- It Can be grown both in **rich and poor soils** having variable texture ranging between **sandy loam to clays of black cotton soils.**
- However, well drained **loam or sandy loam rich in organic matter** is ideal.
- **Highly drought resistant** and can be grown in areas where there is **scanty rainfall** and can withstand **water stagnation also to some extent.**
- Millets can **withstand the salinity up to 7.5 pH.**

Climatic condition:

- Cultivated in **tropical and temperate regions.**
- requires moderate temperature throughout its life cycle.
- Grown even in high altitudes of about **2000 m.**
- Optimum temperature is **25-30^0 C** but it can withstand temp of up to **40^0 C.**
- Rainfall of **40-50 cm** is required.
- Relative humidity – **60-70%**

Land preparation:

- Before the onset of monsoon, **the field should be ploughed with MB plough.**
- After the onset, field should be **harrowed or ploughed** for making **smooth field and well leveled.**
- If the field is not properly leveled and more clods are present, the **germination will going to be affected.**

Agronomical Inputs

Crop	Spacing	Seed Rate	FYM	RDF
Fox tail millet	30 x 10 cm	7.5-10 kg ha^{-1}	6 t ha^{-1}	40:40:0 NPK kg ha^{-1}
Kodo millet	30 x 10 cm	10-12.5 kg ha^{-1}	6 t ha^{-1}	20:20:0 NPK kg ha^{-1}
Little millet	30 x 10 cm	7.5-10 kg ha^{-1}	6 t ha^{-1}	20:20:0 NPK kg ha^{-1}
Proso millet	30 x 10 cm	12.5 kg ha^{-1}	6 t ha^{-1}	40:20:0 NPK kg ha^{-1}
Barn yard millet	30 x 10 cm	10-12.5 kg ha^{-1}	6 t ha^{-1}	40:20:0 NPK kg ha^{-1}

Time of sowing: Millet can be grown in all the season, during *kharif* **Jule-July** is ideal

Depth of sowing: 3-4cm

- **At the time of sowing 50% of N and full dose of P & K should be applied. Remaining 50% of N should be applied at 30 DAS**

Cultivars of Millets

Sl. No.	Crop	Duration	Suitable cultivars
1	**Fox tail millet**	80-90 days	RS-118, K221-1, P.S-4, SIA-326
2	**Kodo millet**	80-90 days	PSC-1, JNK-364, RBK-155, GPUK-3
3	**Little millet**	80-90 days	CO-2, PRC-3, OLM-203
4	**Proso millet**	80-90 days	GPUP-8
5	**Barn yard millet**	80-90 days	Sushruta, Sukshema (TNAU 63)

Water management:

- Millets are grown in *kharif* season does not require irrigation. If dry spell for longer period, life saving irrigation should be provided.
- Summer crop requires 2-5 irrigations.
- Critical stages of crop for moisture stress **are- after germination, tillering, heading and grain filling stages**.

Weed management:

- 2-3 intercultivations at 10 days interval and one hand weeding at 30 DAS.

Harvesting and threshing:

- Crop flowers in 50-60 days and matures in 80-90 days.
- Harvest the crop when earheads are dry either by cutting the whole plant by sickle or the ears separately, dry for few days and then threshing is done with a stone roller or by trampling under the feet of bullocks.

Yield

Sl.No.	Crop	Grain yield (q acre^{-1})	Straw yield (q acre^{-1})
1	Fox tail millet	10-12	0.5 - 1.0
2	Barn yard millet	10-12	0.5 - 1.0
3	Proso millet	8-10	0.5 - 1.0
4	Little millet	8-10	0.5 - 1.0
5	Kodo millet	5-6	0.5 – 0.75

Other names of bajra

- Cat tail millet
- Candle millet
- Spiked millet
- Bulrush millet

- **In Telugu: Sajja**

- **In Kannada: Sajje**

Importance of Bajra

- Bajra is one of the major coarse grain crops and is considered as **poorman's food.**
- It provides **staple food for the poor** in **relatively dry tracts of Asia and Africa.**
- It is the **most drought tolerant crop** among **cereals and millets.**
- Pearl millet is having greater ability to withstand extremely dry climates and can tolerate salinity, poor fertility and high temperatures.
- It is the **fifth important food crop of the world** and **important millet,** known for **high nutritive value.**

Bajra grains contain about

- Moisture-12.4%, protein-11.6%, fat-5%, CHO-67.5%, mineral-2.3%, fibre-1.2%, Ca-50mg, P-269 mg, Fe-14 mg.

- The protein is rich in **tryptophane** and **cystine** but **lysine is absent.**

- Bajra is cooked like **Rice (paraboiled rice in west africa)** or **Chapaties/ roti in India** are **prepared out of flour**

- It is also used as **feed for poultry** and **fodder for cattle.**

- Draw back of the bajra seeds is if seeds are affected by **ergot disease (0.3-0.4%)** due to **ergotinine alkaloid** if consumed by human beings causes **giddiness, vomiting, dirrhorea.**

Origin and distribution

- It is originated from **Sahel region of Western Africa**

Area and Distribution

- **Bajra** occupies as much as **50% of all millets grown in the world.**
- The global statistics pertaining to bajra is combined with those of other millets, hence not distinguishable.
- Globally, millets are grown over **27 m. ha with production of 36 mt.**
- Over **93% of global area of millets** is in **Asia and Africa.**
- **India** alone has **9.8 m. ha area** (43% of global area) with **production of 9.4 mt (largest in the world).**
- Other countries growing millets in large scale are **China (1.1 m. ha), Myanmar (0.2 m. ha), Nepal (0.2 m. ha) and Pakistan (0.3 m. ha)**

- In India, it is mainly grown in the states of **Rajasthan (51%)** followed by **Maharashtra (15%)** and **Gujarath (10%).**

- Other states cultivating bajra in negligible area include **UP, Karnataka, TN, AP and Haryana.**

- The productivity of Bajra is **higher** in the states of **MP and Haryana (1331 kg ha^{-1}),** while **Rajasthan and MH** having **low productivity of 673-788 kg ha^{-1}.**
- In Karnataka grown in **Belgaum, Gulbarga, Raichur, Bidar, Chitradurga.**

Climatic requirements

- It requires hot climate throughout the crop growth period.
- Bajra can be grown in extreme arid condition (400-450 annual rainfall) and having high degree of resistance for drought.
- In Rajasthan, bajra can be grown successfully in regions with 200 mm rainfall.
- It germinate in the temperature range of 15-40^0 C, ideal temperature for growth and development is 30-35^0 C. It can withstand temperature up to 40^0 C.
- If temp <15^0 C germination will be affected, if temp <25 and >40^0 C growth and development will be affected.

- Rainless period is necessary for flowering and grain development.
- High humidity during grain development enhances the possibility of ergot disease.
- The crop may tolerate drought but cannot withstand high rainfall of 900mm or above.

Soil requirements

- Bajra can be grown on a wide variety of soils, **but being sensitive to water logging,** it does best on well drained sandy loams and clay loams.
- It is grown successfully on **black cotton soils, alluvial soils** and **red soils of India.**
- Bajra is sensitive to **acidic soils.**

Land Preparation

- The crop needs very fine tilth because the seeds are very small.
- It is essential to do deep summer ploughing by mould board plough.
- After the onset of monsoon the field should be harrowed twice (or) thrice or ploughed by country plough.
- Care should be taken to remove all the weeds and stubbles from the field.
- The field should be levelled and drains should be provided in the field.

Sowing season

Most of the varieties developed in India are photo-insensitive which permits in growing the crop during *kharif, rabi and summer seasons.*

- **Kharif :** June -July
- **Rabi :** Sept-Oct
- **Summer :** First fortnight of January
- Avoid late planting beyond **July 15th** (In case, sowing is delayed there is a drastic reduction in yield due to more incidence of diseases like downy mildew or ergot, restricted vegetative growth of the crop, high rate of mortality and poor grain setting).

SEEDS AND SOWING

Method of Sowing:

1. Broadcasting
2. Drilling
3. Dibbling and
4. Transplanting

- Among various method, Drilling is most popular.
- Thinning and gap filling should be done at 10-15 DAS.

Seed rate: Drilling – 5 kg ha^{-1}

Dibbling – 3 kg ha^{-1}

Spacing: 45 x 15 cm

Sowing depth: 3 - 4 cm

Bajra cultivars

Varieties	Sowing time	Duration	Yield (q ha^{-1})	
			Seed	Straw
Irrigated				
WCC-75	1st June – 15th July	85-90 days	30-35	100
PHVB-910	1st June – 15th July	85-90 days	30-35	100
Rainfed				
WCC-75	1st June – 15th July	85-90 days	12-15	70-75

Other varieties: BJ-104, BK-560, BD-111, MBH-110, ICMH-451

Nutrient Management

- It is crop of poor and marginal fertility soils.

FYM: 6 t ha^{-1}.

NPK: Irrigated: **100: 65: 25 kg ha^{-1}**

Rainfed: **50: 25: 0 kg ha^{-1}**

Basal dose: 50% N & full dose of P & K

Split dose: 50% N at 30-35 days.

- In rainfed crop, entire quantity should be applied at the time of sowing.

Water Management

- Water requirement of Bajra is **40-45 cm.**
- Generally it is grown as **rainfed crop and drought resistant in nature** but responds well to irrigation.
- However, in case of no rains, the crop may be irrigated **once or twice to a depth of 5 cm**, especially in **heading and grain development stage.**
- Whenever the crop is irrigated, it is always useful to adopt the **ridges and furrow method.**

Critical stages of irrigations are

1. Germination (at the time of sowing)
2. Tillering stage (20-25 DAS)
3. Flag leaf stage (50-55DAS)
4. Flowering (60-70 DAS)
5. Grain formation stage (80-90 DAS)

Under irrigated condition:

- In **sandy loam soils** irrigation should be given at once in **10 days,** where as in **clay loam soils** irrigation should be given at **20 days once,** in general **4-5 irrigation is required** for successful crop of Bajra.

Weed management

- Crop weed competition in Bajra is up to **35-40 DAS.**
- After 40 DAS weeds will be suppressed due to **shading effect of the main crop.** Hence, it is necessary to control weeds till 35-40 days.
- Inter cultivation is done in between rows at 15 and 30 DAS with small implements i.e., small blade harrow - i) to remove weeds
  ii) to stir/loose the top soil
  and iii) to give slight earthing up to bajra plants
- Pre-emergent application of **Atrazine 50 % WP @ 0.5-0.75 kg a.i./ha.**
- Post-emergent application of **2,4-D @ 0.75-1.0 kg a.i./ha** at 15-20 DAS

Cropping system

- **Short duration, drought resistance and suitability to poor fertility** have made pearl millet suitable for both intercropping and sequence cropping.

Sequence cropping: Pearlmillet- Wheat
Pearlmillet - Cowpea
Pearlmillet- Barley

Intercropping system: Pearlmillet + Mungbean (8:2)
Pearlmillet + Urdbean (8:2)
Pearlmillet + Fingermillet (8:2)

Harvesting and yield

- Crop will be mature at 85-90 days after sowing.
- Harvesting will be done by cutting entire plant at base or simply cutting the ear heads.

Yield:

- **Irrigated:** 30-35 q ha^{-1} of seed and 100 q ha^{-1} of straw yield.
- **Rainfed:** 12- 15 q ha^{-1} of seed and 75 q ha^{-1} of straw yield.

Anti-nutritional factors

- Bajra grains contains **polyphenols (tannins)** and **phytic acid.**
- Tannins reduces digestion of proteins and phytic acid reduces bio- availability of minerals.
- Bajra may also contain mycotoxin like Fusarium toxin, which is carcenogenic.
- People who consumes bajra on regular basis as staple food are likely to be affected by **"Goiter"** - an abnormality caused by abnormal hormone secretion by thyroid.

Reasons for low yield of coarse millets

1. Marginal lands are used for their production than other cereals.
2. They are confined to small production units
3. They are often grown as intercrops
4. Uncertain precipitation trends
5. Limited commercial demand

- Finger millet also known as ragi in kannada, kelvragu in tamil, ragi in telagu and muttari in malayalam.
- The common name finger millet is derived from the **finger like branching of the panicle.**

Importance of finger millet

- It is an important minor millet grown in India.
- It is a staple food crop in many hilly regions of the country. In fact, it is the main cereal crop for monsoon season in some hilly areas.
- It is predominantly grown as a **dry land crop** in Karnataka, Andhra Pradesh, and Tamil Nadu.
- Finger millet contributes nearly 40% of total small millet produce of India, occupying nearly 3.2 million ha.
- Ragi is relished mostly by the rural population of southern India for the nutritious meal it provides.

Nutritional importance

- Finger millet is the richest source of calcium (300-350 mg/100 g grain).
- Finger millet contains 65-70% CHO, a high proportion of which is in the form of non starchy polysaccharides.
- It also rich in dietary fiber (3.6 g/100 g) which helps in prevention of constipation, lowering of blood cholesterol and slow release of glucose to the blood stream during digestion.
- The regular finger millet consumer is having low incidence of cardiovascular diseases, duodenal ulcers and diabetes.
- Germinating grains are malted and fed to infants.
- It is also good for pregnant woman.
- It is a nutritive food for adults of different ages

Origin of Finger millet

- According to **Decandoll (1886)** Finger millet probably originated in **India.**
- It might have originated from ***Eleusine Indica,*** a grass that occurs in many parts of **North India.**

- **Vavilov (1951)** – considers ***Eleusine coracana*** to be of ***African origin.***
- It is grown in **India, Africa, Malaysia, Srilanka, Japan & China.**
- **India is the leader** in the area of finger millet improvement.

Area and distribution

- Ragi is widely cultivated in **India, Africa, Sri Lanka, Malaysia, China and Japan.**
- **In India,** Karnataka, Tamilnadu, Andrapradesh, Maharashtra, Orissa, Bihar, Jharkand etc.
- In India it is cultivated in an area of **2.50 m.ha** with a production of **2.20 mt.**
- **Karnataka** is the major state for finger millet production in India, accounts for **55.6% of the area** and **60.7% of production** in the country.
- In Karnataka, Area: **9.16 lakh ha**, Production: **14.02 lakh tones** and **productivity of 1611 kg/ha.**
- It is mainly grown in Haveri, Bellary, Chitradurga, Mandya, Mysore and Bangalore districts.

Climatic requirements

- It is a crop of **tropical** and **subtropical climate.**
- It can be grown successfully up to an altitude of **2100 MSL on hill slopes** as well as in **plains.**
- It is a **hardy crop** and **drought tolerant in nature.**
- It is grown in an areas with annual rainfall between **500 to 1000 mm.**
- Ideal temperature is **25-30^{o}C** and it can withstand temperature up to **40^{0} C.**
- It can be grown under **rainfed** as well as **irrigated conditions.**

Soil requirements

- It can be grown on a **wide variety of soils** ranging from **very poor to very fertile soils.**
- It thrives best on **well- drained sandy loam soils.**
- **Clayey soils, heavy black cotton soils, gravelly** and **stony soils with poor fertility and drainage** are **not suitable.**
- It can tolerate **salinity better than other cereals** with the pH range of **5.5 to 8.0.**

LAND PREPARATION

- The first ploughing with mould board plough should be done immediately after the harvest of the previous crop.
- With the onset of monsoon, field should be ploughed with local plough 2-3 times and finally levelled.
- Seeds are very small and take 5-7 days to germinate.
- Hence, good seeds and land preparation helps in better germination, minimizes weeds problems and effective soil moisture conservation.

Seeds and sowing

- Finger millet is not a season bound crop. So, it can be grown through out the year, if water is available.

1. **Early kharif:** April - May
2. **Kharif:** June - July
3. **Late Kharif:** August - September
4. **Rabi:** Oct - December
5. **Summer:** January - March

Methods of sowing:

1. **Broad casting** – rainfed condition
2. **Drilling (Seeding behind plough)** – rainfed condition
3. **Transplanting –** irrigated condition

Seed rate and spacing:

1. **Seed drilling – 12.5 kg ha^{-1} with 30 x 10 cm**
2. **Transplanting – 5 kg ha^{-1} with 20 x 10 cm**

- In transplanting conditions, Seedlings are raised in nursery bed for 20-25 days and then it is transplanted to main field.

Varietal development in Finger millet

The crop improvement work on finger millet has been carried out in 5 phases at Zonal Agricultural Research Station, V. C. Farm, Mandya (UAS,Bangalore).

Phase I (1931-1951): 11 varieties were released which had an yield potential ranging from **285-512 kg/ha,** which were mostly developed from indigenous collections.

Phase II (1951-1964): Dr. Leslie C. Colman, an eminent Canadian scientist and 1st Director of Agriculture and 1st Associate Director of Research of Zonal Agricultural Research Station ,VC Farm, mandya, made **pure line selections** which had an yield potential of **900-2700 kg/ha.**

Phase-III (1964-1986): witnessed a revolution in finger millet varietal development due to the **introduction of Indo-African crosses of finger millet** by late **Dr. C.H. Lakshmanaiah,** who has been regarded as **"Ragi Brahma"**, his pioneering work resulted in release of **16 varieties** designated as **'INDAF' series.** The yield levels of these verities ranged from **3000-4500 kg/ha.**

Phase IV (1986- 2000): the yield potential has further improved ranging from **4500-5000 kgs/ha** with the development of **"MR Series"** of varieties, which are **resistant to Blast disease.**

Phase V (2000-2012): upon establishment of AICSMIP, emphasis was laid on developing productive lines of **"KMR & GPU Series"** varieties which are suitable for late sowing condition with shorter duration.

Recommended varieties

Varieties	Sowing time	Duration (days)	Grain yield q ha^{-1}	Straw yield q ha^{-1}
Long duration varieties				
Indaf-8	June-July	120-125	40-45 q (I) 22-30 q (R)	90-100 q (I) 50-75 q (R)
MR-1	June-July	120-125	40-45 q (I) 22-30 q (R)	90-100 q (I) 50-75 q (R)
MR-6	June-July	120-125	40-45 q (I) 22-30 q (R)	90-100 q (I) 50-75 q (R)
Medium duration				
Indaf-5	June-August Jan - Feb	105-110	30-35 q (I) 20-25 q (R)	80-90 q (I) 45-60 q (R)
ML-365	June-August Jan - Feb	105-110	30-35 q (I) 20-25 q (R)	80-90 q (I) 45-60 q (R)
GPU-28	July - August	110-115	30-35 q (I) 20-25 q (R)	80-90 q (I) 45-60 q (R)
Indaf-9	April- May Aug – Sep Jan - Feb	100-105	30-35 q (I) 20-25 q (R)	80-90 q (I) 45-60 q (R)
KMR-204	July - August	100-105	30-35 q (I) 20-25 q (R)	80-90 q (I) 45-60 q (R)
GPU-48	April- May Aug – Sep Jan - Feb	100-105	25-30 q (I) 18-20 q (R)	70-75 q (I) 40-50 q (R)
GPU-45	All the season	95-100	25-30 q (I) 18-20 q (R)	70-75 q (I) 40-50 q (R)
Winter Season (September - October)				
Indaf-7	Sep - Oct	115-120	30-35 q (I) 20-25 q (R)	80-90 q (I) 45-60 q (R)
KMR-301	Sep - Oct	115-120	30-35 q (I) 20-25 q (R)	80-90 q (I) 45-60 q (R)

White Ragi Variety: KMR-340

Indaf-11

➢**Suitable for kharif season only**

Nutrient management in Finger millet

FYM: 10 t ha^{-1} (irrigated)

7.5 t ha^{-1} (rainfed)

Bio fertilizer: Seed treatment with Azospirillum @ 400 g ha^{-1} seed.

NPK: 100:50:50 kg ha^{-1} (Irrigated)

50:37.5:40 kg ha^{-1} (Irrigated)

- 50% N and full dose of P & K should be applied at the time of sowing.
- Remaining 50% N should be top dress at 30 DAS.

Weed management

- It is essential to control weeds in the initial stage of plant growth and development.
- Critical period of crop weed competition is **25-30 DAS.**
- Carrying out **intercultural operation** by passing blade harrow for **2-3 times after 15 DAS at an interval of 10 days** helps in controlling the weeds.
- Pre-emergent application of **Butachlor 50% EC @ 2.5 lt/ha or Pendimethalin 30% EC @ 2.5 lt/ha.**

Water management

- Water requirement of Fingermillet is **40-45 cm.**
- Generally it is grown as **rainfed crop and drought resistant in nature** but responds well to irrigation.
- Under irrigated condition, crop should be irrigated **once in 10-15 days in sandy soils** and **once in 20 days in clay soils.**
- Crop is highly **susceptible to excess water/ water logging** condition hence proper drainage should be ensure in heavy soils.
- The **critical stages for irrigation are**

1. Tillering
2. Panicle initiation
3. Flowering
4. Grainformation stage

Cropping system

The major cropping system followed in

1. Crop rotation
2. Intercropping
3. Mixed cropping
4. Strip cropping


Crop rotation with groundnut

Cropping sequence

North India	South India
Ragi - Mustard	Ragi - Tobacco
Ragi - Gram	Ragi - Groundnut
Ragi - Barley	Ragi - Potato - Maize
Ragi - Linseed	Ragi - Potato - Ragi
Ragi - tobacco	Ragi - Sugarcane

Inter cropping system

1. Ragi + Redgram (8:2)
2. Ragi + Field bean (8:2)
3. Ragi + Niger (8:2)
4. Ragi + Ground nut (8:2)
5. Ragi + Green gram/Black gram (8:2)
6. Ragi + Sorghum (8:2)

Harvesting and yield

- The crop matures in about 100-120 days depending on the variety.
- Irrigated or transplanted crop produces more tillers than that grown in drylands.
- Harvesting can be done by whole plant harvest or harvesting only ear heads.

Grain and straw yield: 35-45 q ha^{-1}, 90-100 q ha^{-1} (Irrigated condition)
20-30 q ha^{-1}, 70-75 q ha^{-1} (Rainfed condition)

- The word pulse or legume is derived from Latin word '**Legre**' meaning '**To gather'** because the **pods have to be gathered or picked by hand.**
- These are belongs to the family **Leguminaceae,** form **Nitrogen fixing nodules on their roots.**
- The pulses after splitting produce **Dal** which is a rich source of **proteins.**

- **Indian Institute of Pulse Research (IIPR)** was established in **1993 at Kanpur**
- **In 1992-93, Technology Mission on Pulses** was started by 2 sub terms.

a) NPDP: National Pulse Development Programme.

b) SFPP: Special Food grain Production Programme.

Per capita requirement of Pulses

- Acc. To **ICMR – 150gm /day** and Acc. To **FAO – 140gm /day**
- At present, the per capita availability of pulses in India is only **47gm/day.**

AREA, PRODUCTION AND PRODUCTIVITY OF PULSES IN INDIA

- India is the **largest producer** and **consumer of pulses** in the **world**.
- **Protein requirement** is predominantly substituted with **pulses.**
- India accounts for **33% of total world area** under pulses and **25% of total world production.**
- **Kharif pulses** (Pigeon pea, black gram, green gram, horsegram, Mothbean, Cowpea) cover **45% of total area** and **30% of total pulse production.**
- **Rabi pulses** (Chick pea, pea, lentil, lathyrus) cover **55% of total area** and **64% of production.**

Major pulse producing states in India

Sl. No.	Name of the state	Sl. No.	Name of the state
1	Madhya Pradesh	6	Andhra Pradesh
2	Maharashtra	7	Karnataka
3	Tamil Nadu	8	Rajasthan
4	Gujarat	9	Bihar
5	Odisha	10	West Bengal

- **Area: 23 m.ha, Production: 13-14 mt.**
- **Haryana** has the highest productivity **880 kg/ha.**
- National average productivity is **570 kg/ha.**

Importance of Pulses

- They are **rich source of proteins.**
- The average protein available in pulses is **20-30%.** Pulses are rich in **'Ca' & "P".** They are also good sources of **Vitamins.**
- Pulses provide a **superior quality of fodder & feed** to the cattle, as they are good forage crops with **proteins and minerals content.**
- They are considered as **good green manure crops** because of rich canopy development.
- They improve the **soil fertility** by **biological nitrogen fixation.**

- The **nitrogen needs of pulses is low** & minimizes the N requirement of succeeding crop by around ¼ of its total requirement.
- Pulses help in **Soil and Water conservation.**
- They improve the **physical condition of the soil-** soil aeration, water holding capacity by improving microbial population, breaking of hard pans and moisture retention.
- Pulses are important in **crop mixtures /rotation.**
- They act as **catch crops.**
- Some crops act as **smothering crops** which control weeds & protects soil from erosion E.g.:- Cowpea and Horse gram.
- Pulses can also be used as **better intercrops.**

REASONS FOR LOW YIELDS OF PULSES IN INDIA

The following have been realized as the major constraints in pulse production.

I. Agronomic constraints.

II. Genetical constraints

III. Physiological constraints

I. Agronomic constraints

1. Improper sowing time

- The pulse crops gets last preference and priority in the sowing schedule.
- Late planting not only results in poor growth but also leads to high attack of sucking pests.

2. Low seed rate

- Farmers hardly use recommended seed rate.
- Very poor plant population has been reported in case of arhar, moong and urd in the farmers fields.

iii) Defective method of sowing

- Pulses are hardly sown in rows and become problem in timely operation of weeding, hoeing, spraying, harvesting etc.

iv) Inadequate intercultural operation

- Farmers hardly follow intercultural operation in these crops.
- Pulse crops suffer due to the infestation of weeds because of their initial slow growth.

v) Insufficient irrigation

- Though pulse crops are drought tolerant, one or two protective or life saving irrigations are required, particularly in rabi pulses.
- Production can be enhanced if irrigation is provided at pod development stage of pulse crops.

vi) Sowing under utera cultivation

- Large area under pulses is sown as utera without cultivation and inputs. The yields of such crops is very poor.

vii) Poor management conditions

- Being protein rich crops, pulses require more energy input per unit of production as compared to cereals.
- But on the contrary, they are grown under conditions of energy starvation resulting in poor yields.

viii) Non-availability of efficient Rhizobium culture

- Symbiotic nitrogen fixation takes place very effectively between the legume cultivar and its specific strain of Rhizobium.
- the specific cultures of desired quality are not readily available in the market.

ix) Weed infestation:

- Because of their inherent slow growth rate at the initial stage, pulse crops suffer due to infestation of weeds.
- If weeds are not controlled during this period, marked crop losses ranging from 30-50% have been recorded.

x) Losses due to diseases and insects pests

- Pulses in general are susceptible to a large number of **diseases and insect pests**, which cause **heavy losses.**
- **Multiple resistant varieties** are not available in the pulse crops.

II. GENETICAL CONSTRAINTS

- Lack of suitable genotypes with higher yield potential.
- Lower productivity.
- Non synchronous flowering/fruiting.
- Non-responsiveness to good management.
- Complete or partial absence of genetic resistance to major diseases and pests (eg: *Helicoverpa armigera* under continuous rainfall, causes wilt and sterility mosaic in redgram etc.)

- Indeterminate growth habit of most of the pulses.
- Instability in performance.
- Lack of good and quality and certified seed.
- Non-availability of drought and water logging resistant varieties.

III. PHYSIOLOGICAL CONSTRAINTS

1. Low harvest index
2. Low sink potential

- A lot of dry matter goes for production of stalk, with the result the harvest index is very low.
- For example, in **pigeonpea** out of about **15,000kg total dry matter** produced, the grain share was only **10 percent**.
- On the other hand, in case of most of **dwarf wheats,** the grain share is even more than **33% of the total dry matter.**

3. **Flower drop** is another physiological problem in pulse crops.

- This results in poor pod setting and consequently low yield.

4. Non-responsiveness to fertilizers.
5. Photo and thermo-sensitive phenomenon.
6. Lack of **short duration varieties.**

STRATEGIES FOR IMPROVING THE PRODUCTIVITY OF PULSES

1. Bringing an additional area under **short duration high yielding varieties** to fit in multiple cropping programmes to be grown as **catch crop.**
2. Developing **new cropping systems** like **companion cropping, mixed cropping (or) intercropping** for growing pulses between widely spaced crops such as sugarcane, maize, potato, cotton, arhar, groundnut, bajra and jowar etc. Both under irrigated and rainfed conditions.

3. Multiplication and use of improved seeds of various pulses.

4. Adoption of **efficient plant protection measures.**

5. **Basal placement of phosphatic fertilizers** and treating the seeds with **suitable rhizobium culture.**

6. Growing pulses on **relatively fertile lands** rather than growing them on marginal and sub marginal lands.

7. **Adoption of improved package of practices** like line sowing, control of weeds, harvesting at right time or at physiological maturity to avoid splitting of pods and thereby minimising shattering losses.

8. **Granting subsidy on Government loans** to the growers and providing improved seeds, fertilizers and plant protection materials on concessional price to the farmers.

9. Evolution of **better plant-types of pulses** for boosting pulse production.

New plant ideotypes in pulses

a) non-spreading and erect types.

b) Thermo and photo-insensitive.

c) Early maturing

d) Responsive to applied inputs with high yield potentials.

e) Fairly resistant to water logging, insect pests and diseases.

f) Resistant to drought and frost.

g) High nutritional qualities.

Importance of chickpea

- Chick pea contains **21% protein, 2.2% fat, 62% carbohydrates.**
- It also contain **calcium of about 190 mg/100g**; **Iron 90.5 mg/100g**; **Phosphorus 280 mg/100g.**
- Among the pulses, chick pea has **relatively lower protein content** but of **higher biological value** and **protein digestibility.**
- Germinated seeds can help in **curing scurvy disease.**
- ❖ Scurvy is the name of **vitamin C deficiency.** It can lead to **spontaneous bleeding.**

- Leaves and pods contains **two types of acids.**

  i) Malic Acid (90-96%)

  ii) Oxalic Acid (4-10%)

- Which are used in the preparation of **drugs**, and are prescribed for the **intestinal dis-orders** and **blood purification.**
- Soaked seed and husk are fed to cattle's as a fodder.

Health benefits of chickpea

- Chickpea are good source of **fibre helps in weight loss**
- Chickpea are a good source of **protein and energy**
- Chickpea helps in **stabilizing sugar levels in blood**
- Chickpea may helps in reducing **LDL cholestrol**
- Chickpea may **boost energy level** due to their **iron content**
- Chickpea have **low glycemic index (GI)** which is good for **diabetic patients.**

Area, Production and productivity

- **77% of total area and production** in world is from **India.**
- Important countries growing chick pea are Pakistan, India, Turkey, Mexico, Burma, Ethiopia.
- In India – **Madhya Pradesh** ranks first in Area (2.6 m.ha), production (2.4 m.t) with a productivity of 930 kg/ha followed by Rajasthan.
- The three states **Madhya Pradesh, Rajasthan, Uttar Pradesh** accounts for **84% of Area, 86% production in the country.**
- National average productivity is **810 kg/ha** where as higher average productivity is **1.8 t/ha in Egypt.**

Climatic requirements

- It is a **rabi pulse crop.**
- It requires **cool humid weather.**
- Chick pea is a **long day plant** and requires **sufficient bright sunshine**.
- It is suited for moderate rainfall areas of **400-700mm.**
- **Water-logging** results into **wilt diseases.**
- Optimum temperature regime for chick pea is **24-30°C.**
- The **period of cool temperature decides the duration of the crop**, because of which in **North India**, it comes to harvest in **160-170 days.**
- Where as the **winter is warm in South India** then the duration is shorter of about **90-110 days.**

Soil Requirements

- It can grow on wide range of soils from **medium to heavy black soils.**
- It grows well on **black cotton soils** and **sandy loams.**
- Optimum pH required for crop growth is **6.0 to 7.5 (>8.5pH not suitable).**
- It does not withstand **water -logging, saline and alkaline conditions.**

Types and Varieties in Chickpea

- There are 2 important varietal types available in India, They are

a) Desi type

b) Kabuli type

- Most cultivated type of chick pea is **Desi type.**

Differences between Desi type and Kabuli type

Sl. No	CHARACTERS	DESI TYPE	KABULI TYPE
1	**Area under cultivation**	More area	Less area
2	**Colour of the seed**	Yellow to dark brown	White (or) Pale cream
3	**Size of the seed**	Small	Large ,
4	**Shape of the seed**	Irregular and wrinkled	bold and attractive
5	**Plant structure**	Small and bushy	Taller and erect
6	**Percentage of production**	85%	15%
7	**Yield potential**	High yielders	Low yielders
8	**Adaptation**	Mostly to winter climates	Mostly to spring
9	**Test weight**	17-26 gm /100seed	>26 gm /100 seeds
10	**Place of cultivation**	India and Bangladesh	Africa, Europe, Afghanistan, Pakistan and Chile

Land preparation

- Gram needs **cloddy and rough seed-bed** for **good aeration in root zone.** Hence, a **little land preparation is required.**
- **Very fine and compact seedbed** is not good for chick pea.
- **One ploughing** with MB plough followed by **one harrowing** is enough under normal condition.
- If chick pea crop is taken after a **kharif fellow**, it is recommended to go for **one deep ploughing** during the monsoon which helps in **conservation of rain water** in the soil profile for subsequent use by this crop.

SEEDS & SOWING

- **Date of sowing** has been recognized as **single non-monetary input** affecting the yield of chick pea in all chick pea growing areas.
- Since it is a **Rabi season crop**, optimum time of sowing is **15th Oct – 15th Nov.**
- **Seed rate:** Desi Type **65-70 kg ha^{-1}**

  Kabuli type **80-100 kg ha^{-1}**
- **Spacing:** Desi type **30x10cm.**

  Kabuli type **45x10cm.**
- **Depth of sowing:** 6-8 cm.

Seed treatment

- If chickpea growing area is affected with **wilt disease**, then seeds should be treated with **Carbendazim @ 2g/kg seed or Trichoderma @ 4g/kg seed.**
- If chickpea area is not affected with wilt disease then seeds should be treated with **Rhizobium strain** namely ***Cicer rhizobium*** **@ 500 g ha^{-1} seed + PSB @ 500 g ha^{-1} seed.**

Chickpea varieties

Varieties	Special character	Duration (Days)	Spacing (cm)	Yield (q ha^{-1})	
				Irrigated	Rainfed
Annigeri - 1	Drought resistant	95-100	30 x 10 cm	15-20	7.5 - 10
J.G. - 11	Wilt and drought resistant	95-100	30 x 10 cm	15-20	7.5 - 10
Vishal	Bold seeded desi type	100-110	30 x 10 cm	15-20	7.5 - 10
K.A.K.-2	Kabuli type	80-85	45 x 10 cm	20-25	10-15

Nipping

- Is nothing but **removing the apical buds** of the crop at **30 DAS,** it **stops apical growth (apical dominance) and promotes the lateral branching,** thus the plant become more **vigorous and produce more flowers and pods** and **increases the yield.**
- For Kabuli varieties **nipping is not necessary.**

Nutrient management

- The crop comes up well with a **residual soil fertility.**
- However, the recommended dose of fertilizer for chickpea is
- **Irrigated:** 25:50:50 kg NPK ha^{-1}
- **Rainfed:** 12.5:25:25 kg NPK ha^{-1}
- **'Zn' deficiency** can be corrected by **0.5% $ZnSO_4$ as foliar spray** or **soil application of 25kg/ha.**
- **2% urea foliar spray** at 10 DAS and at flowering stage helps in increasing yield.
- **DAP (Di-ammonium phosphate)** is considered as a best fertilizer in pulses as a source of nitrogen and phosphorous.

Water management

- Gram is mostly grown as a **rainfed crop under residual soil moisture condition.**
- **55% area** of chickpea is under **Rainfed condition.**
- The water requirement of the crop varies from **250-400 mm.**
- Under **drought conditions,** the crop requires **2 light irrigations at critical stages** . 1) at branching (45 DAS) and

  2) at pod formation (75 DAS)
- If water is available **in adequate**, then 4 irrigation should be given at
  1) **Sowing**
  2) **Branching**
  3) **Flowering**
  4) **Pod filling**

Weed management

- Weeds become problematic in chickpea due to its **slow growing nature.**
- The critical period of crop weed competition is **20-25 DAS.**
- Following intercultural operation at **15 and 30 DAS** + **1 manual weeding at 45 DAS.**
- Application of pre-emergent herbicide **pendamethalin @ 2 liters/ha** followed by **one hand weeding at 30 DAS.**

Cropping system

Cropping sequence

- Rice – Chick pea
- Cotton – chickpea

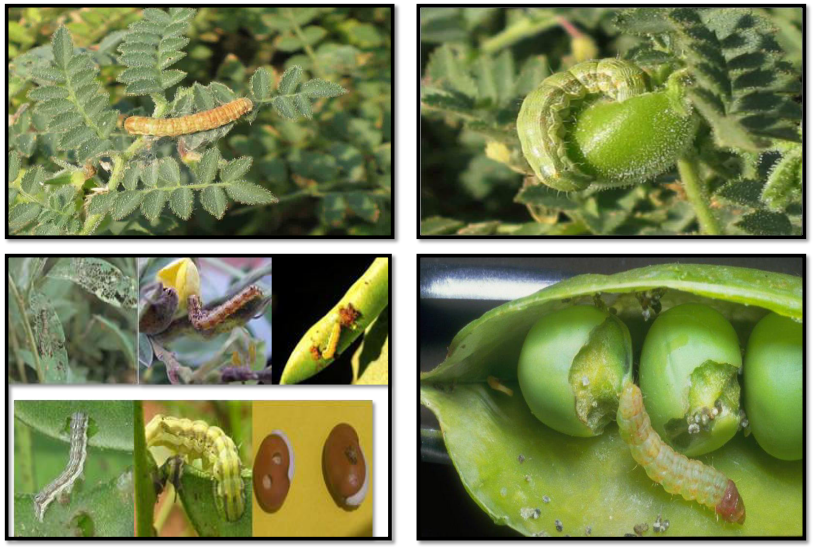
Intercropping

- Chick pea + Mustard
- Chick pea + Linseed
- Chick pea + Sunflower
- Chick pea + Coriander (for South zone)

Harvesting and yield

- In **North India** chickpea duration is **160-170 days.** In **South India** crop comes to harvesting with in **90-110 days.**
- Crop is harvested when **leaf turns to reddish brown and leaf starts shedding.**
- Harvesting is done during **morning to avoid shattering of pods.**
- Plants are pulled out or cut with a sickle and carried to threshing floor.

Yield: 15-20 q ha^{-1}



Pod borer: Serious pest in pulses and leads to 75% yield reduction.

- Generally called as **Garden pea/ field pea.**
- being a legume fixes atmospheric nitrogen and it is rich in **protein** and **essential amino acids.**

Food value:

Protein =22.5%

Fat – 1.8% CHO 62.1 %

Ca= 64 mg

Fe-4.8 mg

Riboflevin-0.15mg

Thiamin- 0.72 mg

Niacin-2.4 mg

Origin and distribution

- **Mediterranean region** is the primary centre of origin.
- **China** first in **area and production,** USSA, Ethiopia and USA.
- **In India, UP stands first** in **area and production**, MP, Bihar, Punjab, Haryana.

Classification of peas

Garden pea	Field pea
➢*Pisum sativum* var. hortense	➢*Pisum sativum* var. harvense
➢Flower colour is white/ cream	➢Flower colour is purple
➢Seed is wrinkled	➢Seed is smooth
➢Sweet to high sugar content	➢Less sweet due to high amount of starch
➢Grown for vegetable and canned purpose	➢Grown for dhal and green manure

Soil and Climatic requirements

- It is a **rabi** pulse crop, requires **cool growing season with moderate temperature.**
- **High temperature** is more injuries than frost.
- **Frost at flowering** will damage the crop.
- **Sensitive to moisture stress** at flowering and high humidity favors disease incidence.
- Optimum temperature is **13-18 ^{o} C.**
- It is suited for moderate rainfall areas of **400-700mm.**
- **Water-logging** results into **wilt diseases.**
- Weel drained soils with **6-7.5 pH** is optimum and sensitive to water logging. **Loamy soils are ideal.**

Seeds and sowing

- The pea is generally sown in India in **Rabi season** from the **Mid of October** to **mid of November.**

Method of sowing:

1. Broadcasting

2. Line sowing using seed drill

Seed rate: 60-80 kg ha^{-1}

Spacing: 30 x 10 cm (Garden pea) and 45 x 10 cm (Field pea)

Depth of sowing: 4-5 cm

FYM: 7.5 t ha^{-1}

NPK: 25:50:50 kg ha^{-1}

Water management

- Water requirement is **400-500 mm**.
- **Tolerant to drought** to some extent, **by one or two protective** irrigation higher yields can be obtained.
- First irrigation at **45 DAS** and second at **pod filling stage.**
- **Light** and uniform irrigation is best.
- **Highly sensitive to water logging** (even for a day) and therefore provide good drainage.

Cultivars, harvesting and yield

Cultivars:

Table peas: Arkel, Bonnvelle, Early badger, Early Dee.

Field pea: Type-163, PG3, Aparns, Hans, Swarna Rekhs, Alankar, DMR-7, 11, KEP-103.

Harvesting: Harvest the crop when the pods fully ripe and threshed after complete drying.

Yield: 20-25 q ha^{-1} and green pods 10-12.5 t ha^{-1}.

Vernacular names of redgram

- **Arhar**
- **Tur**
- **Pigeon pea**
- **congo pea**

Importance of redgram

- Pigeon pea is the **second most important pulse crop** of India after chickpea.
- Contain **22.3% protein, 1.7% fat, 1.5% fiber, 57.6% CHO, 3.5% minerals.**
- Rich in **Ca, Fe, P** and **essential amino acids** like **lysine, argenine, riboflavin, thiamine, niacin.**
- Primarily used as **dhal, tender green seeds as vegetable, crushed dried seeds & seed coat** as **animal feed** and **green leaves as fodder.**

- It helps in **soil rejuvenation:**
  - release of **soil bound phosphorous,**
  - **atmospheric nitrogen fixation,**
  - **recycling of soil nutrients** and
  - **addition of organic matter** and **other nutrients.**
- Hence, pigeonpea crop is a **ideal crop of sustainable agriculture** in the **tropical and sub-tropical regions** of India.
- It is **deep rooted leguminous crop**, it can withstand **severe drought after germination.**

Classification

1. *C. Cajan* var. bicolour:

- **Perennial, late maturity, large bushy plant bearing purple streaked yellow flowers,** mostly grown in **North India.**

2. *C. Cajan* var. flavus:

- **Annual, early maturity, short bushy and yellow flowers**, mostly grown in **south India.**

Origin of redgram

- Its actual place of origin is **very controversial** as some people believe, it originated in **India**, while others say, it originated in **Africa.**
- According to **Vavilov (1928)**, genus Cajanus originated in the Hindustan. As per **Van Der Maesen (1980)** also, the centre of origin of the crop is **India.**
- According to **Bentham (1861)** and **De Candolle (1886),** it originated in **Africa.**

Area and distribution

- India ranks first with about **90% of the world area** and **85% of production.**
- Other important countries growing red gram are **Africa, West Indies, Ceylon, Australia and Malaysia, China.**
- In India, it is grown in an **area of 3.61 m.ha, 2.70 m production with productivity of 747 kg ha^{-1}.**
- In India : **Maharashtra, UP, Karnataka, MP, Gujarat, AP** are major states.
- In India, **Maharashtra, U.P & M.P** together occupy **62% of the area** & **73% of total production.**

Climatic requirements

- It is a **short day plant**
- It is grown in **tropical, sub-tropical & warmer regions** between **30^{o} N & 35^{o} S latitude.**
- It prefers **moist and warm climate - vegetative period.**
  cool and dry period - reproductive stage.
- It can tolerates **heat and drought.**
- It is susceptible to frost.
- **Rainfall: 500 to 600 mm**
- **Temperature: 10-40^{0} C** but optimum temp is **20-28^{0} C.**

Soil requirements

- It can be grown on a wide range of soil from **Sandy loams to clay loams.**
- The crop performs well on **fertile well drained clay loamy soils.**
- **Saline, Alkaline and waterlogged** are not suitable.
- Optimum pH for redgram cultivation is **6.5-7.5.**

Seeds and sowing

Sowing season:

- Redgram is cultivated purely under **rainfed condition.**
- Hence, this crop should be sown during **kharif season.**
- The optimum time of sowing for redgram is **first fort night of May to first fortnight of June.**
- This crop can be sown up to **end of July.**

Method of sowing:

- Redgram should be sown in **line using seed drill.**

Redgram transplanting

➢When **monsoon is delayed,** seedlings are raised in poly bags and are transplanted to the main field after the onset of monsoon at **25-30 DAS.**

Seed rate:

- Pure crop: 15 kg ha^{-1}
- Inter-crop: 7.5 kg ha^{-1}.

Spacing:

- **May-June:** 90-120 cm x 30 cm (early kharif)
- **July:** 60-90 cm x 30 cm (late kharif)

Depth of sowing: 4-5 cm.

Seed treatment

- Seed treatment with fungicides like **Bavistin 1g/kg seed** or **captan or Thiram @ 2.5 g/kg seed** reduces the incidence of both **seed and soil borne diseases.**
- Seed treatment with **Rhizobium culture @ 500 g ha^{-1} seed + PSB @ 500 g ha^{-1} seed** can increase the yield up to **20-30%.**

Redgram cultivars

Varieties	Special character	Duration (Days)	Seed yield (q ha^{-1})	
			Pure crop	Inter crop
TTB-7	Dhal preparation	180-210	12.5 – 15 q	2.5 – 5 q
ICP-7035	Resistant to sterility disease	170-180	12.5 – 15 q	2.5 – 5 q
BRG-1	Dhal and vegetable	180-190	12.5 – 15 q	2.5 – 5 q
BRG-2	Dhal preparation	150-170	12.5 – 15 q	2.5 – 5 q
BRG-4	Dhal and late planting	140-145	8 – 10 q	1.5 – 3 q
BRG-5	Wilt resistant	140-180	12.5 – 15 q	2.5 – 5 q

Nutrient management

- **FYM:** 7.5 t ha^{-1}
- **NPK:** 25:50:25 kg ha^{-1}
- **'Zn' deficiency** can be corrected by **0.5% $ZnSO_4$ as foliar spray** or **soil application of 20-25 kg/ha.**

Water management

- Redgram grown in **kharif season** and **drought tolerant in nature does not require any irrigation.**
- **The water requirement of crop is 350 – 400 mm.**
- The critical period for Irrigation are **flower-initiation** and **pod-filling stages.**
- It can't withstand **water logging** & **requires proper drainage.**

Weed management

- Weeds become problematic in chickpea due to its **slow growing nature.**
- The critical period of crop weed competition is **50-60 DAS.**
- Intercultural operation at **30, 45 and 60 days** using harrow helps in reducing the weed growth.
- **Earthing up** should be made at **60 DAS** at the time of last harrowing.
- Pre-emergent application of **Alachlor or Pendimethalin @ 2.5 ltr ha^{-1}** followed by **one intercultivation at 60 DAS.**

Redgram + Sorghum (2:2)

Cropping system

- Since redgram is a **widely spaced and long duration crop and grown under rainfed condition**, their is a lot of scope for growing short duration **pulse and oilseed crop as a intercrop** between the **rows of red gram.**

Intercropping:

- Sorghum + pigeon pea (8:2)
- Pigeon pea + Finger millet (8:2)
- Pigeonpea + groundnut (8:2)

Sequential cropping:

- Pigeonpea – Wheat/mustard – greengram
- Pigeonpea + greengram – wheat/mustard
- Maize - Pigeonpea

Maize + Redgram (2:1)

Conservation furrow

- Since redgram is growing under rainfed condition, suitable **soil and moisture conservation practices** like **opening of furrow** between the **two rows of redgram.**
- This helps in **conserving and infiltration of more moisture during rainy days.**
- It also helps as **drainage in removing excess water** during **high rainfall situation.**

Harvesting and yield

- The Redgram is said to be **indeterminate in growth habit** where the **flowering goes on continuously** over the months on the **same plant.**
- Flowering, unriped pods & already developed pods at the same time. Hence, the crop is harvested in **2-3 pickings.**
- The whole plants are **cut when most of the pods are dried.**

Yield: 15 q ha^{-1}.

Common names of green gram are

- **Mung bean**
- **Golden gram**

Importance of green gram

- Green gram is the **third most important pulse crop** of India after **chick pea** and **pigeon pea.**
- Contributes **14% in total pulse area** and **7% in total production**
- The protein content in Green gram is **24 per cent.**
- It is **highly digestible pulse crop** than any other pulse crop.
- **Sprouted green gram** can be consumed directly as salad which is **rich in vit.C**
- Due to it's **shorter duration,** it can be fit well in several **multiple cropping systems.**
- It is also grown as a **green manure crop.**
- Inclusion of greengram in cropping systems improves **soil health and fertility.**
- Being a **close growing crop**, it helps in **reducing soil erosion** and also **checks weed growth.**
- Being a legume crop, it **fixes biological nitrogen.**

Origin and distribution

- The origin of green gram is **India.**
- Green gram is widely cultivated throughout **Southern Asia.**
- **Myanmar, Pakisthan, Thailand, Srilanka**, **Indonesia** and **China** are the **principal countries of green gram cultivation.**
- In India, it is grown in an area of **3 m ha** with the production of **1.2 m t** with the productivity of **436 kg ha^{-1}.**
- **In India, area and production** of green gram is highest in **Orissa** whereas **highest productivity** is recorded in **Punjab.**

Climatic requirement

- Green gram is a **tropical pulse crop** largely grown under **semi arid** and **subtropical environment.**
- It is a **drought tolerant crop** and requires **hot climate.**
- It is well suited for all **rainfed areas** with **annual rainfall of 600-75 0mm.**
- It can **tolerate** high temperatures up to **40^{o}C.**
- Optimum temperature of **28-30^{o} C.**

Land preparation

- Land should be prepare well to bring the soil to fine tilth.
- One or two ploughing followed by one harrowing is enough.
- field should be free from weeds.

Seeds and Sowing

- It is a **photo insensitive crop**, hence it can be grown during **kharif, rabi** and **summer season.**
- Kharif crop: May-June (monsoon)
- Rabi: Sep – Oct (residual soil moisture)
- Summer: Jan – Feb (Irrigated)

Method of sowing:

1. Broad casting – relay crop in rice field
2. Seed drilling or sowing behind plough

Seed rate: Sole crop: 15-20 kg ha^{-1}

Inter crop: 10 kg ha^{-1}

Spacing: 30 x 10 cm

Dept of sowing: 3-5 cm.

Seed treatment

- Seed treatment with Rhizobium @ 500 g ha^{-1} seed + PSB @ 500 g ha^{-1} seed.

Cultivars of green gram

Varieties	Sowing time	Duration (days)	Seed yield	
			Irrigated	Rainfed
P.S.16	May-June	65-70	10-12.5 q/ha	5-7.5 q/ha
Pusa baisaki	Jan-Feb	65-70	10-12.5 q/ha	5-7.5 q/ha
PDM 84-178	Jan-Feb	70-75	10-12.5 q/ha	5-7.5 q/ha
KKM-3	Jan-Feb	65-70	10-12.5 q/ha	5-7.5 q/ha

Nutrient management

- It is a crop of **poor and marginal soils**, it can be grown in **residual soil fertility.**
- **FYM:** 7.5 t ha^{-1}.
- **NPK:** 25:50:50 kg ha^{-1} (Irrigated)

  12.5:25:25 kg ha^{-1} (Rainfed)
- **'Zn' deficiency** can be corrected by **0.5% $ZnSO_4$ as foliar spray** or **soil application of 15-20 kg/ha.**
- **Foliar spray: 2% Urea or DAP** at flowering results in higher yield.

Water management

- For kharif crop, irrigation is not required but winter & summer crop require **2-3 irrigations**.
- **Rice fallow green gram** crop is not irrigated.
- **Critical stages:** Flower initiation (35 DAS)

  Pod filling (55 DAS)
- **Total water requirement:** 300 – 400mm
- **Water logging** at **flowering & pod filling** reduce the yield up to **75% and more.**

Weed management

- Critical Period for weed competition is **25-30 DAS.**
- Following intercultural operation at **15 and 30 DAS** with the help of harrowing helps in controlling the weeds.
- Hand weeding at 20 and 40 DAS.
- Pre-emergent application of **Pendimethalin or Alachlor @ 2lt/ha + 1 hand weeding at 30 DAS.**

Cropping system

Cropping sequence

- Paddy followed by Greengram
- Greengram- Rabi Jowar
- Greengram- Rabi maize
- Greengram-Maize-Wheat
- Greengram-Potato

Intercropping system

- Red gram + Green gram (8:2)
- Maize + Green gram (2:1)

Harvesting and yield

- Picking should be done as the pods mature.
- Two to three picking harvesting should be completed.
- Synchrony varieties two pickings or whole plant is harvested with sickle when the 80% of pods mature.
- The pods or whole crop after complete drying should be threshed manually.
- **Yield:** Rainfed- 5-7.5 q/ha and in irrigated:-10-12.5 q/ha

Production constraints of Green gram

1. **Moisture stress:** Generally kharif sown crop suffers from moisture stress due to intermittent dry spells during the growth phase.
2. **Pre-harvest Sprouting:** Kharif sown crop matures in August (Or) September, usually the crop is caught in rains at the time of harvest. Hence there is a sprouting of seeds in the pods causing heavy losses both in terms of yield and quality.
3. **Non synchronous in maturity:** It is usually harvested by pickings. Most of the varieties are Non-Synchronous in maturity. Hence, harvesting is done in 2-3 pickings.
4. **Susceptible to diseases:** Major diseases and pests are: Yellow Mosaic Virus, Leaf Curl, Powdery mildew,

Vernacular names of black gram

- **Urad bean**
- **Minapa pappu**
- **Mungo bean**
- **Black matpe bean**

Importance

- Contains **25% protein,** 1.83% fat, 61% carbohydrate.
- Peculiarity is when ground with water develop **muscilagenous character giving additional body to the mass.**
- Husked dal is ground in to a **fine paste and allowed to ferment with rice flour** to make **dosa or Idli.**
- Chief constituent of **papad.**
- Consumed as dhal or split seeds
- Haulms used as fodder.
- Husk and split beans are used as **livestock feed.**
- Possesses deep root system binds **soil particles and prevent erosion.**

Origin of Blackgram

- **India** is considered as primary centre of origin

Area and distribution

- Distribution is comparatively **restricted to tropical regions** i.e. **India, Pakistan,Bangladesh, Myanmar, Srilanka.**
- **Major states cultivating:** M.P., Maharashtra, A.P, TN, U.P, Orissa and Karnataka.
- Blackgram is grown in an **area of about 3.29 m. ha** with a **production of 1.60 mt** with an **productivity of 485 kg/ha.**
- **Andhra Pradesh** leads with **highest area and production** among states followed by Madhya Pradesh, Orissa, Maharashtra.
- **Karnataka** leads with **highest productivity** followed by Orissa, Andhra Pradesh.

Climatic requirement

- Green gram is a **tropical pulse crop** largely grown under **semi arid** and **subtropical environment.**
- It is a **drought tolerant crop** and requires **hot climate.**
- It is well suited for all **rainfed areas** with **annual rainfall of 600-75 0mm.**
- It can **tolerate** high temperatures up to **40^{o}C.**
- Optimum temperature of **28-30^{o} C.**

Soil requirement

- Black gram can be grown in **all types of soil** from **light soil to heavy textured soil.**
- Since crop is highly suitable for **excess moisture**, ideal soils are well drained **clay loam or sandy loam.**
- Optimum pH range is **5.5 to 7.5.**
- It is highly sensitive for **salinity, alkalinity and sodicity.**

Land preparation

- Land should be prepare well to bring the soil to fine tilth.
- One or two ploughing followed by one harrowing is enough.
- field should be free from weeds.

Seeds and Sowing

- It is a **photo insensitive crop**, hence it can be grown during **kharif, rabi** and **summer season.**
- Kharif crop: May-June (monsoon)
- Rabi: Sep – Oct (residual soil moisture)
- Summer: Jan – Feb (Irrigated)

Method of sowing:

1. Broad casting – relay crop in rice field
2. Seed drilling or sowing behind plough

Seed rate: Sole crop: 20 kg ha^{-1}

Inter crop: 10 kg ha^{-1}

Spacing: 30 x 10 cm

Dept of sowing: 3-5 cm.

Seed treatment

- Seed treatment with Rhizobium @ 500 g ha^{-1} seed + PSB @ 500 g ha^{-1} seed.

Cultivars of Blackgram

Varieties	Sowing time	Duration (days)	Seed yield	
			Irrigated	Rainfed
Karagauv	Aprl-May Jan-Feb	85-90	10-12.5 q/ha	5-7.5 q/ha
T-9	Aprl-May Jan-Feb	85-90	10-12.5 q/ha	5-7.5 q/ha
Rashmi (LBG-625) Bold seeded	**May-Aug** Jan-Feb	70-75	10-12.5 q/ha	5-7.5 q/ha

Water management

- For kharif crop, irrigation is not required but winter & summer crop require **2-3 irrigations**.
- **Rice fallow green gram** crop is not irrigated.
- **Critical stages:** Flower initiation (35 DAS)

  Pod filling (55 DAS)
- **Total water requirement:** 300 – 400mm
- **Water logging** at **flowering & pod filling** reduce the yield up to **75% and more.**

Nutrient management

- It is a crop of **poor and marginal soils**, it can be grown in **residual soil fertility.**
- **FYM:** 7.5 t ha^{-1}.
- **NPK:** 25:50:25 kg ha^{-1} (Irrigated)

  12.5:25:25 kg ha^{-1} (Rainfed)
- **'Zn' deficiency** can be corrected by **0.5% $ZnSO_4$ as foliar spray** or **soil application of 15-20 kg/ha.**
- **Foliar spray: 2% Urea or DAP** at flowering results in higher yield.

Weed management

- Critical Period for weed competition is **25-30 DAS.**
- Following intercultural operation at **15 and 30 DAS** with the help of harrowing helps in controlling the weeds.
- Hand weeding at 20 and 40 DAS.
- Pre-emergent application of **Pendimethalin or Alachlor @ 2lt/ha + 1 hand weeding at 30 DAS.**

Cropping system

Cropping sequence

- Paddy followed by Blackgram
- Blackgram - Rabi Jowar
- Blackgram - Rabi maize
- Blackgram -Maize-Wheat
- Blackgram -Potato

Intercropping system

- Blackgram + Red gram (8:2)
- Maize + Blackgram (2:1)

Harvesting and yield

- Crop comes to maturity at 80-95 DAS. Upon ripening, blackgram pods turn from **green to yellow and then to black.**
- Two to three picking harvesting should be completed.
- Synchrony varieties two pickings or whole plant is harvested with sickle when the 80% of pods mature.
- The pods or whole crop after complete drying should be threshed manually.
- **Yield:** Rainfed- 5-7.5 q/ha and in irrigated:-10-12.5 q/ha

Importance of field bean

- Commonly known as **Avare.**
- Contain **all amino acids**
- It helps in **improving soil fertility** through **atmospheric nitrogen fixation.**
- Green pods are used as **vegetable** and dried seeds used for **dhal purpose.**
- **Drought tolerant crop** and suitable for rainfed and dry land agriculture.
- Rich source of fodder

Origin and distribution

- **India** is considered as **primary centre of origin.**
- It is a crop of **tropical and subtropical region.** It is distributed over all the **tropical and sub tropical countries.**
- **India** is the largest producer of field bean.
- **In India it is grown in** Karnataka and adjoining districts of Tamil Nadu, Andhra Pradesh and Maharashtra.
- **Karnataka** contributes a **major share**, accounting for nearly **90 per cent in terms of both area and production in the country.**
- **Karnataka state** records production of about 18,000 tonnes from an area of 85,000 hectares

Climatic requirement

- It is a **short day plant.**
- It is a **photo sensitive crop.**
- Adaptable to wide areas under diverse climatic conditions such as **arid, semi-arid, sub-tropical and humid regions.**
- It is a **drought tolerant crop** and grows well in dry lands with limited rainfall of **300-400 mm.**
- It is grown with a temperature range of **14-35^0 C** but optimum temperature is **22-28^0 C.**

Seeds and sowing

- It is a **photosensitive crop.**
- But NPT's are **photo-insensitive** in nature and can be grown in all the season in the year.

1. Kharif: June-July
2. Rabi: Sept-Oct
3. Summer: Jan-Feb

Method of sowing:

1. Broadcasting.
2. Line sowing using seed drill.

Seed rate: 25-30 kg ha^{-1} (Pure crop)

10 kg ha^{-1} (Intercrop)

Spacing: 45 x 15 cm (Kharif season)

30 x 15 cm (Summer season)

Depth of sowing: 5 cm

FYM: 7.5 t ha^{-1}

NPK: 25:50:25 kg ha^{-1} (Irrigated & Rainfed)

Varieties of Field bean

Varieties	Characters	Duration	Yield (q ha^{-1})	
			Seed yield	Vegetable yield
H.A-3	➢Suitable for all the season	90-100 days	7.5-10	30-35
H.A-4	➢Suitable for all the season ➢Contains more Sogadu	95-105 days	7.5-10	30-35

➢The smell that appear during the flowering and pod setting time of avare is called as "**Sogadu"**

Harvesting and yield

- The crop will come to harvest at **90-100 days.**
- The crop can be harvest for green pods for **vegetable purpose at 75 DAS.**
- **Yield:** 7.5 – 10 q ha^{-1} (Seed yield)

  30-35 q ha^{-1} (green pod yield)

Cropping system

Cropping sequence

- Field bean – maize
- Field bean – Sorghum
- Field bean – wheat
- Field bean – Finger millet

Cropping pattern

- Finger millet + Field bean (8:2)
- Maize + Field bean (2:2)

Vernacular names of Cowpea

- **Black eyed pea**
- **Southern pea**
- **China pea**
- **Marble pea**

➢It is also called as **weed smothering crop.**

Importance of Cowpea

- Cowpea seeds are highly nutritious with high **protein (23-24%), carbohydrates, minerals and vitamins.**
- It can be used as **pulse, fodder, green manure crop.**
- **Feeding value and forage value of cowpea is very high** compared to other legumes.
- Crop gives **heavy vegetative growth** and **covers ground very quickly** thus it checks weed growth.
- It is a **erosion resistant crop.**
- It is an important **alternate pulse crop on dry land areas.**

Origin and distribution

- Origin of cowpea is considered to be **Africa.**
- Cowpea grown throughout the **tropics and subtropics** as a grain legume mainly for **dry beans, green vegetables, forages and cover crop.**
- Major area lies in **Africa** and few countries of **Asia, America, Australia and Europe.**
- Highest cowpea production nations are **Nigeria, India, Brazil**
- Annual global production **2 mt** from an area of **5 m. ha.**

- **In India,** Cowpea is grown in about **0.5 million ha** with an **average productivity of 600-750kg /ha**.
- Major states grown cowpea are **Maharastra, Karnataka, Tamilnaidu, Madhya Pradesh, Rajasthan, Andhra Pradesh.**

Climatic requirements

- It is a **short day plant** sensitive to **cold and killed by frost.**
- It is a **warm weather crop** adopted to **tropics and subtropics.**
- It can **tolerate heat and dry weather.**
- It can be grown at **low rainfall of 300-400mm (drought resistant).**
- The temperature requirements is **27 - 32^0 C.** It can tolerate up to **40^0 C.**
- Temperature **below 15^0 C** adversely affect the crop growth and development.

Soil requirements

- Cowpea grown in wide range of soils from **sandy to clay soils.**
- The primary soil requirement is **good drainage.**
- It can thrive well in acid soils **pH 5.5- 6.**
- The crop is moderately susceptible to **soil salinity.**

Seeds and Sowing

- It is a **short day plant**, cultivars developed is **photo-insensitive** in nature. Hence it can be grown during **kharif, rabi** and **summer season.**
- Kharif crop: May-June (monsoon)
- Rabi: Sep – Oct (residual soil moisture)
- Summer: Jan – Feb (Irrigated)

Method of sowing:

1. Broad casting – relay crop in rice field
2. Seed drilling or sowing behind plough

Seed rate: Sole crop: 25-30 kg ha^{-1}

Inter crop: 15 kg ha^{-1}

Spacing: 45 x 10 cm

Dept of sowing: 5 cm.

Seed treatment

- Seed treatment with Rhizobium @ 500 g ha^{-1} seed + PSB @ 500 g ha^{-1} seed.

Cultivars of Cowpea

Varieties	Sowing time	Duration (days)	Seed yield	
			Irrigated	Rainfed
C-152	Jan-March (Summer)	90-100	12.5-15 q/ha	7.5-10 q/ha
TVX-944	July-Aug	100-110	12.5-15 q/ha	7.5-10 q/ha
KBC-1	Aug-Sep	90-95	12.5-15 q/ha	7.5-10 q/ha
KBC-2		95-100	12.5-15 q/ha	7.5-10 q/ha
IT-98456-1	Oct-Nov	80-85	12.5-15 q/ha	7.5-10 q/ha
KM-5	Jan-March		12.5-15 q/ha	7.5-10 q/ha

Nutrient management

- It is a crop of **poor and marginal soils**, it can be grown in **residual soil fertility.**
- **FYM:** 7.5 t ha^{-1}.
- **NPK:** 25:50:25 kg ha^{-1} (Irrigated)

  25:50:25 kg ha^{-1}(Rainfed)
- **'Zn' deficiency** can be corrected by **0.5% $ZnSO_4$ as foliar spray** or **soil application of 15-20 kg/ha.**
- **Foliar spray: 2% Urea or DAP** at flowering results in higher yield.

Water management

- For **kharif crop,** irrigation is not required but winter & summer crop require **2-3 irrigations**.
- **Rice fallow green gram** crop is not irrigated.
- **Critical stages:** Flower initiation (35 DAS)

  Pod filling (55 DAS)
- **Total water requirement:** 400-500 mm
- **Water logging** at **flowering & pod filling** reduce the yield up to **75% and more.**

Weed management

- Critical Period for weed competition is **25-30 DAS.**
- Following intercultural operation at **15 and 30 DAS** with the help of harrowing helps in controlling the weeds.
- Hand weeding at 20 and 40 DAS.
- Pre-emergent application of **Pendimethalin or Alachlor @ 2lt/ha + 1 hand weeding at 30 DAS.**

Cropping system

Cropping sequence

- Pigeonpea - wheat – cowpea
- Sorghum + pigeonpea – cowpea
- Cowpea-wheat – Greengram
- Cowpea-cotton – wheat

Intercropping system

- Sorghum + cowpea
- Maize + cowpea
- Pearlmillet + cowpea
- Pigeonpea + cowpea

Harvesting and threshing

- Varieties exhibiting **synchronous maturity,** harvesting is done by **uprooting or cutting entire plant at ground level** when plant shows **90% maturity.**
- Harvested produce is sundried on threshing yard and threshed by trampling either by animals or tractor and winnowed.
- If the varieties does not have **synchronous maturity pods have to be harvested manually.**

Yield: 12.5-15 q ha^{-1} (Irrigated)

7.5 – 10 q ha^{-1} (Rainfed)

Importance

- Horse gram is commonly termed as **poor man's legume.**
- Rich source of **protein** and used for **human consumption** and **cattle feed.**
- fodder is **protein rich fodder**
- Grown usually late ***kharif*** under **marginal lands**
- **Excellent cover crop** and **conserve soil erosion**
- A good **catch crop**
- Medicinal value for **kidney stone disease** and for **allergies**
- **Sprouted seeds** are rich in **Vit – C.**
- Roasted seeds, salted and used in **bakeries**
- Being a legume fixes atmosphere N.

Nutritional value: Protein -25% , Fat-15 and CHO-62%

Origin and distribution

- It is originated from **India.**
- Its cultivation is confined to **Southeast Asian countries.**
- It is grown in **Karnataka, TN, AP, MR, MP, Orissa** and **UP** with 2 m. ha area and 0.7 mt production.
- **Karnataka** ranks first in area (0.283 M ha), production (0.119 M t) and yield of cowpea (0.420 t ha^{-1}).

Soil and climatic conditions

- Horse gram is well adapted to harsh environments in the **arid and semiarid tracts.**
- It comes up well under **scanty rainfall conditions** receiving **less than 500 mm.**
- It is grown on **all types of soils**, essentially, **not profitable** as compared to other **rainfed crops.**
- The crop is grown with **minimum tillage** of one or two ploughings.
- **pH: 6-7** (neutral).

Seeds and sowing

Growing season:

1. Late kharif: August to September.

2. Rabi Crop: First fort night of November.

Method of sowing:

1. Broad casting
2. Line sowing using seed drill

Seed rate: 25 kg ha^{-1}

Spacing: 30 x 10 cm

Depth of sowing: 3-4 cm.

NPK: 25:37.5:25 kg ha^{-1}.

Water requirement: no need for irrigation. Pod filing stage is critical for moisture.

Weed management: One hand weeding and intercultivation at 20-25 DAS.

Varieties: KBH-1 and PHG-9.

Harvesting and yield:

- Crop comes to mature at **90-100 days.**
- When the pods mature turn straw colour, whole plants are uprooted, dry for few days then thresh and separate seeds by winnowing.
- **Yield:** 8-10 q/ha with 10 t fodder/ha

Importance

- Important ***rabi*** **pulse**
- **Oldest** and **nutritious** pulse
- Cover crop
- Eaten as **dhal**
- **Split dhal** are **deep orange** or **yellow** in colour
- It contains **protein of 25%,** CHO 60% and Fat1.8 %
- Rich in **Ca, Fe and Niacin**
- Fix atmosphere N and improves soil fertility
- Easy for cooking

Origin and distribution

- It is originated from **Eastern Mediterranean** consists of **Asia Minor, Greece and Egypt.**
- It is distributed in **India, Turkey, Syria, Pakistan, Spain and Bangladesh.**
- **India** ranks first in **area** but **Turkey** ranks first in **production.**
- In India it grown in **MP, UP, Punjab, Kashmir, Haryana, Rajasthan, WB.**

Soil and climatic requirements

- It is a **rabi season crop.**
- It requires **cold climate during vegetative stage** and **warm temperature at maturity.**
- It can be cultivated up to **3000m AMSL.**
- It can be grown under **residual moisture, hardy plant, can tolerate frost and severe winter.**
- Optimum temperature is **18-30 ^{o} C.**
- Well drained **sandy loam soils** with **neutral pH** is required.
- It is not suitable for **acidic soils.**

Seeds and sowing

- It is a **rabi season crop**, the optimum time of sowing for this crop is **15th Oct – 15th Nov.**

Method of sowing:

1. Broad casting (rice fallows)
2. Ling sowing using seed drill (pure crop)

Seed rate: 30-40 kg ha^{-1}

Spacing: 30 x 10 cm

Depth of sowing: 3-4 cm.

Varieties

1. Pusa-1,4,6 = 100-140 days
2. Punjab-L-912, LL 56 = 150-160 days
3. Type-8: 120-125 days
4. Type- 36: 130-140 days.

Fertilizer management: 25:50:25 kg NPK/ha and 0.5 % $ZnSO_4$ or 20 kg $ZnSO_4$/ha.

Irrigation: 1 to 2 irrigation, 1st 40 DAS and 2nd at flowering or pod formation.

Weed management: Pendimethalin @ 1 kg a.i.ha as pre emergent and **hand weeding** twice at **30 DAS** and **60 DAS.**

Harvesting and yield

- When the plants dry up pods mature and moisture reaches 12%.

Yield: 1.8 to 2 t/ha.

Importance, constraints and strategy to improve fodder production

Terminologies

Forage: The plants which are used for feeding livestock's. This includes both **fodder plants** and **pasture plants.**

Fodders: Plants which are cultivated as **forage crops** and they are **cut and fed to animals**. Eg: Guinea grass, fodder maize.

Pastures: A grazed plant community usually of several species of diverse botanical types. It includes grasses, shrubs, legumes and trees.

Agrostology: Study of grasses, their classification, management and utilization.

Grassland: Land on which vegetation is dominated by the **grasses** which are used directly as **grazing by the animals** or cut and feed systems.

- Grasses may be either **indigenous** or **introduced grasses.**

Rangeland: Land on which the **indigenous vegetation is predominant** viz., **Grasses, shrubs** suitable for **grazing** and are managed as a **natural ecosystem.**

Paddock: It is a **part of the grass land used for grazing** and **separated from the other areas** by a **fence or barrier.**

Hay: Fodder conserved in **dry form** by reducing the **moisture content to <15%.**

- This prevents the **rapid development of biological processes** to **build up the heat.**

Silage: It is the process of preservation of green fodder under **anaerobic conditi**ons at moisture content of **65-75 %** in specialized structure called **silo.**

IMPORTANCE OF FORAGE CROPS

- Live stock production is an **integral part of Indian agriculture.**
- India ranks **first in live stock production** and accounts for **15% of cattle production** in the **world.**
- **States** with **largest acreage under cultivated fodders** are **Rajasthan, Gujarat, Haryana, Punjab, U.P., M.P., Maharashtra, Tamil Nadu.**
- Total area under forage crops in India is **8.3 m.ha** which is **4.2 to 4.9% of total cropped area.**
- There is need to improve the fodder acreage up to **8 to 10% of total cropped area** to meet the deficit of **green fodder** for sustained **live stock production in India.**

Reasons for low productivity of fodder crops

1. Allotment of poor and marginal lands.
2. Poor management practices.
3. Unavailability of seed of fodder crops.
4. Growing less productive forage crops

Strategies to improve fodder production

1. **Increase more area under fodder crops.** Area under fodder crops should be **8-10% (16 m.ha)** out of total cultivable land area as per National Commission on Agriculture.
2. **Growing short duration fodder crops** before or after growing food crop with **residual moisture and nutrients.**
3. Growing fodder crops under **scientific management practices.**
4. Encouraging forage crops in **horti** or **silvi-pasture systems.**
5. Growing more productive crops like NB hybrid and Lucerne
6. Quality forage **seed production** should be **strengthened.**
7. **Growing dual purpose (forage + grain) varieties** in crops like sorghum, bajra and oats with strengthening the research on forages in India.
8. **Growing multicut fodder crop varieties.** Eg: Multi cut fodder sorghum, multi cut oat.
9. Growing suitable fodder crops **under problematic soils** *viz.,* **water logged soils, acid soils and acidic soils.**
10. Encouraging growing of **grasses on bunds and periphery** of the crop lands.

11. Encouraging growing of fodders in **coconut gardens under shade condition.**

12. Development of **high yielding and high quality fodder crop varieties.**

Characteristic Features of Forage/ fodder Crops or ideal characters of forage /fodder crops

1. It should be succulent and juicy and easy palatable.
2. It should have more number of leaves i.e., high leaf-stem ratio, less shattering of leaves.
3. It should contain high amount of carbohydrates or proteins.
4. Resistance to pests and diseases.
5. It should have regeneration (ratooning) capacity.
6. It should have quick growth and smother weeds.
7. More number of tillers and fine stem.

8. Should be photo insensitive and give more number of cuts.
9. Should have shorter life cycle so that it can fit in cropping systems.
10. It should tolerate shade, drought resistant so best suited for agri, silvi pastoral conditions.
11. Should be suited to different soil classes from III to VII.
12. It should be free from hairs and thorns.
13. It should be free (or) less concentration of anti-nutritional factors.

Parameters to be considered in quality fodder production

Growth and yield parameters:

- Green fodder yield
- Dry fodder yield
- Leaf : stem ratio
- No. of tillers

Quality parameters:

- Crude protein content (%)
- Crude fibre content (%)
- Crude protein yield
- Crude fibre yield
- Acid detergent fibre (ADF)
- Neutral detergent fibre (NDF)
- Digestible crude protein (DCP)

Classification of fodder crops

I. Based on family:

a. **Poaceae:** Maize, sorghum, Bajra, Oat

b. **Leguminaceae:** Cowpea, Lucerne, Berseem.

c. **Cruciferae:** Chinese cabbage, Japanese rape.

II. BASED ON THE PROTEIN CONTENT:

a. Low protein forage crops: Ex: Cereals, grasses

b. High Protein forage crops: Ex: Legumes

III. Based on Season:

Kharif	Rabi	Summer
Cowpea	Oat	Bajra
Sorghum	Barley	Multicut sorghum
Maize	**Berseem**	Cowpea
Grasses	**Lucerne**	Grasses

IV. BASED ON LIFE CYCLE

1) Annual or Seasonal

i) Legumes. Ex: cowpea, Berseem.

ii) Non-legumes or cereals. Ex: maize, sorghum.

2) Perennial forage crops

i) Non-legumes or grasses Ex: Guinea grass.

ii) Legumes. Ex: Subabul, Lucerne.

Perennial non legumes

Napier grass	*Pennisetum purpureum*
Hybrid Bajra Napier	*P.americanum x P.purpureum*
Guinea grass	*Panicum maximum*
Para grass	*Brachiaria mutica*
Anjan grass or Buffel grass	*Cenchrus ciliaris*
Rhodes grass	*Chloris gayana*
Rye grass	*Lolium perenne*

Annual or Seasonal legumes

Cowpea	*Vigna anguiculata*
Field bean	*Dolichos lablab*
Cluster bean(Guar)	*Cyamopsis tetragonaloba*
Berseem	*Trifolium alexandrium*

Perennial Legumes

Lucerne	*Medicago sativa*
Stylo	*Stylosanthes hamata* *Stylosanthes scabra*
Hedge Lucerne	*Desmanthes virgatus*

Tree fodders

Agase	*Sesbania grandiflora*
Subabul	*Lucaena leucocephala*
Moringa	*Moringa oliefera*
Glyricidea	*Glyricidea sepium*
Calliandra	*Calliandra calothyrsus*

Introduction

- Oat is primarily cultivated as **food and fodder crop.**
- The cultivation practices are remain **similar to wheat farming.**
- They became very popular **due to their health benefit.**
- **Oat meal** is most famous food made out of oat.
- It is a **rabi season** growing food and fodder crop.
- **oats** contain 66% carbohydrates, **17% protein**, 7% fat and **11% fiber.**

Health benefits of Oats

- Oats are a source of **low calories, high protein and high fibre.**
- Oats helps in **reducing bad cholesterol.**
- Oats are **heart healthy** and **protect from cancer.**
- Oats regulates the **blood sugar levels** by **improving insulin sensitivity.**
- Oats are a **good source of antioxidants.**
- Oats helps in **controlling blood pressure.**
- It helps in **weight loss.**
- It helps in building **strong immune system.**

Origin and distribution

- **Asia minor** is believed to be the origin of oat.
- Oats area and production in the world are **27 m. ha** and **40 mt** respectively.
- The major countries producing the oats are **Russian Federation, USA, Canada, Poland, China, France and Australia.**
- In India, **Punjab, Haryana, UP** and limited areas in **MP, Orissa, Bihar** and **west Bengal** are the important oat growing states.

Climatic requirements

- It is a **rabi season crop.**
- It requires **cool and moist climate** for growth and development.
- It is not suitable for **hot dry climates.**
- **Temp:** Vegetative phase:**15 – 20^0 C**

  Reproductive phase: **25-30^0 C.**
- **Altitude:** 2000 m MSL
- **Rainfall:** 500-900 mm

Soil requirements

- Oat can be cultivated on **wide range of soils.**
- However, it grown best in **loamy soils with good water holding capacity.**
- It requires a soil pH of **5 – 6.5.** It can tolerate up to **7.5 pH.**

Land preparation

- Land should be ploughed 2-3 times with the help of cultivator to bring soil to fine tilt. Later with the help of harrow field should be levelled properly.

Method of sowing:

1. Broad casting
2. Sowing behind the plough with hand
3. **Sowing behind the plough with seed drill**
4. **Dibbling**
5. **Zero tillage sowing**

Agronomic Inputs

Sowing time: 15th October – 15th November

Spacing: 25 x 10 cm (grain), 20 x 10 cm (fodder)

Seed rate: 100 kg ha^{-1}

FYM: 10 t ha^{-1}

NPK: 100:60:40 kg ha^{-1}

- 50% N and full dose of P & K should be applied at basal dose. Remaining 50 % N should be applied at 30 DAS.

Varieties: OS-6, Kent and UPO 50.

Water management:

- Oats requires **higher water than wheat.**
- The water requirement of the crop is **450-500 mm.**
- **4-5 irrigations** provide good yields with an interval of 8-10 days.
- Critical stage for irrigation of oats is **tillering stage.**

Weed management:

- Critical period of crop weed competition is up to **20-30 days.**

a. Intercultural operation/ Manual weeding at 20 and 40 DAS.

b. Pre-emergent application of Pendimethalin @ 3.3 l/ha

c. Post emergent application:

- 2,4-D 36% @1.5 kg a.i./ha at 30-DAS.

Cropping system

- Sorghum-oat-maize
- Maize-oat-maize
- Cowpea-oat + mustard-maize + cowpea
- Sorghum + cowpea-oat + lucerne

Yield

Grain purpose: crop is ready for harvest at **90-100 DAS**.

- The average grain yield of oat is **35 q ha^{-1}.**

Fodder purpose: crop is ready for harvest at **50-60 DAS.**

- The average fodder yield is **30-40 t ha^{-1}.**

Agronomic inputs

- **Sowing season:** All the season
- **Method of sowing:** Line sowing
- **Seed rate:** 37.5 kg ha^{-1}.
- **Spacing:** 30 x 10 cm
- **FYM:** 10 t ha^{-1}.
- **NPK:** 25:50:25 kg NPK ha^{-1}.
- **Varieties:** MFC 08-14, MFC 09-1 and KBC-3.

Harvesting and yield

- Crop will come to harvest at **45-50 DAS.**
- The average yield of green fodder is **35-40 t ha^{-1}.**

Note:

- Crop is highly **susceptible for excess moisture.**
- The crop should not be coincide with **excess moisture stress condition at any stage of the crop.**
- Crude protein content is **21%.**

Importance

- Maize is one of the most **important economic plants of the world**, **serving as forage for cattle.**
- Maize can be feed to the animals during **any stage of its growth** as it is **free from toxic effects.**
- It also has **lactogenic properties.**
- It can be used as **silage** or **hay making.**
- **Crude Protein content: 8-10%**

Fodder maize cultivars

1. African tall

2. Ganga -5, 7 &10

3. Baby corn & sweet corn types also used as fodder purpose.

- **Dent type of maize varieties** are most suitable for fodder purpose.

Agronomical inputs

- **Season of cultivation:** *Kharif*, Rabi and Summer.

Seeds & sowing

- **Method of sowing:** Line sowing, Broadcasting
- **Spacing:** 30 x 10 cm
- **Seed rate:** 100 kg ha^{-1}.
- **Depth of sowing:** 3-4 cm.

Nutrient Management

- As maize is an **exhaustive crop**, fertilizer management is very important for **obtaining higher green fodder yield and maintaining soil fertility.**

FYM: 10 t ha^{-1}

NPK: 150:75:75 kg ha^{-1}

- **50% N and 100% P & K** should be applied at the time of sowing.
- Remaining **50% N** should be applied at **30 DAS** at the time of **final earthing up.**

Water Management

- Maize is **very susceptible** to **excess water and moisture stress.**
- Water stagnation for **3 days will spoil the entire crop.**
- Maize can **tolerate heavy rains** provided **water does not stand in the field for long periods.** Therefore proper drainage is essential.
- **500-600mm of water** is required during its lifecycle.
- **Tasseling and silking** stage are very critical.
- At this stage water shortage for **2 days reduce yield by 20%.** If it is for **6-8 days yields are reduced by 50%.**

Weed management

- Crop weed competition in maize is up to **25-30 DAS.**
- After 30 DAS weeds will be suppressed due to **shading effect of the main crop.** Hence, it is necessary to control weeds till 25-30 days.
- Inter cultivation is done in between rows at 15 and 30 DAS with small implements i.e., small blade harrow - i) to remove weeds
  ii) to stir/loose the top soil
  and iii) to give slight earthing up to maize plants
- Pre-emergent application of **Atrazine 50 % WP @ 1-1.25 kg a.i./ha (Sole crop)**
- **Pendimethalin 30% EC @ 1 kg a.i./ha (Intercrop) followed by one hand weeding at 30 DAS.**

Cropping systems

Cropping sequence:

- Maize-oats-sorghum
- Pearlmillet-Lucerne -Maize
- Maize-berseem-sorghum

Intercropping:

- Maize+cowpea (1:1)

Harvesting and yield

- As a **fodder crop** it is important to cut maize at the **right stage**, when the **cobs are just being formed (65-75 DAS),** because the feeding value goes down rapidly thereafter.
- If it is for **silage,** harvest at **dough stage.**

Yield: 50-60 t ha^{-1}.

1. **Better regeneration capacity.** Produces several **thin & succulent tillers** with **more no. of juicy & succulent leaves** which make it more palatable than grain sorghum.
2. Supply fodder for **long time due to its multi cut nature.**
3. **Rapid growth of plants** and **tolerate to shoot fly** & **leaf spot diseases.**

- **CP: 7-7.75% (Crude protein)**

Cultivars of fodder sorghum

- **Single cut:** CSH-1, CSH-6.
- **Dual purpose :** M.P. Chari and Pusa Chari.
- **Multi cut:** COFS 29(>5 cuts).

Agronomical inputs

Season: *Kharif*, Rabi and Summer

Seeds & sowing

- **Method of sowing:** Line sowing using seed drill, Broadcasting
- **Spacing:** 30 x 10 cm
- **Seed rate:** 50 kg ha^{-1} (Single cut), 10 kg ha^{-1} (Multi cut).
- **Depth of sowing:** 3-4 cm.

Manures & Fertilizers:

- Sorghum requires **heavy doses of fertilizers** because it removes nutrients in heavy amount from the soil. Manures and fertilizers both play an important role in sorghum cultivation.

FYM: 10 t ha^{-1}.

NPK: **Irrigated:** **90:50:40 kg ha^{-1}**

Basal dose: 50% N & full dose of P & K

Split dose: 50% N at 30-35 days.

- **40 kg N/ha after each cut** in multi-cut type verities should be adopted .

Water Management

- Requires less irrigation as it is **drought resistant one (35-40 cm).**
- Irrigate immediately after sowing and give light irrigation at 10-15 days interval depending upon the weather and type of the soil.
- However, in case of no rains, the crop may be irrigated **once or twice to a depth of 5 cm**, especially in **heading and grain development stage.**

Weed management

- Sorghum is a slow growing crop up to **25-30 DAS.**
- After 30 DAS weeds will be suppressed due to **shading effect of the main crop and also due to allelopathic effect**. Hence, it is necessary to control weeds till 30 days.
- Inter cultivation is done in between rows with small implements i.e., small blade harrow - i) to remove weeds
  ii) to stir/loose the top soil
  and iii) to give slight earthing up to jowar plants
- Pre-emergent application of **Atrazine 50 % WP @ 0.5-0.75 kg a.i./ha.**

Harvesting and yield

- Sorghum is harvested when the **ear heads are fully emerged** and the grain is in the **milky or early dough stage.**
- Care is necessary not to cut the sorghum for feeding the animal **before its flowering,** as otherwise there is a risk of cattle poisoning by the cyanogenic glucoside contained in the young plants.
- For **single cut varieties** harvesting at the **60-65 days after sowing (50% flowering stage).**
- In **multicut varieties first cut** is taken at the **50 DAS** and **second cut** should be taken **40-45 days after the first cut.**

Yield:

1. **Single cut varieties** – 40-50 t/ha
2. **Multi cut varieties** – 100-120 t/ha/yr.

Toxicities of fodder sorghum

- **Three types of poisoning** is noticed in fodder sorghum

1. Prussic acid or HCN or Hydrogen cyanide poisoning
2. Toxicity due to Tannins
3. Nitrate poisoning

1. Prussic acid or HCN or Hydrogen cyanide poisoning:

- **Lethal dose:** 2 mg/kg body weight of animal.
- **In foliage,** 200 ppm on wet weight basis & 500 ppm on dry weight basis.

Control measures

1. Cultivate **sweet sudan type of jowar** varieties.
2. Always harvest at **50% flowering.**
3. Give **normal irrigation & N dose.**
4. Protect the crop from **pests and diseases.**
5. Conservation of sorghum in the form of **silage.**
6. Intravenous injection of **50 ml of 20% $NaNO_3$** followed by **75 ml Na thiosulphate** or **3 g NaNO3 + 15g Na thiosulphate in 200 ml water.**

2.Tanning Content:

- Cause bitterness and affects palatability and digestibility in forage sorghum.

3. Nitrate poisoning (ppm):

- 0-3000 – Virtually safe
- 3000-6000 - moderately safe. limit to 50% of total ration.
- 6000-9000 – potentially toxic
- >9000ppm – dangerous to cattle & will cause death.

Treatment:

1. **Methylene blue @20mg/kg** body weight for cattle.
2. **Antibiotic supplementation**
3. Additives like **rapeseed oil meal, grain mixture, molasses, sodium chloride.**

Common name: Egyptian clover

- Berseem is an **annual leguminous fodder crop.**
- It is considered as **KING OF FODDER** crops because of its **nutritional qualities.**
- It is main fodder for **horses, camels and donkeys.**
- It remains **soft and succulent** at all stages of growth.
- It can be grown **without irrigation** in areas with **high water table conditions.**
- crude protein content is **25-30%** and it is **good soil binder.**

Origin and distribution

- Berseem is believed to be originated to **Egypt.**
- It is the main forage legume and it is cultivated in **Syria and Persia.**
- In India, it is a **prominent fodder legume** in irrigated areas of **Punjab, Delhi, Rajasthan and Uttar Pradesh** and other parts of **Western and Northern India.**

Climatic requirements

- Grows in **tropics, subtropics and temperate regions.**
- Prefers **dry and cool climate.**
- Grown during ***rabi* season** with **high humidity.**
- It can be grown up to an **altitude of 1700 m.**
- **Rainfall – 150 to 200 mm.**
- **Temperature: 15-20^{0}C** optimum for **vegetative growth and branching.**
- **25-35^{0}C** optimum for **flowering and seed setting.**
- It cannot tolerate **frost temperature below 4-5 ^{0}C.**

Soil requirements

- All soils with mild cold winter
- It grows well in **medium to heavy soil**
- **Clay loam soil** rich in **calcium and phosphorus**, soil must be well drained.
- pH **5.5-8.5** is suitable.
- Can tolerate **salinity, alkalinity** and is thus useful for **reclaiming brackish and alkaline lands.**

Field preparation

- The land should be well tilled, levelled and should be free from weeds.
- One MB ploughing followed by 1-2 harrowing is required to bring soil to a fine tilth .
- Fine seed bed is prepared since the seed is small.

Varieties: JB-1, JB-2, JB-3, UPB-103, IGFRI-99-1, IGFRI-54.

Seeds and sowing

Sowing season: It is a rabi season crop sown during **October to November.**

Method of sowing:

- Broad casting in rice fallows.
- Line sowing using seed drill.
- Relay cropping in rice fields.

Seed rate: 10-15 kg ha^{-1} (Line sowing).

20-30 kg ha^{-1} (Broadcasting).

Spacing: 30 x 10 cm.

Depth of sowing: 2-3 cm.

Manures & Fertilizer

- Berseem response well to manuring.
- **FYM**: 10 t ha^{-1}
- **NPK:** 25:50:25 kg ha^{-1}
- **full dose of N, P & K** should be applied as **basal** dose.
- Micronutrient deficiencies are common with regard to **B, Mo, Fe and Zn** and has to be corrected.
- Foliar application of **0.1% borax** or **soil application of borax @10 kg/ha** and **Mo as Ammonium molybdate @1- 1.5 kg/ha.**

Water management

- Water requirement is **quite high**.
- Initially irrigation is given at **weekly interval** later at **10-12 days interval.**
- Crop requires **140cm of water** in a year.
- In places where irrigation water is not sufficient for berseem, **oat can be grown as an alternate crop.**

Weed management

- Requires thorough weeding in initial stages.
- Critical period of crop weed competition is upto 25 DAS.
- ***Chicorium intybus*** is associated weed of berseem.
- 2 hand weeding at 21 DAS and after 35 to 40 DAS.
- Intercultural operation at 20 and 40 DAS.

Cropping system

- Berseem can be substituted with **wheat** in **rice-wheat sequence** to minimize the incidence of ***Phalaris minor*** in **wheat.**
- Berseem can also be grown as **inter crop with Napier Bajra** for **sustained supply of forage for dairy units.**
- Maize + rice bean-berseem-sarson

Harvesting and yield

- The first cut can be taken at **55-60 DAS** or at **50% flowering stage.**
- Subsequent cuts are obtained at **25-30 days interval.**
- On an average **3 cuts** can be harvested in an year.
- **Yield: 70-80 tonnes/ha/year** in 3 cuttings.

- **Common name: Alfalfa**/ snail clover/Chilean clover
- It is regarded as **QUEEN OF FORAGE** crops.
- Also called as **GREEN GOLD** of forage crops.
- **Alfalfa** is an Arabic word means **'the best'**
- **CP: 25-30%, DCP: 15% and TDN: 58%**

Origin and distribution

- It was originally a native of **South western Asia**.
- It was introduced to **India in the year 1900.**
- In India, it is a **prominent fodder legume** in irrigated areas of **Punjab, Delhi, Rajasthan and Uttar Pradesh** and other parts of **Western and Northern India.**

Climatic requirements

- Grows in **tropics, subtropics and temperate regions.**
- Prefers **dry and cool climate.**
- Grown during ***rabi* season.**
- It can be grown up to an **altitude of 2400 m.**
- **Temperature: 15-20^{0}C** optimum for **vegetative growth and branching.**
- **25-35^{0}C** optimum for **flowering and seed setting.**
- It cannot tolerate **frost temperature below 4-5 ^{0}C.**

Soil requirements

- All soils with mild cold winter
- It grows well in **medium to heavy soil**
- **Clay loam soil** rich in **calcium and phosphorus**, soil must be well drained.
- pH **5.5-8.5** is suitable.
- Can tolerate **salinity, alkalinity** and is thus useful for **reclaiming brackish and alkaline lands but it cant tolerate acidic pH.**

Field preparation

- The land should be well tilled, levelled and should be free from weeds.
- One MB ploughing followed by 1-2 harrowings are required to make a fine tilth .
- Fine seed bed is prepared since the seed is small.

Varieties: CO-1, T-9, RL-88 and IGFRI-s-244.

Seeds and sowing

Sowing season: It is a rabi season crop sown during **October to November.**

Method of sowing:

- Broad casting in rice fallows.
- Line sowing using seed drill.
- Relay cropping in rice fields.

Seed rate: 10-15 kg ha^{-1} (Line sowing).

20-30 kg ha^{-1} (Broadcasting).

Spacing: 30 x 10 cm.

Depth of sowing: 2-3 cm.

Manures & Fertilizer

- Berseem response well to manuring.
- **FYM**: 10 t ha^{-1}
- **NPK: 15: 120 : 40 kg ha^{-1}**
- **Full dose of N, P & K** should be applied as **basal** dose.
- Micronutrient deficiencies are common with regard to **B, Mo, Fe and Zn** and has to be corrected.
- Foliar application of **0.1% borax** or **soil application of borax @10 kg/ha** and **Mo as Ammonium molybdate @1- 1.5 kg/ha.**

Water management

- Immediately after sowing and life irrigation on 3rd day.
- Then once in 10 days depending on soil type and weather condition.
- Sprinklers can also be installed

Harvesting and yield

- The first cut can be taken at **55-60 DAS** or at **50% flowering stage.**
- Subsequent cuts are obtained at **25-30 days interval.**
- On an average **9 cuts** can be harvested in an year.
- **Yield: 90-100 tonnes/ha/year** in 9 cuttings.