CROP PRODUCTION TECHNOLOGY

Crop Production Technology-I

(*Kharif* crops)

Department of Agronomy

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Chapter 1
RICE (*Oryza sativa*) 2n=24.

Rice is the main staple food crop for more than 60% of the world population. Around 6-9% protein is present in aleuron and endosperm of rice. The straw is used as cattle feed, thatching of roof and in cottage industry for preparation of hats, mats, ropes, etc. Rice husk is used as animal feed, paper making and as fuel source. Rice bran is used as cattle and poultry feed and defatted bran, which is rich in protein, can be used in the preparation of biscuits. Rice bran oil is used in soap industry. Rice bran wax, is the by product of rice bran oil and used in industries. Rice bran oil is available in the market in the name of Porna for edible purpose (no cholesterol).

Rice Export: Basmati rice constitutes the major share of rice export from India. Nearly two-third of Basmati rice produced in India is exported. The export of Basmati rice during 2001-02 was 667.07 lakh mt, which showed a quantum jump of 66.91 per cent at 2015 lakh mt in 2009-10. It is revealed that export of basmati rice increased from 2001-02 to 2009-10 whereas, the export of non-basmati rice increased from 667.07 lakh mt in 2001-02 to 5286.08 lakh mt in 2007-08 and then decreased to 139.37 lakh mt in 2009-10, mainly due to policy decision.

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

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

1. *Indica*: Indigenous to India. It is adapted to subtropical-tropical regions. In India, the varieties are very tall, photosensitive, lodging, poor fertilizer responsive, moderate filling and late maturing.

The morphological differences between the varieties are very wide and awnless.

2. *Japanica*: It is confined to subtropical temperate regions (Japan, China, and Korea). Varieties are very dwarf, erect, non-lodging, photo insensitive, early maturing, high yielding and fertilizer responsive. The morphological difference between the varieties is very narrow and awnless. Hence, crosses were made between Indica and Japanica—first cross was ADT 27 during 1964.

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

Distribution

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

Rice growing seasons:

Aus/Autumn: Ashu means (quick) sowing in pre-monsoon period and harvest at August/September

Aman/Kharif: Safety or stability, sown in June and harvest in winter season

Boro/Summer: sown in Jan-Feb and harvest in April –May (varieties-Gautam, Krishna, Hasma)

Genetic Improvement;

T N.1: Dee –gee-Woo-gen (dwarf and N responsive) X Tasai Yung Chung (Toll and drought resistance)

IR-8: Dee –gee-Woo-gen X Peta (Broun tipped sort leged) release 1966 60-80q/ha 140-145 days

Jaya: TN 1XT141

Jagannath: Mutant of T 141

Pusa Basmati -1: World first scented high yielding from IARI

First fine scented rice: Pusa R H 10

First hybrid scented rice: PHB 71

Hybrid Rice: First hybris rice was developed by cytoplasmic male sterility restorer gene in China and in India during 1994 APRH1 APRH2 (Andhra P), KRH1 (Karnataka), MGR1(TN) For Bihar P 6444, PA 6201, DRRH1 are suitable.

Golden rice: it contains β carotene, use in treatments of Xerophthalmia (partially or fully blind). Prof. Ingo Portykus (Zurich) and Prof. Peter Beyer (Germany) produced golden rice using *Daffodils* and bacterium *Erwinia uredovora* gene that encode β carotene while crown

gall bacterium *Agrobacterium tumifacience* provided the plasmids that served as gene courier into rice tissue.

Area Production and Productivity of rice in India;

Rice is the most important cereal food crop of India, which occupies about 24 per cent of gross cropped area of the country. It contributes 42 per cent of total food grain production and 45 per cent of total cereal production of the country. Rice production in India has increased during last 60 years by about 3.5 times from 250.3 lakh tons during the first 5-yr plan period to 857.3 lakh tons during the tenth plan period. The productivity of rice has increased from 1984 kg per hectare in 2004-05 to 2372 kg per hectare in 2011-12 which is far below the global average of 2.7 tons/ha. The productivity of rice is higher than that of Thailand and Pakistan but much lesser than that of Japan, China, Vietnam and Indonesia. Indian share in global rice production has been hovering in the range of 19.50 to 24.52 % as shows the below given table. Below given table shows the world rice production and percentage share of India in total production:

Area Production and Productivity of rice in India

Year	World Prodn Mt	India's share (In %)	Area Mha	Production Mt	Productivity (kg/ha)	% Irrigated area
2005-06	423	21.7	43.66	91.79	2102.0	56.0
2006-07	427	21.86	43.81	93.36	2131.0	56.7
2007-08	438	22.08	43.91	96.69	2202.0	56.9
2008-09	459	21.61	45.54	99.18	2178.0	56.8
2009-10	457	19.49	41.85	89.13	2129.7	56.6
2010-11	449	21.38	36.95	95.98	2177.0	
2011-12	456	22.88	41.2	104.32	2372.0	
2013-14		22.75	44.1	106.6	2416	

State-wise Production (MT) in India during last three years:

	2009-10	2010-11	2011-12
Punjab	11.3	10.83	11.31
Haryana	3.62	3.48	3.96
U P	10.78	12.01	12.89
Bihar 3.6mh, 6.7mt,	3.59	3.32	4.75
A.P.	11.03	14.38	9.02
Orrisa	6.96	6.55	6.01
Tamil Nadu	5.91	6013	6.32
W.B	14.6	12.33	11.65

Climate and Soil

Rice can be grown in different locations under a variety of climate. The Indica varieties are widely grown in tropical regions. Japonicas, which are adapted to cooler areas, are largely grown in temperate countries. Both Indica and Japanica rice varieties are grown in subtropical regions. However, the crosses between Indica and Japanica are grown through out the world. Rice needs hot and humid climate. It is best suited to regions, which have high humidity, prolonged sunshine and an assured supply of water. Temperature, solar radiation and rainfall influence rice yield by directly affecting the physiological processes involved in grain production and indirectly through diseases and pests. The critical low and high temperatures for rice are normally below **20°C and above 30°C** respectively, which vary from one growth stage to another. Temperature affects the grain yield by affecting tillering, spikelet formation and ripening and it influences the growth rate just after germination and increases almost linearly with increasing temperature within a range of **22–31°C**. At later stages, it slightly affects tillering rate and the relative growth rate. During reproductive stage, the spikelet number per plant increases as the temperature drops. Growth and germination require 20-32°C for blooming 26.5-29.5°C at ripening 20-25°C.

Rice Ecosystems

Based on land and water management practices, rice lands are classified as low land (wet land) and upland (dry land). In India, the principal systems of rice growing are

1. Dry system (upland)
2. Semi-dry system
3. Wet system (lowland)

Four major ecosystem:

- Irrigated (21Mha)
- Rainfed low land (14 Mha)
- Rainfed up land (6Mha),
- Flood prone (3Mha**)**

1. Dry System or Upland Rice: In India, it is normally grown in eastern part of India *i.e.*, Assam, West Bengal, Orissa, Bihar, Uttar Pradesh and central part of India (Madhya Pradesh, part of Andhra Pradesh and Maharashtra). This system is called Aus in West Bengal, aus/ahu in Assam, beali in Orissa, bhadi or Kuari in Uttar Pradesh. In Tamil Nadu, it is mainly grown in Chengleput, Virudhunagar, Sivaganga, Nagapatinam, Thiruvallur, Kanchipuram,

Pudukkottai and Kanyakumari districts. It is grown in areas where the rainfall is more than 850 mm and it is well distributed. In North India, it is mainly grown in SWM seasons and in Tamil Nadu, it is grown during NEM seasons/bimodal rainfall areas of Kanyakumari districts.

(a) ***Field preparation*****:** The field is ploughed and harrowed to fine tilth taking advantage of summer rains and early monsoon showers. Application of gypsum at 1.0 t/ha is recommended whenever soil crusting and soil hardening problem exists. During the last ploughing, organic manures like FYM or compost at 12.5 t/ha is applied and incorporated.

(b) ***Season*****:** May-June

(c) ***Varieties*****:** Varieties having 90-110 days are recommended. viz Turanta, Prabhat, Saket 4, Saroj Dhanlakshmi, Sushksmrat, C R Dhan 40, Abhishek

(d) ***Seed rate and seed treatment*****:** The seed rate is 75 kg/ha. The seeds are treated with fungicide like Bavistin or Thiram @ 2 g/kg of seeds, 24 hours before sowing and the seeds are treated with Azospirillum at 3 pockets (600 g) per ha of seeds.

(e) ***Sowing*****:**

Broadcasting: The seeds are sown by broadcasting when the moisture is at the optimum level

Line sowing: Line sowing at 20 cm is better than broadcasting. Sowing/dibbling behind the country plough or using seed drill to ensure optimum population, reduce the seed rate and for early inter-cultivation.

(f) ***After cultivation*****:** Thinning and gap filling should be done 10–12 DAS, taking advantage of immediate rains.

(g) ***Nurient management*****:** 80:40:40 kg NPK /ha. Full dose of P and K and half N applied at the time of last ploughing. N at 20 kg/ha should be applied in two splits *viz*. 20–25 DAS and second at 40–45 DAS.

(h) ***Weed management*****:** Under upland condition, weeds reduce the yield to the extent of 50%. First weeding should be done at 15–20 DAS and second weeding may be done on 45 DAS. Application of Thiobencarb at 2.5 l/ha or Pendimethalin at 3.0 l/ha on 8 DAS as sand mix may be done, if adequate moisture is available followed by one hand weeding on 30–35 DAS. Bispyriback sodium @ 40g ai (Nomini Gold 400 ml/ha) with 600 litres water/ha at 18-20 DAS.

2. Semi dry Rice: It is practiced where at early-stage rice is like dry system but after 45-60 DAS after receiving the huge amount of rains the crop is plough criss cross to maintain the plant population and to control the weed this process known as Beushining. And remaining practices followed like as Wet system or low land rice.

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***3. Wet system or low land rice*:** In India, low land rice is established by transplanting the seedlings in which separate nursery is raised (or) direct seeding of sprouted seeds in the puddled soil. For transplanting, the seedlings are raised in wet nursery, dapog nursery and dry nursery.

Transplanted rice

Wet nursery: The seed rate of 30, 40 and 50 kg/ha is recommended for fine, medium and coarse rice.

Pre-treatment of seeds (before sowing)

(a) ***Dry seed treatment*:** Mix any one the fungicide at 2 g/kg of seed (Thiram, Captan, Carboxin or Carbendazim). Treat the seeds at least 24 hrs prior to soaking for sprouting. The seeds can be stored for

30 days without any loss in viability.

Treatment of seeds at the time of soaking the seeds for sprouting

(a) ***Wet seed treatment*:** Treat the seeds in Carbendazim or Pyroquilon or Tricyclozole solution at 2g/lit of water for 1 kg of seed. Soak the seeds in the solution for 2 hrs. Drain the solution, sprout the seeds and sow in the nursery bed. It gives protection to the seedlings up to 40 days from seedlings disease such as blast and it is better than dry seed treatment.

(b) ***Seed treatment with Azospirillum*:** Three packets (600 g/ha) of Azospirillum culture are to the mixed with sufficient water wherein seeds are soaked overnight before sowing in the nursery bed. The bacterial suspension after decanting may be poured over the nursery area itself.

(c) ***Seed treatment with Pseudomonas fluorescence*:** Three packets (600 g/ha) of Pseudomonas culture should be added in water wherein seeds are soaked overnight before sowing in the nursery bed. It can be mixed with *Azospirillum* culture, as it is not inhibitory to *Azospirillum.*

Soaking and sprouting the seeds

The seeds are soaked for 10 hrs. Drain the excess water. The seeds should not be soaked in running water, which removes the minerals and nutrients. Keep the soaked seeds in gunny bag in dark room and cover with extra gunnies for 24 hrs for sprouting. The seeds should not be covered with thick material, which develops heat and reduces the aeration.

Preparation of nursery for sowing: Dry, Wet and Dapog method

Dry method: 5-8 m long, 1.2 m wide and 0.30 m raised bed s are prepared and dry seeds are sown, frequent water is done to germinate the seed. Apply **1.0:0.50:0.50Kg NPK/100 m^2**

Dapog method: 5-8 m long ,1.2 m wide and 0 .30 m raised beds are prepared sedds are broadcast **@1.0 kg /m^2 thus 40-45 m^2** area is sufficient to raised nursery for one ha area.

apply **2.5:1.50:1.50kg NPK/45 m^2.** When seedlings are **2-3 leaf** stage at **12-14 DAS** should be pulled out and transplanted in to main field.

Wet method: About 800 m^2 area for planting one ha is required. Raise the nursery near the water source Apply 1 t of FYM or compost to nursery and spread the manure uniformly. Before ploughing, allow water to a depth of 2.5 cm. Before last puddling, apply 1.0:0.50:0.50 kg NPK/100 m^2 area. After 10 DAS topdress 1.0 kg N/100 m^2 area. When seedling are 4-5 leaf stage at 21 DAS should be pulled out and transplanted in to main field.

Water management: For water management in nursery, first drain the water 18–24 hrs after sowing and allow enough water to saturate the soil from 3–5th day. From 5th day onwards, increase the quantity of water to a depth of 1.5 cm depending on the height of seedlings. Afterwards, maintain 2.5 cm depth of water.

Weed management

Apply any one of the pre-emergence herbicide like Butachlor or Thiobencarb at 2.0 lit/ha or Pendimethalin at 2.5 lit/ha or Anilophos at 1.25 lit/ha on 8 DAS to control weeds in the nursery. Keep thin film of water at the time of herbicide application and should not drain the water after application.

Main field preparation for transplanted rice

Wet rice requires a well puddled soil. The land is ploughed repeatedly 3 or 4 times with an interval of about 4 days between each puddling by country plough or mould board plough or tractor drawn cage wheel or by using power tiller with a standing water of **3–5** cm. Optimum depth of puddling is 10 cm for clay and clay loam soils.

Application of organic manures

Apply 10 t FYM or compost/ha and spread the manure uniformly on the dry soil before applying the water. If FYM or compost is not available, apply green manure/green leaf manure at 6.25 t/ha.

Compute the green matter using the formula.

Yield/m^2 in kg × 10000.

Incorporation of green manure

Stem nodulating *S. rostrata* can be grown during April -May. Adopt a seed rate of 50-60 kg/ha. Treat the seeds with Rhizobiam culture. Cut the crop at 45–60th day to have maximum green matter (25–30 t/ha). Plough or incorporate the green manure or green leaf manure directly into the soil using mould board or tractor. Then, maintain 2.5 cm of water in the

field. Incorporate the green manure to a depth of 15 cm using Burmese Saturn and allow to decompose for 7 days. When the green manure is applied, rock phosphate can be used as cheaper source of 'P'. It also harnesses the decomposition of stubbles in the second crop. Finally level the field using levelling board.

Transplanting

Puddle and level the fields after applying basal fertilizers. Seedlings are dibbled at **20×10 for early and 20×15** cm spacing for medium and late duration varieties, at **2-3 cm** depth. Plant density and geometry varies with soil fertility, genotypes and soils. Number of seedlings/hills for wet nursery are 3–4 and it is 6–8 for dapog and 4–6 for saline soil. To manage aged seedlings, increasing basal N by 25% and 4-5 seedlings/hill is recommended.

Application of biofertilizer

1. Azolla is a water fern which is used as a biofertilizer for rice. Blue green algae, *Anabaena azolla* lives in the dorsal cavity of azollae which fixes 'N'. upto 25–30 kg/ha. It is raised as a dual crop and also applied as green manure.

2. Blue green algae: Broadcast at **10 kg/ha** of powdered blue green algae flakes 10 days after transplanting. Maintain thin film of water. BGA multiplies well from March to September and can be used for any rice variety raised during that period.

3. Dipping roots in Azospirillum slurry: Prepare the slurry with 5 pockets (1000 g/ha of *Azospirillum inoculant*) *in 40 lit of water and dip the root portion of the seedling for 15*–30 minutes in bacterial suspension and transplant the seedlings.

4. Soil application of Azospirillum: Mix 10 pockets (2000 g/ha of Azospirillum inoculant with 25 kg FYM and 25 kg of soil and broadcast the mixture uniformly in the main field before transplanting.

L. Water management

Among the cereal crops, the productivity per mm of water used is very low in rice, which is about 3-7 kg/ha mm of water. Total water requirement for rice is 1800–2000 mm which depends on the duration of crop, soil type and climate. At the time of transplanting, shallow depth of 2 cm is adequate, since higher depth of water results in reduction in tillering. Up to 7 days, maintain 2.0 cm of water. At establishment stage, 5.0 cm submergence of water has to be continued throughout the crop growth period. For loamy soil, irrigation at one day disappearance of ponded water during summer, and 3 days after disappearance during winter

may be done. Critical stages for water requirement are: **1. Primordial initiation 2. Booting 3. Heading 4. Flowering**. **5. Milk stages.**

Nutrients management:

Short duration varieties 100:40:30 kg/ha N P2O5 K2O/ha

Medium and long duration varieties 120: 60:40 kg/ha N P2O5 K2O/ha

All P2O5 and K2O should be applied as basal at the time of puddling as quartering method only in course textured (low CEC), K may be applied in two splits 50% at basal and 50% at maximum tillering stage or panicle initiation stage. In clay soil, 'N' should be applied in three splits *viz*., 50% basal + 25% at max. tillering + 25% at panicle initiation stage. **Zn** deficiency can be corrected by dipping rice roots in 1% ZnO (Zinc oxide) or by basal application of ZnSO4 at 25 kg/ha.

(*a*) ***Nitrogen*****:** N will be lost by different ways; 1. Denitrification loss, 2. Fixation by microbes, 3. Leaching loss, 4. Volatilization loss, 5. Run-off, 6. Ammonium fixation, and 7. Crop uptake. Among the losses, denitrification and leaching **losses** are more in paddy soil under submerged due to low redox potential. To increase N use efficiency, the following methods may be followed:

• **Choice of fertilizer:** The choice of fertilizers is Ammonium Sulphate > Ammonium chloride >Ammonium sulphate nitrate > Urea > CAN. In India, 85% of production is urea due to less unit cost and most of the farmers are using urea.

• **Split application of 'N':** Application of N in 3–4 splits depending on soil type will increase NUE. If green manure is applied, skip basal application of N. Under this situation, 'N' as top dressing in 3 splits at 10 days interval between 15 and 45 days after transplanting is recommended for short and medium duration varieties.

• **Slow-release fertilizer:** Use of chemically manufactured slow-release N fertilizers to increase the NUE. *e.g.,* **IBDU**-Isobutylidene di urea and **UF**-Urea formaldehyde. Slow release by **coated urea** with physical/mechanical means. *E.g.,* (*a*) sulphur coated urea, (*b*) neem coated urea, (*c*) gypsum coated urea, (*d*) mud ball urea etc.

• **Placement of urea super granules:** Bigger size urea super granules are placed directly into the reduced zone (below 10 cm depth) to avoid loss of N.

• **Use of nitrification inhibitors:** To control the conversion of NH4 to NO3 inhibiting the activity of nitrosomonas and nitrobacter. *E.g.*, AM, N-Serve etc., but these are not available in India.

Weed management

The weeds reduce the yield of transplanted rice by 15–20%. Crop weed competition is up to 20–30 days for short duration varieties and 30–40 days for long duration varieties after transplanting.

(a) Weed control measures

• **Through land preparation:** Summer ploughing and puddling reduce weed population.

• **Straight row planting:** It is more effective to operate rotary weeder or wheel hoe in between rows of crop. Now IRRI has developed single and double row **Cono-weeder**, which can uproot and burry the weeds and are faster.

• **Flooding paddy at effective root depth:** Proper water management of 6–8 weeks submergence controls the weeds effectively. Aquatic and broad-leaved weeds are not affected by this method.

• **Hand pulling/weeding:** It is laborious and is not economical.

• Weed control by **Chemicals** is quicker and less laborious. Large area can be covered in a short time with a limited amount of labour and it is cheaper. The disadvantages are

1. No herbicide will kill all the species of weeds,

2. Initial cost is higher.

(b) Integrated Weed Management (IWM)

• Use Butachlor 2.5 l/ha or Thiobencarb 2.5 lit/ha or Pendimethalin 3 lit/ha or Anilophos 1.25 lit/ha as pre-emergence application on 3 DAT as sand mix (50 kg of sand) followed by one hand weeding on 30–35 days after planting (or)

• Use herbicide mixture: Pre-emergence herbicide mixture *viz*., Butachlor 1.20 l/ha + 2,4 DEE 1.5 lit/ha (or) Thiobencarb 1.20 l + 2,4 DEE 1.5 lit/ha (or) Pendimethalin 1.5 l + 2,4 DEE 1.5 lit/ha as sand mix (or) Anilophos + 2, 4 DEE ready mix at 1.25 l/ha followed by one hand weeding on 30–35 DAT as sand mix will have a broad spectrum of weed control in transplanted rice.

• Maintain **2.5 cm** of water at the time of herbicide application. Water should not be drained for 2 days (or) fresh irrigation should not be given.

• If pre-emergence herbicides are not used, 2, 4 D sodium salt (Fernoxone 80% WP) at 1.25 kg/ha dissolved in 625 lit of water, is sprayed 3 weeks after transplanting using high volume sprayer.

Harvest and post-harvest technology

(a) ***Harvesting*:** Harvesting is to be done at optimum time in the tropics, otherwise, there is loss of grain shedding, scattering, lodging and also damage by birds, over maturity and lodging. Timely harvesting ensures good grain quality, a high market value and improved consumer preference/acceptance. In India, harvesting between 27 and 39 days after flowering gave maximum head rice recovery. The moisture content at the time of harvest is 18–20%. Taking the average duration of crops as an indication, drain the water from the field 7–10 days before the expected harvest as the drainage hastens the maturity and improves harvesting conditions. When 80% of the panicles turn straw colour (or) most of the grains at base of the panicle in the selected tillers are in hard dough stage, the crop is ready for harvest. Maturity may be hastened by 3–4 days by spraying 20% NaCl a week before harvest to escape monsoon rains.

(b) ***Post-harvest technology*:** Post harvest technology encompasses an array of handling and processing system from the stage of maturation till consumption of the produce and includes threshing, cleaning, grading, drying, parboiling, curing, milling, preservation, storage, processing, packing, transportation, marketing and consumption system:

1. Threshing: The methods are generally classified as manual, animal or mechanical. The common method of separating grains from panicle is hand beating (hand threshing or using mechanical thresher (small or big thresher). A loss under manual threshing is 8%. IRRI designed a portable thresher. Most of the farmers are using mechanical thresher in the areas where labour availability is a problem.

2. Drying: It is the process that removes moisture from the grain mass for safe storage and preservation of quality, viability and nutritive value. Drying should begin within 12 hours but not later than 24 hours after harvesting. Rice is normally harvested at moisture content of 20% or more. If the moisture content is not reduced to below 14% shortly after threshing, the grain quality is deteriorated because of microbial activities and insect damage. The grains should be dried to 12–14% moisture level. In general, 4–5 days of seed drying are required.

Winnowing and cleaning: Presence of impurities like foreign seeds and trashes is more likely to deteriorate in storage and reduce milling recovery rate. Cleaning is mostly done by hand winnower, which takes advantage of wind for removing impurities. Now mechanical winnower is available. Combine harvester is a multipurpose one, which is useful for harvesting, threshing, winnowing and cleaning in one operation. It is highly profitable and economical.

4. Grading: The grains are graded for uniformity in size, shape and colour. Seed cleaner cum graders are also available for effective cleaning and grading.

5. Storage: Low temperature and low moisture are necessary for long-term storage of rice for seed. Rice seed of 10–12% moisture content can be stored in good condition at 18°C for more than 2 years.

(d) ***Rice processing*:**

1. Parboiling: In this process, rough rice is soaked, steamed and redried before milling. The advantages of parboiling are: 1. Easy dehusking, 2. low incidence of pests and diseases 3. By milling of raw rice, 80% of fat and18% of crude protein are lost, but starch increases by 5%.

2. Curing: The new rice has low swelling capacity and has the tendency to yield a thick viscous gruel during cooking. To overcome the above defect in newly harvested paddy, methods have been developed to hasten the ageing in fresh rice and such process is called as curing. Steaming for 15–20 minutes is sufficient to bring satisfactory curing effect.

3. Milling: Rice milling involves the removal of husks and bran from rough rice to produce polished rice. Time of harvest and season may affect the milling yield of rice.

4. Polishing: Removal of very fine bran (often called whitening) 2–3 times**.**

II. Direct seeding

The varieties recommended for different seasons, main field preparation, puddling, application of organic manure/green manure, seed treatment and sprouting of seeds are similar to that of transplanted wet rice.

(a) ***Seeds and sowing*:** The seed rate is **60, 70 and 80 kg/**ha for fine medium and coarse rice but **now under modern technique only 25-30 kg seed/ha.** Sprouted seeds are sown in lines using drum seeder. It is more economical and labour saving.

(b) ***Nutrient management (kg/ha)*:** Application of 100: 60: 40 kg of N, P2O5 and K2O respectively is recommended .50% N should be applied at 20 DAS and the remaining 25% N each at maximum tillering and panicle initiation stage. ZnSO4 at 25 kg/ha is applied as basal. Application of Azolla at 1.0 t/ha at

15 DAS and then incorporation on 3rd week after application is recommended. For light soils, potassium can be applied in two splits *viz*., 50% basal and 50% at tilling/panicle initiation. In general, P and K are applied as basal.

(c) ***Water management*:** Maintain thin film of water at the time of sowing. Drain the water, where the water is stagnating. Allow enough water to saturate the soil from 3 to 5 days. From the 5^{th} day onwards, increase depth of water to 1.5 cm. Then afterwards, maintain 2.5 cm of

water up to tillering. Then, maintain 5.0 cm of water throughout the crop growth. Stop irrigation 10 days before harvest.

(d) ***Weed management*:** The most critical period is 25-30 DAS. Conventional method is hand weeding thrice at 20, 40 and 60 DAS. For effective weed control, IWM is recommended. Pre-emergence application of Pretilachlor at 0.45 kg a.i./ha (Sofit 50 EC) or Thiobencarb at 1.25 kg a.i./ha (2.5 lit of commercial product–saturn 50 EC) on 6–8 DAS followed by one late hand weeding on 40th day. Pre-emergence application of pretilachlor 0.3 kg a.i./ha + safner is more effective for control of weeds in wet seeded rice followed by one hand weeding. Butachlor 1.25 kg a.i./ha + Safener + one hand weeding may also be followed. Post emergence of **Bispyribac Sodium 40g ai/ha** (Nomini gold 400ml/ha).

III. SRI methos; Strated from Medagasker 1980 and spread>25 countries now.

Seed rate 5kg/ha, Spacing 25×25 cm, single seedling (10-12 days old)

Nutrients 120:60:40 kg NPK/ha

IV. **Scented Rice:**

Varieties: Pusa Basmati 1, Pusa Basmati 14, Pusa Basmati 370. Pusa Sughandha 2,3,5, Basmati 370, Kasturi Basmati,Rajendra Suhasini , Rajendra Bhagwati, Rajendra Kasturi. Bhagalpur Katarni. Hisar basmati

Nutrients 100:60:60, kg NPK/ha

Harvesting: at Physiogiological maturity stage to maintain fragrance/aroma in rice and for maximum head rice recovery (65%)

Yield: 35-40q/ha

Semi deep water Rice: Sudha Amulya,Nalini Rajendra Mahsuri

IV. **Deep water Rice:**

Varieties: Madhukar, Jalmagna, Chakia 59, Jaladhi,Vaidehi, Janaki, and Sudha.

Nutrients: 60-80:30:30, kg NPK/ha

Yield: 30-35q/ha

IV. **Hybrids Rice: Seed rate: 5-6 kg**

Varieties: PHB71, K R H2, PA 644, Pusa R H 10(scented), and Pant Hybrid Rice -1

Nutrients 120-60:30: kg NPK/ha

Yield: 100-110q/ha

Saline: Narendra Usar-1, 3, CSR 5, 10, 23.

Chapter 2
MAIZE (Zea mays.L)

Maize is one of the important cereal crops in the world's agricultural economy both as food for men and feed for animals. Because of its higher yield potential compared to other cereals, it is called as "**Queen of Cereals"**. Several food dishes *viz*., chapatti are prepared from maize flour. Green cobs are roasted and eaten by the people. Popcorn is used for popped form; green cob for table purpose. Corn has low fibre content, more carbohydrate and most palatable. It is widely used in preparation of cattle feed and poultry feed. It can be used as green fodder and has no HCN content. It can be preserved as silage. Food products like corn meal, corn flakes etc., can be prepared. It is used in making industrial products like alcohol, corn starch (dextrose), glucose, corn oil, corn syrup etc., and used in canning industry, production of polymer, making paper, paper boards, bread etc., Maize grain contains proteins (10%), carbohydrates (70%), oil (4%), albuminoides (10.4%), crude fibre (2.3%) and ash (1.4%). Maize grain has significant quantity of vitamin A, nicotinic acid, riboflavin and vitamin E. Maize is low in calcium, but fairly high in 'P. Maize protein 'Zein' is deficient in two essential amino acids *viz*., Lysine and 'Tryptophane'.

Classification

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

1. Flint corn (*Zea mays indurate*): Starchy endosperm enclosed with hard hammy endosperm. Kernel size is large with flat bottom and round at the top, high proportion of starch, colour may be white or yellow, mostly grown in India.

2. Dent corn (*Z. mays indentata*): Because of formation of dent on the top of kernel having white or yellow, it is called as dent corn. Maize kernels have both soft and hard starches. The hard starch extends on the sides and the soft starch is in the centre and extends to the top of the kernel. Depression or dent in the crown on the seed is the result of drying and shrinkage of soft starch. This type is widely grown in USA.

3. Pop corn (***Z. mays averta***)**:** Kernel size is small. Hard and corneous endosperm is present. After heating the pressure built up within the kernel suddenly results in an explosion of the grain is turned inside out.

4. Sweet corn (*Z. mays saccharata*): The kernals are translucent, horny and more wrinkled when dry. Presence of recessive gene "su" (sunken-1, sunken-2) break the conversion sugar to starch in endosperm that results in sweet taste of kernels. It is mainly grown in Northern half of USA. The cobs are picked up green for canning and table purpose.

5. Flour corn (*Z. mays amylaceae*): It resembles to the flint corn in appearance and ear characteristics. The grains are composed of soft starch and have little or no dent (called as "soft corn"). It is widely grown in USA and South Africa.

6. Pod corn (*Z. mays tunicata*): Each kernel is enclosed in a pod or husk in an ear, which enclosed in husks, like other types of corn.

7. Waxy corn (***Z. mays cerabina***)**-** The kernel looks to have waxy appearance and gummy starch in them, because of amylopectin. Starch is similar to that of tapioca starch for making adhesive.

Origin: Mexico and Central America.

Area and Production

It is cultivated in an area of 138 Mha with a production of 602 Mt. It is grown in USA, China, Brazil, Mexico and India. USA ranks first in area, production and productivity (6865 kg/ha). India occupies 5th place in area and 11th place in production**.** In India, area ,production and productivity is 8.4 Mha , 19.61 Mt. and 23.55 q/ha respectively (2009-10) In India, it is cultivated in Uttar Pradesh, Rajasthan, Madhya Pradesh, Karnataka and Bihar. The production level is in the order of Uttar Pradesh > Bihar > Karnataka. In Bihar It is cultivated in Kharif, Rabi and Zaid with total area, production and productivity is 0.689 Mha , 2.834 Mt. and 41.13 q/ha respectively (2012-13)

Climate

It is essentially a tropical crop. It is a C4 short day plant. Though it is a tropical crop, it has got high adaptability to wider climate (55°N–45°S). It can be grown up to 2500 m above MSL. This crop is not suitable when night temperature drops below 15.6°C. Maize requires moist and warm weather from germination to flowering. Most suitable temperature for germination is 21°C and for growth is 32°C. Extremely high temperature and low RH at flowering desiccate the pollen resulting in poor pollen grain formation. Temperature more than 35°C reduces the pollen germination. Temperature < 15°C delays silking and tasseling. Rainfall of 500–750 mm of well distributed rain is required for growth.

Soil: Maize is best adapted to well-drained sandy loam to silty loam soil. Water stagnation is extremely harmful to the crop, therefore proper drainage is must. Maize cannot thrive on heavy soils especially on low lands. pH ranges from 5.5–7.5. The alluvial soils of Uttar Pradesh, Bihar and Punjab are very suitable for growing maize crop. Salinity and water

logging are harmful at seeding stage. Continuous water logging for 3 days reduces the yield by 40–45%.

Growth Stages

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

Varieties

Hybrids: The duration of hybrids is 100-105 days. Some of the important hybrids are Deccan, Ganga Safed, Ganga-2, Ganga-4, Ganga-5, Ganga-7,9, Histarch and Sangam, DHM117, SHM-2, QPM1,2,3,4,5, amd VQPM 9

Promising Composites: The duration of composites is 85-90 days, e.*g.*, Hemant, Laxmi, Suwan, Diyara composite, Madhuri, Vijay, Kisan, Sona, Vikram, are important varieties (4.5–5.5 t/ha).

Cropping System

Some of the important cropping systems in India are maize-potato, maize-berseem, maize-chickpea/safflower (rainfed) and maize–potato–wheat.

The important rainfed intercropping are maize + green gram, maize + groundnut, maize + soybean, maize+cowpea and maize+red gram. In North India, short duration maize varieties like Kathri and Sathi (65–75 days) is grown as intercrop in sugarcane in Uttar Pradesh.

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

System of Maize Cultivation

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

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

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

Seed treatment: The seed treatment is done with any fungicide (Captan /thirum/carbendazim @ 2.5g/kg seed) followed by Azospirillum (3 pockets). Seed treatment with 3 pockets of Azospirillum followed by soil application of Azospirillum

@10 pockets (2 kg/ha) with FYM at 50 kg/ha can be followed.

Seed rate: The seed rate for Desi 12-15 kg, composite is 15-18 kg/ha and for hybrids, it is 20 kg/ha.

Spacing: 60 × 20 cm (83,333 plants/ha).

Method of sowing

A) Sowing on ridges in heavy rain fall region

B) Sowing in flat bed in medium rainfall area

C) Sowing in flat furrow dry region and low rainfall area

Fertilizer management: Among the cereals, it requires huge amount of fertilizers. If there is no soil test recommendation, a blanket recommendation of NPK at 120:60.5:40 kg/ha is recommended for irrigated maize. Apply fertilizer 5 cm below the soil and 10 cm away from the root zone. 100% P and K should be applied as basal. 'N' should be applied in 3 splits *viz*., 25% basal, 50% on 25 DAS and 25% on 45 DAS. In all the cereal crops, there is two peak stages of uptake, where as in maize, there are three peak stages of uptake. For transplanted crop, 'N' should be applied at 50% basal and 25% each at knee high stage and teaselling stages.

Ist peak	30–35 days (Knee high stage)
IInd peak	50–60 days (Tasselling)
IIIrd peak	70–80 days (dough stage)

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

Water management: It requires 400–500 mm of water. Critical stages for irrigation are teaselling and silking. Peak consumption of water also occurs during this period (taselling and silking). In Clay/clay loam soils, totally 8 irrigations are required. For light soils, two more irrigations are needed.

Germination phase: Two irrigations 1st after sowing, 2nd as life irrigation 4th day)

Vegetative phase: Three irrigations at 12th day, 25th day and 36th DAS.

Flowering phase: Two irrigations on 48th and 60th day

Maturity phase: One irrigation on 72nd day

Weed management: The crop—weed competition is upto 45 days. Application of pre-emergence herbicides like Simazine and Atrazine at 1.0 kg ai /ha, followed by one hand hoeing and weeding on 30–35 DAS is recommended. There should be adequate soil moisture. The soil should not disturb immediately after application. It is better to use high volume sprayer fitted with deflected type or flat fan nozzle. If pre-emergence herbicide is not applied, post emergence application of 2, 4 D Na salt (Fernoxone 80 WP) at 1.0 kg a.i./ha on 2 or 3rd leaf stage for sole crop of maize is recommended. For maize + soybean/pulse intercropping system, pre-emergence application of alachlor at 2.0 kg a.i./ha (Lasso 50% EC), followed by one hand weeding is recommended.

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

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

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

Quality protein maize: high in lysine (3.5%) and tryptophan 5% and 11% protein; Protina, Shakti, Rattan, release in 1971 such variety called opaque-2 composite. Various hybrids viz, Shaktiman 1, 2, 3 and QPM 1, 2, 3, 4, 5, 6, 7, 8, 9.

Sweet corn: Madhuri, Priya

seed rate:8-10 kg/ha Spacing 60×20 cm

Baby corn: HM-4, Golden baby, VL -42, Pro agro seed rate: 35-40 kg/ha: Spacing 40×20 cm

Popcorn: Amber, VL amber, Perl popcorn

Seed rate: 20-25 kg/ha Spacing 60×20 cm

Fodder maize: African tall, J1006

Seed rate: 40-45 kg/ha Spacing 30×10 cm

Chapter 3
JOWAR OR SORGHUM (Sorghum bicolor) 2n =20

It belongs to family Poaceae and genus sorghum. Sorghum is one of the major food crops of the world, particularly Africa and Asia. In India, it ranks third in major food crop, especially central and peninsular India. It is used in various forms, similar to rice as cooked food, malted, flour for dosai and making chapatti or rotti, popped, semolina etc. It is a very good dry and green fodder and a good concentrate feed for cattle and poultry. Raw material is used for starch Industries. It is used in production of alcohol similar to corn and used for preparation of sorghum syrup (20–25% sugar) from sweet sorghum varieties. It is also used for production of Jaggery. It contains high amount of aconitic acid, which prevents the crystallization of sugar. It contains 10–12% protein, 72.6% carbohydrate, 3% fat, 1.6% mineral and contains more of fibre. It has the capacity to withstand drought or excess moisture (92% of sorghum is grown under rainfed). It comes up well even in marginal soil under moisture stress. It does well in low rainfall areas. It makes comparatively quick growth than maize. It is dormant during stress condition and it resumes its growth, when optimum condition occurs.

Undesirable qualities: It contains high amount of Niacin, which interface with the synthesis of Tryptophane, which is the precursor for synthesis of IAA. "***Pellagara***" is nutritional disorder due to presence of high amount of Leucine: iso-leucine ratio (3.4). When it is reduced, yield is also reduced.

This disease is common in Africa. It contains considerable amount of oxalic acid, which interface with absorption of Ca and metabolism of Ca. Phytin 'P' is not utilized due to high oxalic acid. Oxalic acid also affects the Fe uptake. Low digestibility and low palatability is due to presence of phenolic compounds and glycosides, tannin and lignin. Sorghum contains "cynogenic glucoside" called 'Dhurin'. This glucoside is converted into HCN in the stomach of ruminants. It causes bloating and reduce the transfer of O2 to the blood steam and causes death of the animal. It is called "***sorghum poisoning"/*(*sorghum effect*)**. HCN content is more than 100 ppm in the early stage. Critical level is 50 ppm. It (50 ppm) normally occurs during 60-65 DAS or at heading stage. If it is harvested earlier, it should be dried and fed to cattle. "***Sorghum injury***"—Sorghum stubbles/roots have high C: N ratio (50:1), *i.e.*, it contains low amount of 'N'. Hence, microbes take the soil 'N' for decomposition than from the decomposed stubble, which causes temporary immobilization of soil 'N'. Hence, succeeding crop after sorghum is affected due to N deficiency in the early stage called sorghum injury. Succeeding crops need higher N.

Origin: Warth (1937): **Africa** and Decandolle (1984): Abyssinia.

Classification: Harlen and De-Wet (1971), gave a modified and simple classification based on spikelet type.

(a) ***Basic races*****:** 1. Bicolor, 2. Guinea, 3. Caudatum, 4. Kafir, 5. Durra.

Now cultivated sorghum is *Sorghum biclor*.

(b) ***Hybrid races*****:** *Guinea bicolor, Caudatum bicolor* etc.

Climate: It is a short day C4 plant. Long day condition delays flowering and maturity. It is a warm weather plant and is grown even in 1500 m from MSL. Well distributed rainfall of 300-400 mm is optimum sorghum. Rainfall at maturity affects the quality of grain. Low temperature with cloudy weather at flowering induces sugary disease. The temperature requirement is minimum 8 to 10°C, optimum 26-29°C and maximum 35-40°C. Sorghum can tolerate high temperature throughout its life cycle better than any other cereal crops. It can tolerate high temperature throughout their life cycle, better than any other cereal. It is highly resistant to desiccation. It can tolerate water logging. Low temperature at flowering affects the seed set. Sorghum can tolerate drought condition. Because (*a*) it remains dormant during moisture stress and resumes growth when favourable condition reappear, and (*b*) it possesses (*i*) high resistance to desiccation, (*ii*) low transpiration rate, and (*iii*) largest number of fibrous roots.

Soil: It is grown under variety of soil. Soil with clay loam or loamy texture having good water retention is best suited. It does not thrive in sandy soils, but does better in heavier soils. It does well in

pH range of 6.0–8.5 as it tolerates considerable salinity and alkalinity.

Area, Production and Productivity: The World production is 147 m.t. and it is cultivated in USA, Brazil, Argentina, China and India. In India, it is staple food crop of north Karnataka, Maharashtra, Andhra Pradesh, Gujarat, Madhya Pradesh and Rajasthan. **In India, it is cultivated in an area of 11.5 m.ha. with a production of 11.08 m.t. and a productivity of 950 kg/ha**. In India, 92.0% of the area is under rainfed. It is mainly grown as kharif crop and smaller extent as rabi crop in Maharashtra, Karnataka, Andhra Pradesh and Madhya Pradesh. In Maharashtra, Karnataka, Madhya Pradesh and Andhra Pradesh, sorghum is grown in both **kharif and rabi**. The area under cultivation is high in Maharashtra followed by Karnataka, Madhya Pradesh and Andhra Pradesh. At present, Maharashtra has the largest area accounting 43% of Indian area under sorghum and 51% of total production.

Rainfed Sorghum

Rainfall: Average and well distributed rainfall of 300-400 mm is optimum for rainfed sorghum.

Field preparation: Field has to be prepared well in advance taking advantage of early showers. FYM @) 12.5 t/ha is applied at last ploughing. Chiselling is recommended to break hardpan once in three years. Depending on the rainfall and soil type, different land shaping methods may be adopted for conservation of the moisture. Black soil having high rainfall areas, formation of broad bed and furrow is recommended. In black soils having low rainfall, form compartmental bunding or sow the seeds in flat bed and form furrows between crops during inter cultivation or during third week after sowing for both the soil types or form dead furrow at 3 m interval.

Varieties: Local: Varsha, MAU 1, MAU 2. All India Co-ordinated Sorghum Improvement Project (AICSIP) developed 15 sorghum composite varieties **(CSV 1 to CSV 15 produce grain yield of 3 -3.5 t/ha, in 110-115 days) and 18 hybrids (CSH 1 to CSH 18, produce grain yield of 3.2 -4.3 t/ha, in 100-110 days).** CSH 1, CSH 6 and CSH 9 (3.0 t/ha) are best for kharif season. CSH 15 and CSH 18 is best for rabi season.

Seed rate: The seed rate is 12-15 kg/ha.

Seed treatment:

Seed treatment is done with Azospirillum and phosphobacteria each 3 pockets (600 gm). In main field, application of 2 kg of Azospirillum and 2 kg of phosphobacteria with 25 kg of FYM + 25 kg of soil is recommended. Then, the seeds are treated with Thiram/Bavistin @ 2 g/kg of seeds. If possible, the seed is palletized with 15 g of chlorpyriphos in 150 ml of gum before sowing and seeds are dried.

Sowing: The seeds are sown before onset of monsoon at 5 cm depth with seed cum fertilizer drill or by seed drill or by country plough. Pre monsoon sowing/dry seeding *i.e.*, sowing a week or 2 weeks before on set of monsoon is followed.

Spacing: The spacing for sole crop of sorghum is 45×15 cm (1,80,000 plants/ha) and 60/30×15 cm for intercropping and paired row system.

Manuring: Application of FYM or compost at 12.5 t/ha during last ploughing is recommended. 80:40:40 kg NPK /ha where 50% N, and entire P and K should be applied as basal, remaining 50% N as top dressing at 25–30 DAS depending on the rainfall.

Growth stages: There are five growth stages.

1. Seedling stage: 1–15 days

2. Vegetative stage (Grand growth (30–40)) : 16–40 days

3. Flowering/Reproductive stage: 41–65 days

4. Maturity: 66–95 days

5. Ripening: 96–105 days

Weed management: Keeping the sorghum fields free of weeds from 2nd week after germination till 5th week is good. If sufficient moisture is available, spraying **atrazine 50 %WP @ 1kg ai /ha** as pre-emergence within three days of sowing followed by one hand weeding/inter cultural operation may be done. For sorghum based intercropping system with pulses, pre-emergence application of pendimethalin (Stomp 30 EC) at 3.0 lit/ha followed by one hand weeding at 30 DAS is recommended.

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

• Post emergence application of 2,4-D Na salt at 2.0 kg/ha at 25–30 DAS

• Intercropping with red gram

• Crop rotation with trap crops like cotton, sunflower, groundnut, cowpea, etc., which induce germination of weed seeds, but they are not themselves parasitized

• Heavy application of N and FYM and flooding the field

• Spraying Urea 10 % solution on 25–30 DAS

• Using germination stimulants like Strigol and ethylene gas

Cropping system:

Sorghum + red gram at 3:1 ratio

Sorghum + soybean at 4:2 ratio

Sorghum + green gram at 4:2 ratio.

Sorghum + cowpea (2:1); sorghum + black gram (2:1)

Thinning: Thinning should be completed 10–15 days after emergence leaving one plant per hill.

Harvesting and threshing: Most of the high yielding varieties and hybrids mature in about 100–115 days. The right stage for harvest is, when the grain becomes hard having less than 25% moisture. Do not wait for stubble and leaves to dry, because hybrid sorghum appears

green even after the crop is matured. Harvest may be done at physiological maturity. Harvesting is done by cutting the entire plant or removing the ear heads first and cutting down the plants later and is allowed to dry for 2–5 days. Threshing is done with the help of thresher or beating the ear heads. The threshed grain is dried in the sun for a week to bring the moisture content to 10–12% for safe storage.

Yield: The grain yield varies from 2–3 t/ha under rainfed conditions and the dry stover yield varies from 8–10 t/ha.

II. Irrigated Sorghum

It is raised by either direct seeding or transplanting. Irrigated transplanted crop has advantages like main field duration is reduced by 10 days; shoot fly attacks will be economically controlled in the nursery; seedlings which show chlorotic and downy mildew symptoms can be eliminated; optimum population can be maintained as only healthy seedlings are used and seed rate is reduced by 2.5 kg/ha.

Varieties: CSV 1 to CSV 15 produce grain yield of 3.5 -4 t/ha, in 110-115 days) ,*CO 25* (115–120 days, grain yield of 6.0 t/ha, straw yield of 17.5 t/ha), ***CO 26*** (105–110 days, grain yield of 6.0 t/ha, straw yield of 19.0 t/ha), ***BSR 1*** (105–110 days, grain yield of 6–6.5 t/ha, straw yield of 9.6 t/ha).

Hybrids: (CSH 1 to CSH 18, produce grain yield of 4.5-5.0 t/ha, in 100-110 days) ***CSH 5*** (100 days, grain yield of 4.5 t/ha, straw yield of 12.5 t/ha), ***COH 4*** (105–110 days, grain yield of 6.5 t/ha, straw yield of 20.0 t/ha), ***COH 5*** (100 days, grain yield of 6.8 t/ha, straw yield of 19.0 t/ha).

Seed rate: The seed rate for direct sowing is 10 kg/ha and 7.5 kg/ha for transplanting.

Nursery

(i) **Preparation:** For planting one ha, about 7.5 cent (300 m2) nursery area is required, near the water source. Application of 750 kg of FYM or compost for 7.5 cent nursery is done and another 500 kg for covering the seeds after sowing is used. Forming raised beds of 2 m × 1.5 m with 30 cm spacing to a depth of 15 cm is done. Pretreatment of seeds for both direct seeded crop and raising in the nursery is must. The seeds are treated 24 hours before sowing with carbendazim/ captan/thiram @ 2 g/kg of seed. And then, the seeds are treated with 2% KH_2PO_4 for 6 hours and shade dried for 5 hours. The seeds are treated with 3 pockets of Azospirillum (600 g/ha) using rice kanji as binder.

(ii) **Sowing:** Forming rills using fingers, broad casting the seeds and covering with 500 kg of FYM is done.

(iii) **Irrigation:** Irrigations are given immediately after sowing, 3rd day, 7thday, 12th day and 17th day (Totally five irrigations).

(iv) **Transplanting:** Age of seedling is 15-18 days. The seedlings are dipped in Azospirillum solution (5 pockets -1000 g) dissolved in 40 lit. of water) for 15-30 minutes. Planting at 45 × 15 cm spacing at a depth of 3–5 cm with one seedling per hill on the side of ridge is done.

Main field preparation (direct seeded and transplanted crop: Sorghum does not require fine tilth. The field is ploughed with an iron plough once and twice with a country plough. To overcome the sub soil hard pan in Alfisol, chiseling the field at 0.5 m interval to a depth of 40 cm on both the direction of the field followed by disc ploughing once and cultivator ploughing twice is done. Application of 12.5 t FYM or compost/ha with 2 kg of Azospirillum (10 pockets/ha) is recommended. Ridges and furrows are formed at 45 cm apart using ridge plough.

Fertilizer management

Transplanted crop: If soil test recommendation is not available, the blanket recommendation of 90:45:45 kg NPK/ha is recommended. 50% N and entire P and K should be applied basally before planting and remaining 50%N is applied on 15 DAS.

Direct seeded crop: Blanket recommendation of 90:45:45 kg NPK/ha is followed. Application of 50% N, and entire P and K should be applied basally and the remaining 50% N on 25–30 DAS.

Micronutrient: For Zn deficient soils, 25 kg ZnSO4/ha is applied at the time of sowing/transplanting.

If ZnSO4 is not applied basally and if Zn deficiency is noticed, ZnSO4 at 0.5% concentration is sprayed. For Fe deficient soils, 50 kg FeSO4 is applied at sowing or at planting. If FeSO4 is not applied basally, FeSO4 1% concentration at 2 or 3 stages is sprayed.

Spacing: The spacing is 45 × 15 cm (1,48,000 plants/ha) for both direct and transplanted crop. For raising intercrop and paired row system, a spacing of 60/30 × 15 cm may be adopted. Raising one row of pulses in between 60 cm row spacing is common.

Thinning and gap filling: In the direct sown crop, thinning one seeding per hill and gap filling the thinned-out seedlings is done on 10–15 DAS, maintaining a spacing of 15 cm between plants.

Weed management: Sorghum is slow growing in the early stage and is adversely affected by weed competition. Keeping the fields free of weeds up to 45 days is good. Pre-emergence herbicide Atrazine 50 WP at 500 g/ha (atrazine 0.25 kg/ha) on 3 DAS using high volume sprayer followed by one hand weeding on 30–35 DAS is recommended. If pulse crop is raised as intercrop, do not use atrazine. If herbicide is not used, for transplanted crop, two hoeing and weeding on 10 and 30–35 DAS should be done. In the case of direct seeded crop, two hand weeding on 15–20 DAS and 35–40 DAS should be done.

Water management: Total water requirement is 450–500 mm. Irrigation at 50% depletion of available soil moisture or 0.6 IW/CPE ratio is sufficient. There are four critical stages *viz.*, (1) seedling, (2) vegetative, (3) flowering, (4) dough stages. Stress at one week before and one week after flowering is very critical. Under moisture stress condition, 5 irrigations are sufficient. For normal condition, 8 irrigations are to be given *i.e.* on 1st day, 4th day, 15th, 28th, 40th, 53th, 64th, 76th and 88th days. Irrigation should be stopped after 88–90 DAS. As contingent plan, spraying 3% Kaolin (30 g in one litre of water) during periods of stress will mitigate the ill effects.

Harvesting and processing: When the crop matures, leaves turn yellow and the grains are hard and firm and moisture content will be less than 25%. At this stage, the earheads are cut separately and dried for 2–3 days and threshing using mechanical thresher is done and the grain is dried to 12% moisture for safe storage. The straw is cut after a week and allowed it to dry and then stacked for fodder.

Cropping system

Sorghum–Ragi; Sorghum–Cotton; Sorghum–Onion; Sorghum–Green gram.

Intercropping

The sorghum crop is intercropped with Cowpea, Soybean, Black gram and green gram.

Fodder sorghum: **Single cut varieties** (25 seed kg/ha): Pusa chari 6, Pusa chari 9, HC 136, Jawahar Chari 6 (JC 6), UP chari 1, 2, HC 171, 260, 306.

Multi cut varieties (10kg seed/ha): Pusa Chari 23(PC 23), Haryana chari, SL 44, **Meethi Sudan, SSG**59-3, MP Chari, Jawahar Chari JC 69.

Hybrids fodder sorghum (10 kg seed/ha): CSH 13, CSH 15, PCH 106, **Hara Sona**, MFSH3.

Sweet sorghum: RSSV 84 released in 1992 produce **51.4 t/ha green cane**, 17.8% brix content and 1.88 t/ha grain, but only suitable for jaggary (raw sugar) due to cristlization problems. Other varieties as RSSV24, 45, 46, 57, 59, NSS 216, 219.

Chapter 4
PEARL MILLET (OR) BAJRA *(Pennesitum, glaucum)*

It is a stable food crop of about 100 million peoples in rural areas of India and Sub Saharan Africa. Roti or Chapatti, which are unleaved flat breads prepared using pearl millet flour are common in Asia.

Porridges and cooked grains are also used. In northern India, it is prepared during winter while wheat

becomes common in summer diet. It is also used for fried preparations, foods such as fermented products and beer. Varieties of pancakes are prepared using pearl millet flour in Africa and pearl millet beer is used throughout Africa. Fura or cheese is the traditional African snacks prepared using steamed pearl millet flour and cream. It is used as fodder in Africa and Asia. Oxalic acid content is very high. So it is not relished by cattle. It is rich in protein (12.6%) and fat (5%), fibre (1.2%) and 60–70% of Carbohydrate. It is normally rich in Ca, Vitamin Riboflavin and Carotenoides. In Central America, it is mainly cultivated for forage purpose. It is also grown as pasture grass. Of the 150 sps of *Pennesitum, P. glaucum* is the cultivated species for grain and *P. purpurea* is the forage species.

Origin-Africa

Area, Production and Distribution: It is largely grown in India. The important pearl millet producing countries are India**,** Africa, Pakistan, China, Sudan and Egypt. In India, it is cultivated in an area of 10 m.ha with a production of 7.9 m.t and productivity of 791 kg/ha. Area under cultivation is high in Rajasthan, followed by Maharashtra, Gujarat and Uttar Pradesh. The production is more in Rajasthan, followed by Maharastra, Gujarat, Tamil Nadu and Uttar Pradesh.

Stages: There are four crop stages namely **s**eedling stage (1–18 days), Tillering stage (19–35 days),

Flowering phase (36–55 days) and Maturity phase (56–85 days)

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

temperature and low rainfall. It is grown as kharif crop in Northern India, while in Tamil Nadu, Karnataka and Punjab, it is grown under irrigated condition during summer.

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

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

Hybrids: Under All India Co-ordinated Research project, many hybrids have been developed. PHB 1 to 15 with yield potential of 4.5-5.5 t/ha).HHB 146, Pusa hybrids 1201 and 1202. Proagro 9444, 9450 etc. Among them, HB-3 and PHB 14 is the best (6.0 t/ha). But all hybrids are susceptible to downy mildew. To overcome the downy mildew, CMS line MS.5071 was used and five New Hybrid bajra were developed. Among them, NHB.5 is the best for disease resistance and wide adaptability besides giving higher yield.

Composite: WCC 75 (World Cumbu Composite developed at ICRISAT, Hyderabad) is suited for both irrigated and rainfed. Duration is 95 days. Irrigated crop yields 3.0 t and rainfed crop yields 2.0 t/ha. Pusa composite 443, Pusa composite 443 have sown grain of yield 3.0 t /ha in 85-90 days.

I. Rainfed crop: Direct seeding either broadcasting or sowing behind country plough.

II. Irrigated condition: (*a*) Raising seedling in the Nursery and transplanting. (*b*) Direct sowing.

a. Seed Rate and Seed Treatment

The seed rate for direct sowing is 5 kg/ha and for transplanting, it is 3.75 kg/ha. Ergot affected seeds are removed using salt solution (1 kg of NaCl in 10 lit of water), to prevent primary infections and shade dried. Seed treatment is done with fungicides-captan or thiram 2 g/kg of seed, followed by Azospirillum seed treatment (3 pockets or 600 g/ha seed rate).

b. Transplanted Crop

Nursery preparation: Nursery area required 300 m^2 for one ha. The land is ploughed in such a way to bring fine tilth. Application of 750 kg of FYM or compost is done and incorporated. Raised beds of 3.0 m × 1.5m with 30 cm channel are formed. Small rills not deeper than 1 cm on the raised bed are opened. About 3.75 kg of seeds is sown and 500 kg of FYM or compost is used for sprinkling for covering the seeds.

Field preparation for both irrigated and rainfed crop: Deep ploughing with Iron plough and country plough is to be done twice to bring fine tilth. If there is hard pan, chisel ploughing is done. About 12.5 t/ha of FYM or compost is applied during last ploughing. Application of Azospirillum to the soil is done @ 10 packets/ha (2 kg).

Land Shaping: For irrigated crop (transplanting), either ridges and furrows at 45 cm apart or beds of convenient size depending upon the water availability are formed. For rainfed crop, flat sowing is followed. For rainfed crop, Pora method of sowing is better than Kera method.

Transplanting: Pull out of the seedlings is recommended when age of seedling is 15–18 days. Transplant single seedling at spacing of 45 × 15 cm (similar row spacing is adopted for rainfed crop also) with 3-5 cm depth. Dipping the roots in bio-fertilizer Slurry (dissolve 5 pockets of Azospirillum in 40 lit. of water) for 15–30 minutes may be done.

Direct sown crop: Soaking the seed in 2% potassium chloride or 3% NaCl for 6 hours followed by shade drying for 5 hours is done. As in transplanted crop, a spacing of 45 × 15 cm at 3 cm depth .Seed rate is 5 kg/ha.

Fertilizer management: If soil test recommendation is not available, the blanket recommendation

is followed as given below:

Irrigated crop: Hybrids 80-100 : 40-50 : 40 kg N : P_2O_5 : K_2O/ha.

Varieties 80 : 40 : 40 kg N : P_2O_5 : K_2O/ha.

Rainfed crop: 60 : 30 : 30 kg N : P_2O_5 : K_2O/ha.

Application of 50% N and 100% P and K is recommended as basal at 5 cm depth and the remaining 50% N at 15 days after planting for transplanted crop and 30 DAS for direct sown crop is applied. For Zn deficient soil, application of $ZnSO_4$ at 25 kg/ha is done. Iron deficiency occurs in saline and calcareous soil. Based on the level of deficiency, 12.5–25 kg of $FeSO_4$ is recommended. If it is not applied basally, foliar application of 1% $FeSO_4$ at vegetative phase is recommended.

Water management: It is a highly drought tolerant crop and water requirement is 300–350 mm. Irrigation at available soil moisture of 50% or optimum IW/CPE ratio 0.4 is sufficient. The critical stages are tillering and flowering. Normally 5 irrigations are recommended for the stages *viz.*, **tillering, panicle initiation, flowering, dough stages** in addition to sowing irrigation. Under limited

moisture conditions, three irrigations can be recommended for panicle initiation, flag leaf and flowering in addition to sowing irrigation.

Thinning and gap filling: In the direct sown crop, after 1st weeding at the time of irrigation, gap filling and thinning is done to a spacing of 15 cm between plants. In rainfed crop, thinning should be done 10-15 DAS.

Weed management: Weed reduces the yield by 50%. Crop weed competition is up to 35 days. Pre-emergence application of atrazine at 500 g/ha followed by hand weeding on 30–35 days after transplanting or sowing. If the herbicide is not used, weeding is done on 15th day and again between 30 and 35 days after transplanting. For direct sown crop, hoeing and weeding may be done on 20–25 DAS and second weeding on 35–40 DAS. Atrazine should not be used for intercropping systems.

Cropping system: Some of the important crop rotations are:

1. Bajra – Barley Intercropping system in North India
2. Bajra – Wheat Bajra + Groundnut
3. Bajra – Gram Bajra + Black gram
4. Bajra – Pea Bajra + Green gram
5. Bajra – Potato Bajra + Castor

   Bajra + Cowpea

Harvesting and Threshing: When the leaves turned yellow colour and when the seeds become hardened and having 20% moisture, harvesting is done by removing the ear heads first and cutting down the plant's latter on. The ear heads after harvesting should be dried well in sun before threshing. The grains are separated either by beating the ear heads by sticks or by trampling by bullocks. If mechanical thresher is available, thresh it or spread it and drag a stoneroller over it. The threshed grain should be cleaned and dried in the sun to bring the moisture to 12–14% for safe storage.

Yield	**Grain yield (**t/ha)	**Stover yield (t/ha)**
Irrigated	3.5 -5.0	10.0
Rainfed	2.0 -3.0	8.0

Chapter 5
SMALL/MINOR MILLETS

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

1. Finger millet (Ragi mandua): *Eleusine coracana*
2. Italian millet (Thenai, Kakun, Fox tail): *Setaria italica*
3. Kodo millet (Varagu): *Paspalum scrobiculatum*
4. Proso millet (Panivaragu, Cheena): *Panicum millaceum*
5. Barnyard millet (Kudiraivali, Sawan): *Echinochloa frumentacea*
6. Little millet (Samai): *Panicum milliare*

1. FINGER MILLET (RAGI, MANDUA) *Eleusine coracana* L. Gaertn.

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

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

Area and Production: In India, it is cultivated in an area of 19.1 lakh ha with a production 27.62 lakh tonns and productivity of 1440 kg/ha. It is predominantly grown in the peninsular Indian states of Karnataka, Andhra Pradesh, Orissa, Uttar Pradesh and Tamil Nadu. The production is high in Karnataka, followed by Tamil Nadu, Uttar Pradesh, Orissa and Andhra Pradesh. The average productivity is high Tamil Nadu, followed by Karnataka and Uttar Pradesh.

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

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

Varieties: Short duration varieties (85-95days) are VR 708, VL 352, GPU 45, RAU 3 and VL 348. Medium and late maturity varieties (100-115 days) are VL 149, GPU 28, GPU67, GPU85, RAU 8, BM 2 and A404

Seed rate and sowing: 10 kg/ha seed sown at spacing 25 cm with 2.5 cm depth.

Main field preparation and planting: The field is ploughed thoroughly to get a fine tilth with mould board plough. FYM or compost at 12.5 t/ha is incorporated. Application of NPK is done as per soil test or a blanket recommendation of 60:30:30 of NPK kg/ha is recommended. Half N and full P and K are applied basally. Application of 10 packets of azospirillum/ha by mixing with 25 kg sand and 25 kg FYM before transplanting is done or root dipping is done for 15–30 minutes with Azospirillum 5 packets (1000 g) in 40 lit water. Beds of 10–20 m^2 are formed with suitable irrigation channels. Let water in to the bed and level the bed. Planting 18–20 days seedlings at 2/hill at a depth of 3 cm with a spacing of 15 × 15 cm is done. The remaining half N is top dressed in two equal splits on 15th and 30th day after transplanting coinciding the weeding. In the case of aged seedlings beyond 21 days, the number of seedlings is increased to 3/hill and N by 25% is increased to reduce the loss.

Water management: Depending upon the duration of the crop (80, 100 and 120 days) and stage of the crop, irrigations may be given. The critical stages are tillering and pre flowering stages.

Weed management: Application of Butachlor 2.5 l/ha or Fluchloralin 2 l/ha or pendimethalin 2.5 l/ha as pre-emergence with 600 liters of water. If pre-emergence herbicide is not applied, hoeing and hand weeding is done on 15^{th} and 30^{th} day after transplanting. For rainfed directed seeded crop, application of post emergence herbicide like 2,4-DEE or 2,4-D Na salt at 0.5 kg/ha is done on 10^{th} day after sowing depending on moisture availability.

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

Pest and disease management: To control mosaic virus, spraying Monocrotophos 36 WSC 0.05%

is recommended. To control blast, spraying of carbendazim 500 g/ha is recommended. If needed, 2nd and 3rd spray may be given at 15 days interval after 1st spray. To control root aphids, dimethioate at 3 ml is mixed with 1 of water and drenching is done.

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

Yield:	**Grain yield (q/ha)**	**S t o v e r yield (q/ha)**	**Maturity duration**
Short duration varieties	15-18	25-30	90-95 days
Medium and long duration varieties	20-25	30-35	100-115days

2. ITALIAN MILLET (Thenai, Kakun, Fox tail): *Setaria italica*

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

Origin: China

Area and distribution: It are cultivated in India, China, Eastern Europe, Southern parts of former USSR and some extent in African and American countries. In India, it is cultivated in Karnataka, Andhra Pradesh, Madhya Pradesh and Uttar Pradesh.

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

Varieties:	Maturity duration	Grain yield (q/ha)	Stover yield (q/ha)
Short durarion MS 4872, MS 4884, BR 7	65-70	12-15	25-30

Medium durarion TNAU 145,151 and GPUP 21, 70-75	15-18	30-35

3. KODO MILLET (Varagu); *Paspalum scrobiculatum*

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

Origin: India

Area and distribution: It is grown mostly in Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu and Uttar Pradesh.

Soil and climate: It is grown from gravelly and stony upland poor soils to loam soils and it comes well under adverse conditions and even in poor soils, some yield can be obtained. It thrives best on well drained sandy loam to loamy soils. It makes rapid growth in warm and dry climate and requires rainfall of 400–500 mm.

Varieties:	Maturity duration	Grain yield (q/ha)	Stover yield (q/ha)
Short durarion JK13, 41, 65, 76, 155, 439	85-90	12-15	25-30
Medium durarion: GPUK,Pali, Didari, Niwas No 1	95-110	15-18	30-35

4. COMMON MILLET (Panivaragu, Cheena, Proso millet): *Panicum millaceum*

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

Origin: India

Area and Distribution: It is grown extensively in India, Japan, China, Egypt, Arabia and Western Europe. In India, it is largely grown in Madhya Pradesh, Eastern Uttar Pradesh, Bihar, Tamil Nadu, Maharashtra, Andhra Pradesh and Karnataka.

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

resistant and can be grown in areas where there is scanty rainfall. It can withstand water stagnation to certain extent.

Varieties:	Maturity duration	Grain yield (q/ha)	Stover yield (q/ha)
Short durarion RAU 2, Ko 4 and Arjun	75-80	10-12	20-25
Medium durarion: SIA 326, SIA 2593, 3085, PS 4	80-85	12-15	25-32

5. BARNYARD MILLET (Kudiraivali, Sawan): *Echinochloa frumentacea*

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

Origin: India

Soil and climate: It can grow in poor soils but requires fairly fertile soils for good yields. Light soils including red loams, alluvial and black cotton soils are all suitable for its cultivation but it thrives best on rich, well-drained loam soils. It is cultivated in tropical and temperate regions up to 2000 m altitude. It requires moderate temperature and grows successfully with 50–75 cm rainfall. Although

water requirement is less, it has no capacity to recover after long spell of drought

Varieties:	Maturity duration	Grain yield (q/ha)	Stover yield (q/ha)
Short durarion VL 172	80-85	12-15	30-32
Medium durarion: VL 207, RAU 3, RAU9	85-90	15-18	32-35

Chapter 6
GREEN GRAM *(Vigna radiata)*

Features of green gram: It is an excellent source of high-quality protein near about 24%. Moong is consumed as whole grains as well as dal, sprouted whole moong is used in South India. In sprouted moong ascorbic acid (Vitamin-C) is synthesized and the amount of riboflavin and thiamine also increased. Being a leguminous crop, it can fix atmospheric N, it is also used as green manuring crop and helps in preventing soil erosion. Being a short duration crop it fits well in any crop rotation. It helps to control the erosion of soil. After picking of pods, it may be used as green fodder or as green manure. The husk of the seed can be used as cattle feed.Green gram contributes 14% in total pulses area and 7% in total pulses production in India.

Origin: Green gram is the native of India and Central Asia. In India moong is grown in almost all the states. It is grown in about 3.1 Mha with the total production of about 1.1 Mt of grain.

Area and distribution

Greengram is widely cultivated in India, Sri Lanka, Myanmar, Pakistan, China, Fiji, Australia, America and Africa. Greengram is widely cultivated throughout southern Asia, including India, Pakistan, Bangladesh, Sri Lanka, Thailand, Laos, Kampuchea, Vietnam, Indonesia, Malasia, South China and Taiwan. It is also grown to a lesser extent in many parts of Africa and the USA, especially Oklahoma and has recently been introduced in parts of Australia. The area under this crop is around 3.2 million hectares with the production of 0.95 million tones and a productivity of 304 kg/ha. In India the area under this crop is highest in Rajasthan (799.5 ha) followed by Maharashtra (546 ha). The production under this crop is highest in Maharashtra (193.3 t) followed by Andhra Pradesh (166.7 t).

Botanical description: Small herbaceous plant growing to a height of 30-100 cm. The leaves are trifoliate with long petioles; the leaflet being large, ovate and entire. Both the stems and leaves are covered with short hairs, generally shorter than those in black gram. Inflorescence is axillary racemes. The pods are 6-10 cm long, round and slender with green colour. Germination of seed is epigeal type. The crop is fully self-pollinated.

Climatic requirement: green gram is primarily a crop of rainy season. But with the development of early maturing varieties, it has proved to be an ideal crop for spring and summer season. It is grown mainly as *Kharif* season crop but it is cultivated as second crop in *Rabi* seasons in Andhra pradesh, Tamilnadu, Orissa and Madhya pradesh. In West Bengal, it is grown after Aus Paddy (autumn) and after Potato (Zaid crop). Green gram is best suited in

the areas having an annual rainfall of 600-750 mm. Moong is considered to be the hardiest of all pulse crops. It requires a hot climate and can tolerate drought to a great extent. It can be grown from sea level to an elevation of 2000 metres. It is grown in *Kharif* and *Summer* seasons in north India but in south and south west it is also grown as *Rabi* season crop.

Soil: Moong crop is grown on a variety of soils from red lateritic to black cotton soils. A well-drained loamy to sandy loam soil is best suited for moong cultivation. Saline and alkaline conditions should be avoided for moong cultivation. The crop performs best in soils with 6.5-7.5 pH.

Varieties:

Samrat: This variety matures in 60-65 days. It is Suitable for summer and *Kharif* season with a yield potential of 12-15 q ha^{-1}.

Pusa Vishal: This variety matures in 65-70 days. It is Suitable for summer and *Kharif* season with a yield potential of 12-15 q ha^{-1}.

Asha: This variety is suitable for irrigated condition in *Kharif* season. It is resistant to yellow mosaic virus, matures in 75-80 days and yield potential is 12-15 q ha^{-1}.

Narendra moong 1: This variety matures in 65-70 days, susceptible to yellow mosaic virus, and yield potential is 12-15 q ha^{-1}.

Pant moong 1: This variety matures in 75 days in *Kharif* and 65 days in summer, resistant to yellow mosaic virus, and yield potential is 10-12 q ha^{-1}.

Pant moong 2: This variety matures in 65-70 days in *Kharif* and 60-65 days in summer, resistant to yellow mosaic virus, and yield potential is 10-12 q ha^{-1}.

Pant moong 3: This variety matures in 75-85 days and is suitable for growing in *Kharif* saeson, moderately resistant to yellow mosaic virus, and yield potential is 10-15 q ha^{-1}.

Pant moong 4: This variety matures in 65-70 days, resistant to yellow mosaic virus, and yield potential is 10-12 q ha^{-1}.

Varsha: It is developed from Haryana, matures in 55-60 days, it has good cooking quality and yield potential is 10 q ha^{-1}.

RS-4: This variety developed from Rajasthan; average yield is 6-8 q ha^{-1}.

Jawahar-*45:* This variety is suitable for eastern and western part of northern and peninsular zones of India in *Kharif* season. Matures in 75-85 days and yield potential is 10-13 q ha^{-1}.

Cropping system: Moong is grown as mixed crop with pigeon pea, sorghum, pearl millet, maize and cotton during *Kharif* season. Intercropping of moong can be done with spring

planted sugarcane. Sugarcane is planted at distances of 90 cm from row to row. Two rows of moong 30 cm apart in the centre of sugarcane rows leaving 30 cm distance between cane and moong rows are sown with a seed rate of 7-8 kg ha^{-1}. The important cropping systems with moong bean in north India are mentioned below:

1. Maize-Wheat-Greengram
2. Potato-Wheat-Greengram
3. Greengram-wheat
4. Greengram-potato

Field preparation: A thorough land levelling is must for quick drainage. The crop requires fine seedbed preparation. In *kharif*, the land preparation involves 2-3 cross ploughings or harrowings followed by planking. Summer green gram can be grown after harvesting of wheat crop with minimum preparatory tillage. However, in order to obtain a good crop, a very heavy pre-sowing irrigation may be given and the field ploughed twice with harrow to give a good tilth.

Time of sowing: a) *Kharif:* Second fortnight of June to first fortnight of July

b) Rabi: October to November

c) Summer: Middle of March to middle of April.

Seed rate and spacing: During *Kharif* season 12-15 kg seed per hectare should be sown in 45 cm apart while during *Rabi* and summer seasons 20 kg seed per hectare should be sown in rows 30 cm apart. The seeds are sown in furrows opened by plough or line sown using seed drill.

Seed treatment: Before sowing seed should be treated with Thiram or Carbendazim (Bavistin) at the rate of 2.5 g/kg of seed. *Rhizobium* culture is a must to get a bumper crop. *Rhizobium* culture helps in the development of nodules on the roots which are beneficial for fixing atmospheric nitrogen in the soil.

Manures and fertilizers: Greengram is generally raised on the residual fertility of soil. In case of light soils of poor fertility, it needs addition of organic manures like FYM or compost @ 8-10 tonnes/ha. If organic manure is not available, fertilizer application is necessary. Mungbean fixes atmospheric nitrogen in association with *Rhizobium*. The N fixation starts from 2nd week after sowing with its peak at 40-50 DAS. To meet the requirement of N before start of N fixation, 15-20 kg N/ha is applied along with 40-60 kg P_2O_5/ha as basal at the last ploughing. The response of crop to K fertilization is rare.

Application of 20 kg/ha each of zinc sulphate and elemental sulphur is essential for higher yields.

Water management: For rainy season crop, irrigation is not needed but drainage is very important. For *Rabi* and *summer* five to six irrigations may be given. The first irrigation should be given about 20-25 days after sowing. The subsequent irrigations should be given at an interval of 12-15 days and irrigation should be stopped after 40-45 days of sowing.

Weed control: Two weedings at 20 days interval from 25 days after sowing keep the field free from harmful weeds. Chemicals like Fluchloralin (Basalin) 1kg a.i. per hectare in 800-1000 litres of water may be applied as pre-planting spray.

Diseases: Important diseases are yellow mosaic, mosaic mottle, leaf crinkle, leaf curl, seed and seedling rot, cercospora leaf spot, anthracnose and charcoal rot. The symptoms and control measures are given below-

Yellow mosaic virus:

Symptoms: Appears with a month of sowing. Leaf lamina becomes yellow and scattered round spot. These spots expand rapidly and the leaves show yellow patches alternating with green colour of the leaves.

Control measures:

1. Grow resistant varieties like Asha, Pant moong-4, Narendra moong-1 etc.
2. Spraying of Oxydemeton methyl (Metasystox) (0.1%) + Melathion (0.1%) at 10 days interval is very effective.

Mosaic mottle:

Symptoms: Leaf margin shows upward rolling, become deformed, irregular light green areas appeared alternating with normal green in leaf surface.

Control measures:

1. Grow resistant/tolerant varieties
2. Spraying of Oxydemeton methyl (Metasystox) (0.1%) + Melathion (0.1%) at 10 days interval is very effective.

Leaf crinkle: Symptoms appear first in third leaf after 3-4 weeks of sowing. Leaves become enlarge followed by crinkling

Control measures:

1. Rogue out disease plant as soon as they appear.

Leaf curl:

Symptoms: It is a viral disease; chlorosis appear around the lateral vein near the leaf margin of young plants. The affected leaves show curling of margins downwards while the veins on the under surface of the leaf show reddish-brown discoloration.

Control measures:

1. Spraying of Oxydemeton methyl (Metasystox) (0.1%) + Melathion (0.1%) at 10 days interval is very effective.

Cercospora leaf spot:

Symptoms: Caused by two species of cercospora fungus, small round spots with violet red in colour may be observed.

Control measures:

1. Spraying of Mabcozeb 75 WP at the rate of 2 kg in 1000 litre of water per hectare at 10 days interval is very effective.

Anthracnose:

Symptoms: Diseased is caused by fungus *Colletorichum capsici*, dark brown circular spot appears initially, later the spots increase in size by developing concentric ridges and the colour turns into ash colour.

Control measures:

1. Spraying of Mabcozeb 75 WP at the rate of 2 kg in 1000 litre of water per hectare at 10 days interval is very effective.

Charcoal rot:

Symptoms: Diseased is caused by a fungus *Macrophomina phaseoli*. This disease is characterized by rotting of roots and stems of the plant. Affected parts of the plant turn into reddish-brown to black in colour.

Control measures:

1. Diseases can be controlled by treating the seed with Brassicol (0.25%) before sowing.

Insect pests:

Pod borer *(Helicoverpa obsolete* Fab.): This is more destructive insect pest and the crop is damaged at the time of pod formation. It is polyphagous in nature. The caterpillar feeds on foliage and then bores the green pod and feeds on the ripening grains within the pods. Deep

ploughing immediately after harvest of preceding crop helps to expose the pupae to hot sun and also, they get killed by birds. Spraying the crop with insecticides at the fruiting stage has been found effective in control this insect pest. Malathion 25 EC or Methyl Parathion 50 EC or Cypermethrin 10 EC @ 1.0 ml per litre of water.

Hairy Caterpiller*:* The adult moths of these caterpillars lay eggs in large clusters and the young larvae congregated. The red hairy caterpillar may damage the crop at seedling stage.

Control: Dusting by 2% Methyl parathion dust at the rate of 25-30 kg ha^{-1} can be effective to control this disease. Spraying of Endosulfan 1.5 litres in 1000 litres of water can also be efficient.

Leaf hopper: The adults and hymps of this hopper suck the juice from the leaves but also occasionally from the upper surface. As a result of sucking the sap, the leaves turn brown and curl from the edge.

Control: Basal application of Phorate (Thimet) 10% granules at the rate of 10 kg per hectare is very effective. Spraying of monocrotophos 36EC at the rate of ml/Litre of water can also be done.

Jassids: The adults and nymphs of this insect suck the sap from the leaves and the damage is more severe when the plants are young. The leaves are crumpled and the plants look sick.

Harvesting and threshing: Shuttering of pods is a great problem; therefore, picking should be done as soon as the pod matures. Harvesting should be completed in two to three pickings. The varieties which are quite synchronous in maturity require only two pickings or sometimes the whole crop may be harvested with sickle. The pods of whole crop after complete drying should be threshed manually.

Yield: A well-managed crop may produce 12 to 15 quintals of grain per hectare.

Chapter 7
BLACK GRAM *(Vigna mungo* L.)

Blackgram *(Vigna mungo* L.Hepper) also known as Urdbean/mash has wider adaptability. It is an important pulse crop of tropical and sub-tropical area. Blackgram is one of the important *kharif* pulse crops of India. It is very rich in protein (25%) and is the richest in phosphoric acid among pulses. It is used for preparation of "bari" (spiced ball) which makes a delicious curry. It is the chief constituent of "Papad." Its husked dal is ground into a fine paste and allowed to ferment and then the fermented dal is mixed with equal quantity of rice flour to make *'dosa'* and *'idli'*. The dal of black gram is also used in the preparation of *'halwa'* and *'imarti*'. Excessive use of black gram causes flatulence which can, however be prevented by adding little as a foetida, pepper and ginger in the culinary preparations. It should not be taken by those who are easily predisposed to rheumatic diseases and urinary calculi as it contains oxalic acid in high concentration. It fits well as 'catch crop'. It is also an important crop for cultivating as *'paira crop'* in paddy. The green plant (*i.e.*, used as fodder) is very nutritive and it is very useful to milch cow specially. It can also be grown as *'green manuring crop* '. It has deep root system which binds the soil particles very tightly and also acts as cover crop and protects the soil from erosion. Black gram, being leguminous crop, has the capacity of fixing atmospheric nitrogen and enriches the soil with nitrogen and organic matter and thus help in maintaining the fertility of soil. The by-product of black gram i.e. dry plants and churi is used as a cattle feed. The black gram also helps in controlling diabetes, sexual dysfunction, disorders related to nervous, hair and digestive system.

Origin

Black gram is a native of India as is seen from Vedic literature. There is mention of urd seed in Vedic texts such as Kautilya's "Arthasastra" and "Charak Samhita". According to Zokovskij (1962) urd originated in India from *Phaseolus sublobatus* (wild progenitor).

Area and distribution

Blackgram, occupies 2.97 million ha and contributes 1.25 million tonnes to pulse production with a productivity of 419 kg/ha. The area under this crop is highest in UP (539 ha) followed by Maharashtra (480 ha). The production under this crop is highest in Andhra pradesh (251 tonnes) followed by UP (239 tonnes). Like green gram, it is cultivated mainly as *kharif* crop almost in all states and has a premier place in hill agriculture. In northern plains, it is also cultivated during spring as a catch crop. In southern and south-eastern region, it is cultivated in rice fallows during *rabi*.

Classification

According to Bose (1932) *Vigna mungo* is subdivided into two sub-species.

(1) *Vigna mungo* var. niger: It includes varieties which mature early and have bold seeds of black colour.

(2) *Vigna mungo* var. viridis: It includes varieties having longer maturity period. Seeds are of small size and green colour.

Climatic requirement

It requires warm and humid conditions during growing season. It is generally cultivated as both summer and rainy season crop. It can be grown successfully from sea level up to an elevation of 1800 meters. It is comparatively more tolerant to waterlogging and moisture stress than green gram. The optimum temperature for growth ranges from 25-35^{o}C. However, it can tolerate temperature up to 42^{o}C. Heavy rains and cloudy weather at the time of germination and during flowering stage are harmful to its successful cropping. Short days are conducive for higher productivity.

Soil requirement

Blackgram is cultivated on a variety of soils, but well drained loams or slightly heavy clay loam soils with neutral pH are best suited. In scanty rainfall areas, heavy soils are preferred. Owing to its salt tolerance, it can be grown in moderate saline and alkali soils. The crop can be successfully grown in soils with pH 5 to 8.

Field preparation

The crop does not require fine tilth but the field should be levelled and free from weeds. The land preparation involves 1-2 deep ploughing followed by 2-3 harrowing and planking. Its *utera* cropping in rice involves no land preparation, as seeds are broadcast in standing crop of rice.

Sowing Time

Black gram is cultivated in different season depending on the climatic condition. In northern India, it is grown in *summer* and *Kharif* season whereas in southern India, it is grown in *Kharif* and *Rabi* season. The sowing time for different crop seasons are:

(i) *Kharif*: Onset of monsoon in later part of June and early part of July.

(ii) *Rabi*: October to November.

(iii) Pre-*Kharif or zaid* : Last week of February to first week of April.

Seed rate and spacing

In *kharif*, the crop is sown in rows 30-45 cm apart due to vigorous plant growth, while in other seasons, a narrow row of 20-30 cm is recommended. The plants are thinned to a spacing of 5-10 cm after germination and establishment. Thus, a seed rate of 15-20 kg/ha in *kharif* is the optimum, while in other seasons, double the seed rate of *kharif* is required. For utera cropping, the highest seed rates are used, ranging from 30-50 kg/ha. The optimum population is 4 lakh/ha in *kharif*, and 10 lakh/ha in spring and summer seasons. The optimum seeding depth is 4-6 cm.

Seed treatment

Seed should be treated with Agrosan GN or Emison-6 or Carbendazim 50% (Bavistin) or Mancozeb 75% WP (Dithane M-45, Indofil M-45 etc.) @ 3.0 g or Trichoderma viridi @ 5 g per kg of seed before sowing to prevent the incidence of diseases. Seed should be inoculated with Rhizobium culture for better nodulation and nitrogen fixation.

Sowing method

The seed is generally sown by broadcasting or drilling. The seed should be sown in furrows. Seed drill is used for sowing the seed in lines. In *utera* cropping it is broadcast in standing rice crop.

Cropping system

Blackgram and greengram are mutually replaceable in the various systems, except that the water requirement of blackgram crop is slightly more than that of greengram. However, in summer (3rd week of February to first week of April), blackgram is not suitable due to lack of early-maturing varieties. It is sometimes grown alone for manuring rice or as second crop after the cereal. The important rotations with blackgram in north India are: Paddy - Potato - Black gram, Maize -Potato-Black gram, Sorghum-Black gram-Wheat, Maize-Toria -Black gram, Maize -Wheat-Black gram, Pigeonpea -Black gram-Wheat, Maize-Mustard- Black gram, Black gram -Toria -Wheat- Mungbean.

Mixed/ Intercropping: Black gram may be grown mixed with other traditional crop such as Sorghum, Maize, pearlmillet, Pigeonpea during *Kharif* Season. In this system, seeds of different crop are mixed together and broadcasted in the well prepared soil followed by planking to cover the seed with soil. Black gram can profitably be grown as inter crop in widely spaced crop like pigeon pea, maize, sugarcane and sorghum. One to two rows of Black gram can be planted in between two rows of pigeon pea planted 75 cm apart on

account of its slow growth during first 75-90 days. This space could otherwise be occupied by weeds causing some problem to crop. In case of paired row planting, two rows are made closer and thus this extra space is provided in between two pairs of rows. Black gram may be inter cropped with spring planted Sugarcane.

Varieties

B-76 (Kalindi): Plant is dwarf and bushy. Pods are hairy and seed are bold and black in colour. Mature in 80-85 days with yield 15-20 q/ha. This variety is suitable for sowing from end of February to early July in West Bengal.

HPU-6: Mature in 100-120 days with yield of 10-12 q/ha. It is a suitable variety for growing in Kangra and Kulu Valleys of Himachal Pradesh.

Krishna: The variety gives average yield of 8-10 q/ha in 90-100 days maturity period. Seed are bold and black in colour.

Kulu-4: Maturity period is 120 days. Average yield is 8-10 q/ha. It is a suitable variety for cultivation in Kulu Valley in Himacba1pradesh.

Mash-48: It is a semi dwarf variety with average yield of 15-20 q/ha. It is resistant to drought. Plants are spreading type. Maturity day is 85-90 days. It is susceptible to viral disease.

Naveen: Maturity period is 90-95 days. Seed are yellowish green in colour. Average yield is 10-12 q/ha. It is a suitable variety for cultivation in North Bihar as a catch crop between harvesting of maize and sowing of wheat.

Pant U-19: Plant are erect and short with maturity period of 80-85 days in *Kharif* and 75 days in spring and summer. Pods are hairy and black at maturity. Average yield is 10-12 q/ha. It is resistant to yellow mosaic virus disease.

Pant U-30: Plant identified: Short and erect. Pod: Hairy and black at maturity: Seed: Medium in size and brown in colour. Maturity: 80-85 days. It is resistant to powdery mildew and yellow mosaic disease. Yield: 12-15 q/ha.

Pusa-I: Plants are medium tall and semi spreading with average yield of 12-15 q/ha. Pods are medium long and hairy containing 5-6 seeds. It is resistant to yellow mosaic disease.

T-9: Plants are dwarf and semi-erect with dark green leaves and hairy pods. Average yield is 10-12.5 q/ha. This variety is susceptible to yellow mosaic disease. It is suitable for cultivation for summer and spring season. This variety is recommended for general cultivation in Haryana. It is a short duration (75-90 days) variety.

T-27: Plants are tall and spreading with dark green foliage and yellow colour flower. Pods are hairy and green in early stage and black at maturity. Average yield is 12-15q/ha.

T-65 : Plants are tall and spreading with dark green foliage and yellow colour flower and straight hairy pods which is green in early stage and brownish at maturity. Seed are shining green in colour and crop maturity period is 120-140 dayswith average yield of 10-14 q/ha.

Fertilizer requirement

Apply 20 kg nitrogen with 40-60 kg P_2O_5 /ha. It is also beneficial if the seeds are treated with *rhizobium* as it helps in better nitrogen fixation. Seed treatment with PSB will also improve the phosphorous availability to the plants. The fertilizers should be drilled at the time of sowing in such a way that they are placed about 5-7 cm below the seed. When the crop is raised as intercrop, the fertilizer applied to main crop may also meet its requirement. Application of S @ 20 kg/ha and Mo 0.5 kg/ha is also beneficial.

Water management

Irrigation in black gram depends upon the amount and distribution of rainfall during the growing season. Being a rainy season crop it does not require irrigation but in the absence of rains, irrigation should be given at flowering and pod filling stage. Under irrigated conditions of *rabi*, spring and summer seasons, the crop requires 3-5 irrigations at 15-20 days interval.

Weed management

The short stature of crop in sole stands provides scope for intense weed competition. Initial 30-40 days after sowing is critical period of crop-weed competition. For weed control two hand weeding at 20-25 and 30-40 days after sowing are required. Under irrigated conditions pre-plant incorporation of fluchloralin or pre-emergence application of pendimethalin or alachlor @ 1 kg/ha are recommended for weed control.

Disease management

Cercospora leaf scope: Angular, brown or red colour spots with grey or brown centre and radish purple border are formed on leaves, stalks and pods. Spray the crop with Blitox -50 or Indofil M -45 @ of 1.5 to 2 .0 Kg/ha in 500 l of water.

Bacterial leaf scope: Symptoms appear as water soaked dots on the under surface of the leaf which remain small in size and the surrounding tissues becomes necrotic. Spray the crop with copper oxychloride @ of 1.52 to 2.0 Kg in 500 l of water.

Root rot: Affected plants show yellow and green areas on leaves, badly affected leaves turn completely yellow, and reduce yields considerably. To control this disease, treat the seed with thiram @4 g/kg seed.

Insect management: Hairy caterpillars, flea beetles, jassids and white fly damage this crop. For the control of white fly spray 1 litre malathion 50 EC or 625 ml dimethoate 30 EC or 625 ml metasystox 25 EC at 2-3 weeks interval in 625 l of water per hectare with manually operated sprayers. These sprays will also reduce the losses by yellow mosaic virus.

Chapter 8
PIGEONPEA (*Cajanus cajan* L.)

Pigeonpea (*Cajanus cajan* L.) is the second most important pulse crop in the country. In Hindi it is also known as Arhar. India accounts for over 75% of acreage and production of the globe. It is consumed extensively as dal, as it is rich in protein (21%), iron and iodine. It is also rich in essential amino acids like lycine, tyrocene, cystine and arginine. In some parts of India green pods are used as vegetable. The pod husk and seed husk are used as feed for cattle. The dry sticks are used for thatching and fuel purpose. The deep roots improve physical properties of the soil. Pigeonpea being a legume possesses valuable property as restorer of nitrogen in soil. The plants shed large number of leaves, which add organic matter to soil.

Origin

India is believed to be center of origin and diversity of pigeonpea. The closest wild relative of pigeonpea (*Atylosia canifolia*) was found in India and Australia. The centre of origin is the eastern part of peninsular India, including the state of Orissa, where the closest wild relatives (*Cajanus cajanifolia*) occur in tropical deciduous woodlands. From India it was domesticated to East Africa and West Africa. There was first encountered by Europeans, so it obtained the name Congo Pea. By means of the slave trade, it came to the American continent, probably in the 17th century.

Area and distribution

Pigeonpea is grown in over 50 tropical countries of the world especially in more arid regions of Africa, Asia and the Americas. In India, it is cultivated as an annual crop, but in other countries, it is grown as perennial crop, where pods are harvested at regular intervals. In some countries, it is mostly grown as a kitchen garden crop for vegetable purpose. The major pigeonpea producing countries of world are India, Myanmar, Malawi, Uganda, Kenya, Tanzania, Nepal, Congo and Haiti. Pigeonpea occupies 3.38 million ha area with a production of 2.27 million tonnes, accounting for 15.6% and 18.7% of the total pulse area and production of country, respectively. It is mainly grown in Maharashtra, Uttar Pradesh, Madhya Pradesh, Bihar, Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu. In Punjab and Haryana, early-maturing varieties are grown, which escape frost.

Classification

All the cultivated *Cajanus* are classified into two groups:

(i) ***Cajanus indicus var. bicolor***: Also known as arhar, comprises most of the perennial types that are late-maturing, tall and bushy. Pods are dark coloured and each pod has 4 to 5 seeds. The standard petal, which is the largest of the 5 petals in the flower, possesses red veins on the dorsal side. Pods are synchronous in maturity.

(ii) ***Cajanus indicus var. flavus:*** Also known as tur, comprises the commonly cultivated varieties, which are relatively short stature, early maturing and bear yellow flowers and plain pods with 2-3 seeds. Pods do not mature at a time and picking is done at an interval of 15-16 days.

Climatic requirement

Pigeonpea is cultivated in wide range of climatic conditions in tropical and subtropical areas with a temperature range of 20°- 40°C. Pigeonpea can be grown between 30^{o}N and 35^{o}S latitudes and thrives well in areas with 500-1000 mm of rainfall. Its drought hardy nature makes it a crop of low rainfall situations. However, it cannot withstand water logging and frost. Moist and humid conditions during vegetative phase and dry conditions during reproductive phase are suitable for successful raising of pigeonpea. Low temperature at pod filling stage results in delayed maturity. Pigeonpea is a short-day plant with critical photoperiod of 13 hours. Low light intensity at pod formation is harmful. For flowering and pod setting 24^{o}C is the optimum.

Soil requirement

Pigeonpea can be grown on a wide range of soils. However, sandy loam to clay loams are ideal. The soil should be deep, well drained and free from soluble salts. It can be grown on soils with a pH range of 5.5-8.0 successfully. It cannot tolerate soil acidity owing to aluminium toxicity.

Cropping system

Pigeonpea can be intercropped or sown mixed with a number of other crops like sorghum, maize, rice, groundnut, sesame, urdbean, greengram, cowpea, ragi and soybean, and an additional yield may be obtained. These crops do not adversely affect the pigeonpea crop, because by that time pigeonpea starts growing (end of September), the intercrops are ready for harvesting. There is a possibility of raising early maturing pigeonpea as a summer crop with intercrop of greengram or cowpea. In this cropping system, pigeonpea may be sown in mid-April keeping a row-to-row distance of 75-90 cm, intercropped with 2-3 rows of greengram. Greengram becomes ready for harvest by the end of June (65-70 DAS). The

wheat crop may be sown immediately after the harvest of pigeonpea. Short-duration pigeonpea fits well in the following crop rotations:

- Pigeonpea-wheat-greengram
- Pigeonpea-wheat / potato / sugarcane

Field preparation

Pigeonpea with its deep root system (>150 cm) can break hard pans in plough layer and hence called "biological plough". In case of hard pan in the soil, sub-soiling is done. A clod and weed-free seed-bed for proper germination and establishment of seedlings This is achieved by opening the soil through soil-turning plough or disc harrow followed by the cross-harrowing or ploughing with desi plough on or before the onset of monsoon. Finally, the seed-bed should be planked and levelled. Thorough levelling is essential for quick drainage and also to avoid water logging. Sowing pigeonpea on a ridge and furrow planting is preferred to overcome water logging.

Seed rate

Seed rate of 8-10 and 10-15 kg/ha is required for long duration and short and medium duration varieties. During *rabi* season, 15-18 kg/ha of seed is needed.

Sowing method

Seed should be sown behind the plough or with the help of seed drill in rows. The row spacing in *kharif* varies from 40-60 cm in short and medium duration varieties to 60-90 cm in long duration varieties. In *rabi* season, the crop is grown in 30 cm rows. After germination, the seedlings are thinned to maintain an intra-row spacing of 15-20 cm. The optimum population thus varies from 60,000-1, 00,000 in *kharif* and 1.5-3.0 lakh/ha in *rabi*.

Seed treatment

Before sowing, seed should be treated with thiram @ 2.5 g/kg seed. Seed should also be treated with Rhizobium culture, especially when pigeonpea is being taken for the first time in the field or after a long duration. In pigeonpea, seed inoculation with *Trichoderma harzianum* alone or serial inoculation of *T. harzianum,* followed by Rhizobium may significantly reduce wilt incidence, enhance nodulation and root/shoot growth, but simultaneous inoculation of *T. harzianum* + Rhizobium was ineffective.

Sowing time

Pigeonpea sowing in *kharif* under rainfed condition varies from June-July, depending on onset of monsoon. For summer pigeonpea, early May sowing is followed in north India. Time

of sowing should be adjusted in such a way to avoid rains and frost at flowering and reproductive stages. For early *rabi* planting in Bihar, eastern Uttar Pradesh, West Bengal, September sowing is ideal. The *rabi* cultivation of pigeonpea in rice fallows is increasingly popular, and is sown immediately after rice harvest in southern India. In Haryana, T-21 is sown from mid-March to mid-June, UPAS-120 from March to Ist week of July. Manak and Paras are sown from mid of June to July end and in the second fortnight of June in Uttar Pradesh and northern Rajasthan. Medium-early varieties are sown in the first fortnight of April for double cropping. The late pigeonpea is sown with the onset of monsoon, preferably by first week of July.

Varieties

Early maturing varieties: UPAS 120, Manak, Paras, ICPL 151 and AL201 are suitable for rotation with wheat.

Wilt-resistant varieties Asha (ICPL 87119), Maruti (ICP 8863) and Pusa 9 are wilt resistant varieties.

Varieties resistant to sterility mosaic: Bahar, Asha, and BSMR 736.

Recently hybrids, viz. PPH 4, CoPH 1, CoPH 2, AKPH 4101, AKPH2022 and ICPH 8, have been released, which have high yield potential.

Fertilizer requirement

Seed treatment with *Rhizobium* culture is beneficial. Use of FYM @ 5-10 t/ha is common under rainfed situation. The recommended fertilizer dose is 15-20 kg N and 40-60 kg P_2O_5/ha. Conveniently, 100 kg diammonium phosphate is applied per hectare area. Use of PSB culture improves the available phosphorus status in the soil. At times of waterlogging for quick recovery immediately after drainage, 50 kg N/ha as top-dressing is applied to alleviate adverse effects of waterlogging.

Water management

Long duration pigeonpea with deep root system and flushes of flowering can withstand drought. The short duration cultivars, however, are grown with irrigation only. Post-rainy season crop responds better to irrigation. The critical stages for irrigation are branching, flowering and pod filling. The crop requires 20-25 cm water to produce a tonne of grain. At times of prolonged drought, irrigation at flowering and pod filling stages is highly rewarding in *Kharif.*

Weed management

The initial 7-8 weeks period of crop i.e., from sowing to branching stage is critical period of crop-weed competition in medium and long duration varieties. In short duration varieties initial 4-6 weeks from sowing is critical. Thus, it is important to keep the crop free from weeds during this period. The dominant weed species consisted of *Trinthema monogyna, Cyprus rotundus, Amaranthus viridis, Phylanthus niruri, Sorghum halepense,Cynodon dactylon* Commelina bengalensis L., *Euphorbia parviflora* L., *Celosia argentena* L., *Amaranthus spinosus* L., *Echinochloa colona* L., *Digitaria sanguinalis, Dactyloctenium aegyptium* L., *Ageratum conyzoides* L., *Eclipta alba* L., *Portulaca oleracea* L., etc.

Hand-weeding at 25 and 45 days after sowing or application of weedicide immediately after sowing is useful for weed control. Pre-plant incorporation of fluchloralin @ 1kg/ha or pre-emergence application of pendimethalin 1kg/ha are effective in controlling weeds. The above herbicides integrated with one hand-weeding or mechanical hoeing at 6-8 weeks after sowing is more effective to either of the methods alone.

Disease management

Wilt: The plant remains green and show wilting. Removal of roots shows browning of the xylum which curtail the uptake of nutrients.

Sterility mosaic: This is caused by virus. The virus is transmitted by mites which results in malformation of flowers and no pods will be formed.

Phytophthora stem blight: Brown colour spots will appear on the stem and the rotting will start at these spots and plant becomes week and fall down.

Control: Before sowing, seed should be treated with thiram @ 2.5 g/kg seed. Use of resistant varieties is best in disease-prone areas. Use crop rotation. Remove the excess rain or irrigation water. There should be proper aeration in the field.

Insect management

Pod borer is the major insect in North India. Early-maturing varieties get comparatively less damage from pod-borers than late-maturing varieties. For its control spray monocrotophos 36 SL@750 ml/ha or 187.5 ml cypermethrin 25 EC or 300 ml fenvalerate 20 EC or 537.5 ml deltamethrin 2.8 EC in 750 liters of water per hactare at 50 % pod formation stage.

Harvesting

Early varieties are harvested in the month of November, whereas medium and late varieties by January to March. When more than 80% pods are mature, the plants are cut close to the

ground and bundled. These are taken to threshing floor and staked upright, dried for a few days and shaken vigorously to separate pods. The resultant material, i.e. pods and dry leaves, is beaten with sticks or is trampled by bullocks. The seeds and husk are separated by winnowing. The proportion of seeds to pod is generally 50-60%. Threshed and cleaned produce should be further sun dried to reduce the moisture content to 10-11%.

Chapter 9
GROUNDNUT (*Arachis hypogaea* L.)

The groundnut (*Arachis hypogaea* L.) belongs to Leguminosae/ Fabaceae family. It is also called peanut, earthnut, monkeynut and mungfali. It is a soil erosion resistant crop and being a legume crop, it can fix the atmospheric nitrogen and is useful as a rotational crop. Groundnut cake is chief oil cake feed to animals (7-8% N, 1.5% P2O5 and 1.2% K2O) and also used as manure. Groundnut seed contains about 47 to 51% oil and 26% protein. Peanuts are rich in nutrients, providing over 30 essential nutrients and phytonutrients. Peanuts are a good source of niacin, folate, fiber, magnesium, vitamin E, manganese and phosphorus.

Origin and history

"Arachis hypogaea" is the Greek word, *Arachis* meaning legume and *hypogeae* meaning below ground, referring the pod formation in the soil. Groundnut is a native of Brazil (South America), as many closely related species are found there. The crop has spread from Brazil to Peru, Argentina and Ghana, from where it was introduced by the Portuguese into Africa from where it was introduced into Jamaica, Cuba, West Indies islands and North America. It was then transported along the American west coast to Mexico and then across the Pacific to Philippines, from where it has spread to China, India, Malaysia and Indonesia. In India, groundnut had first reached on the east coast of the then Madras province.

Area and distribution

Groundnut is grown in almost all the tropical and subtropical countries of the world. The important groundnut growing countries are China, India, USA, Nigeria, Indonesia, Myanmar and Sudan. Globally it is grown in an area of 24.7 million hectares with an annual production of 34.4 million tonnes and productivity of 1.3 t ha^{-1}. India ranks first in area (7.3 Mha) and second in production (7.8 Mt) contributing to about 40% of the area and 36% of world production. Gujarat ranks first both in the area (1.9 Mha) and production (2.6 Mt). Productivity is highest in Tamil Nadu (1630 kg ha^{-1}) followed by Gujarat (1360 kg ha^{-1}). The four states Gujarat, Andhra Pradesh, Tamil Nadu and Karnataka account for 80% of the area and 80.5% of ground production in the country.

Growth and development

Groundnut is self-pollinated crop with hypogeal germination type, belongs to sub-family papilionaceae and family leguminosae. The crop has relatively deep tap root system with well-developed lateral root system and the nodules are formed on the roots.

Classification

Morphologically groundnuts have been divided into two groups.

(1) **The erect or bunch type**-include *Arachis hypogaea* subspecies *fastigiata.* Pods in erect type are borne in bunch close to the base of plant. Erect types are normally short duration. Seeds have no dormancy and sometimes the first form pod may sprout before harvest if conditions are suitable. This is due to presence of water-soluble auxins.

(2) **The trailing or spreading type**-include *Arachis hypogaea* subspecies *procumbens.* Pods are spreading so harvesting is difficult. Comparatively it is longer duration crop than bunch type. Seeds have dormancy which can be broken by storing the shelled seed 15 days after harvest at 40ºC for 12 days.

Climatic requirement

Groundnut is grown in the tropics and subtropical countries, lying between 45ºN and 35ºS, and up to an altitude of 1000 m. The arid and semi-arid regions with 500-700 mm rainfall during crop growth period are ideal for ground production. The crop can be grown successfully in places receiving a maximum rainfall of 1250 mm. The rainfall should be well distributed during flowering and pegging stages. The groundnut, however, cannot withstand frost, long and severe drought or water stagnation. Soil temperatureIt seems that plant will grow best when the mean temperature is from 24-33ºC. During ripening period, it requires about a month of warm and dry weather.

Soil requirement

Groundnut is grown on a wide variety of soil types but, thrives best in well-drained sandy and sandy loam soils, as light soil helps in easy penetration of pegs. Heavy and stiff clays are not desirable for groundnut cultivation as pod development is hampered in those soils. Groundnut gives good yields in the soils with pH between 6.0-6.5.

Cropping system

Groundnut is grown in rotation with wheat, lentil, chickpea, pea, barley, etc. It is grown as a mixed crop with pearl millet, maize, sorghum, castor and cotton. Groundnut can also be followed by safflower where early varieties are grown and moisture remains in the soil at the time of harvest. The most common cropping systems are: Groundnut-wheat/barley/ chickpea/field pea / lentil. In Andhra Pradesh and Maharashtra sorghum is grown after harvest of groundnut.

Field preparation

Groundnut is a deep-rooted crop but looking to its underground pod forming habit, deep ploughing should be avoided. Because deep ploughing encourages development of pods in deeper layers of soil which makes harvesting difficult. One ploughing with soil turning plough followed by two harrowings would be sufficient to achieve a good surface tilth up to 12-18 cm depth.

Seed treatment

For seed purposes, pods should be shelled by hand one week before sowing. Hand shelling ensures little damage to seeds. Pods shelled long before sowing time are liable to suffer from loss of viability and storage damages. Bold and healthy seeds should be used for sowing. Treat the selected kernels with 5 g of Thiram or Captan or Ceresan per kg of kernels so as to check various seed and soil borne diseases. Seed should be inoculated with proper strain of Rhizobium culture particularly in those places where groundnut is to be grown for the first time.

Seed rate, spacing and sowing method

Seed rate depends upon the growth habit of variety and seed weight for obtaining good yields. Seed rate can vary according to the region also. In bunch types, the row-to-row distance is kept 30-40 cm and in spreading types 45-60 cm. For this, 80-100 kg of seeds per hectare would be enough for bunch types and 60-80 kg for spreading types. Plant to plant distance would be 15 and 20-22.5 cm for bunch and spreading types respectively. Sowing of groundnut is done either by seed drill or behind the country plough or by hand dibbling. Sowing can be done through tractor-mounted groundnut planter. The depth of sowing should be 5 cm.

Sowing time

Sowing time of rainfed crop is in the last week of June to first week of July. In irrigated conditions it is last week of June. In *rabi*, groundnut is sown in southern states during November-December, mostly in rice fallows. Summer groundnut in Gujrat, Maharashtra and Madhya Pradesh is sown during the second fortnight of January up to the first fortnight of February.

Varieties

Jyoti: It is a bunch type of variety with dark green foliage. It matures in 95-110 days. It is susceptible to tikka disease. It yields about 12-15 quintals per hectare under rainfed

conditions and 20-22 quintals per hectare under irrigated conditions. Seeds are bold and contain 53 per cent oil. Its shelling percentage is 78%.

RS-1: It is a spreading variety. It matures in 135-140 days. It is tolerant to tikka disease. It yields about 15-20 quintals per hectare. It has 77 per cent shelling out turn. Seeds are of medium size and contain 48 per cent oil.

Chitra: It is a semi-spreading variety. Foliage is of dark green colour. It matures in 125-130 days. Its yield potential is 25-30 quintals per hectare. Seeds are of medium size and contain 49 per cent oil. Its shelling percentage is 72. It is suitable for growing in Uttar Pradesh.
Amber: It is a spreading variety. It matures in 115-120 days. Seeds are medium in size and contain 48 per cent oil. Its yield potential is 30-35 quintals per hectare. Its shelling percentage is 72. It is suitable to grow in Uttar Pradesh.

PG. NO.1: It is a spreading variety recommended for cultivation under rainfed conditions in Punjab. It matures in 130 days. It has a shelling percentage of 69. It yields about 14-16 quintals per hectare. Seeds contain 49 per cent oil.

Moongphali No. 145: It is a spreading variety, but with a smaller lateral spread then PG No.1. It is recommended for cultivation on sandy soils, both under rainfed and irrigated conditions. It yields about 20-25 quintals per hectare under irrigated conditions and. 15-18 quintals per hectare under rainfed conditions. Its shelling out turn is 76 per cent. It matures In 125 days. Seeds are of medium size and contain 50 per cent oil.

BG-1 & BG-2: It is also bunch variety recommended for cultivation in whole Bihar State. Shelling percentage is 69. Seeds are bold and contain 49 per cent oil. Yield potential is 20-22 q/ha.

Kopergaon No.1: It is a semi-spreading variety. The crop matures in 125 days. It is suitable for growing in Kharif as well as Rabi season. It has a yield potential of about 15-20 q/ha with 48 per cent oil content.

TMV-6: It is a semi spreading variety, which matures in 125 days. It is recommended to grow under rainfed conditions. It is a good table variety. It has 48 per cent oil. Its yield potential is 10-15 q/ha.

Fertilizer requirement

Groundnut, being legume, needs more phosphorous, and being an oilseed requires more sulphur, besides it needs more calcium for shell formation and filling. Seed inoculation with efficient strains of *rhizobium* can partially meet nitrogen requirement of the crop. To sustain

overall health of soil and continued good yields, a desirable level of organic carbon in the soil (0.3-0.7%) must be maintained. Well decomposed FYM or compost @ 5-10 tones/ha should be applied about 15-20 days before sowing. Apply 15 kg N, 50 kg P2O5 and 25 kg ZnSO4/ha at the time of sowing. Phosphorus should be applied preferably through single super phosphate; it provides sulphur in addition to phosphorous. The fertilizers should be placed at the time of sowing about 4-5 cm in the side of the seed and 4-5 cm below the seed level. Calcium too has pronounced effect on proper development of pods and kernels. Use of gypsum @ 100-150 kg/ha at the time of field preparation can add to the yield.

Water management

Generally irrigated groundnut accounts an area of 20% of total groundnut area in India. Being a rainy season crop, groundnut does not require irrigation. Care should be taken that at the time of pegging the soil must be friable and have sufficient moisture content in soil. The field should be well drained. Flowering and pegging are the most critical stages for irrigation. In the southern part of the country where groundnut is grown in *Rabi* season too, three to four irrigations are necessary. The last irrigation before harvesting will facilitate the full recovery of pods from the soil.

Scheduling of irrigation

In irrigated/rainfed condition for sandy loam soil, the scheduling of irrigation is done at 25% depletion of available of soil moisture (DASM) throughout the growth period results in high pod yield. Irrigation at 25% DASM from pegging to early pod development and at 50% DASM at other stages appears to be ideal for high water use efficiency. An IW/CPE ratio of 1.0 at moisture sensitive stages and 0.6 during other stages leads to high water use efficiency.

Weed management

A reduction of 20-45% in yield due to weeds has been recorded. Two weedings 20 and 45 (days after sowing) DAS are recommended. No weeding or intercultural operation should be done after pegging has commenced; pegs have started moving undergrounds. Earthing up can be done in bunch and semi spreading types to facilitate maximum penetration of pegs. Pre-emergence application of Pendimethalin @ 1 kg a.i./ha along with 2 inter-cultures at 30 and 45 DAS have been recommended in irrigated conditions. Fluchloralin (Basalin) at the rate of 1 kg a.i. per hectare dissolved in 800-1000 litres of water can also be used as pre-planting incorporation.

Disease management

Tikka Disease or Leaf Spot: *Cercospora arachidicola* ***and*** *Cercospora personatum* are responsible for Tikka disease of groundnut. The disease appears 3-4 weeks after sowing till maturity. The spots on leaves are circular to irregular and are surrounded by a yellow halo. The spots on the upper surface look like reddish brown to black, whereas on lower surface these spots are smooth and light brown in colour. Spots produced by *C. personatum* are circular, smaller, dark brown to black in colour and are not surrounded by a yellow halo. Spots look rough and carbon black on lower surface. Spots mostly appear on leaf but sometimes on petiole and stem also. Severely infected leaves may drop off prematurely. Spray the crop two to three times with Dithane M- 45 or Blitox-50 @ 1.5-2.0 kg/ha at 10-15 days interval starting from the first appearance of spot. Removal of disease debris and use of certified seeds etc. reduce the disease intensity.

Collar Rot and Seed Rot: This disease is caused by fungus *Aspergillus niger*. The symptoms may appear as rotting of seed, pre emergence soft rot of the hypocotyls and post emergence collar rot of the seedlings. Due to collar rot, there is girdling of the collar region and the leaves become chlorotic. This is followed by wilting and death of the affected branches. The affected collar region becomes shredded and is soon covered by the growth of conidiophores and conidia. The highest mortality occurs at about 50 DAS. Select healthy seed for sowing. Treat the seed before sowing with Thiram or Captan @ 3.0 g / Kg seed.

Sclerotium Rot: Fungus *Sclerotium rolfsii* is responsible for thw disease. Affected plants parts show white thread like fungal growth and the leaves turn into yellow to brown. Soil application of Brassicol @ 10-15 kg per hectare is beneficial before sowing.

Charcoal Rot: This disease is caused by soil borne fungus *Microphomina phaseoli*. A red brown water soaked lesion appears on the stem of the infected plants. Spraying of Brassicol @ 10-15 kg per hectare is beneficial before sowing.

Rust: This disease is caused by fungus *Puccinia arachidis.* The symptoms are characterized by the development of red pustules on leaves and the pustules are later on become dark brown. Spraying of Zineb @ 2 kg in 1000 litres of water per hectare as soon as initial symptoms are observed can be effective.

Insect management

White-grub, a menace in the light soils of Rajasthan, Bihar, Uttar Pradesh, Punjab and Haryana can be controlled effectively by treating seed with Chlorpyriphos 20 EC or Quinalphos 25 EC@ 15 ml/kg of seeds. White grubs live in soil and remain active from July

to September. The grubs feed on the functional roots of the plants, leaving behind only tap root. Major sucking pests like aphids, jassids and thrips can be effectively controlled by spraying 500 ml malathion 50EC in 500 lt. of water per hactare. Setting up light traps for destroying moths may control leaf minor. Carbaryl 50 WP 0.02% spray is most economical.

Peg formation and pod development of groundnut.

Factors influencing quality of groundnut

- **Volume weight of pods:** It is the weight per unit volume of pods, which indicates maturity and development of kernels when the pods are disposed by volume. Varieties with small pods have higher volume weight than those with bigger pods.
- **Shelling percentage:** It is the percentage of kernels to pods by weight. It depends on thickness of the shell and development of kernel. Irrigated crop generally has low shelling percentage than that from rainfed crop. Average shelling percentage ranging from 68 to 76%.
- **Hundred kernel weight:** Average 100 kernel weight ranges from 30g in TMV2 to around 78 g in M13.
- **Oil content:** Usually hypogeae runners have higher oil content than Spanish bunch type. Oil content generally ranges from 48-51%.

Pegging and pod development

After fertilization the ovary gets stimulation and the basal portion of it takes a spindle shape structure known as peg. Carrying the ovary at its tip the peg enters into the soil and when it gets sufficient darkness in soil, the ovary rest in soil horizontally. This process is known as pegging. The ovary entering into the soil starts swelling because of its circular growth and develops into pod then the ovules inside the ovary also starts developing; this is called as pod development.

Aflatoxin

Damp nuts (high moisture) if stored will ferment and allow the development of poisonous mould such as *Aspergillus flavus* and *Aspergillus parasiticus* in kernels during post harvest processing and storage, leads to contamination of carcinogenic substance called aflatoxin both for humans and livestock. The oil expressed from such produce will be rancid and cake when fed to poultry will result in a heavy mortality of birds. About 81 % of the kernels are immediately crushed for oil and hence aflatoxin is not a major problem in the domestic market. However, it is of concern in respect of exportable commodities i.e. kernel, oil cake etc. It is desirable to store groundnuts in gunny bags as pods rather than kernels. The gunny bags are stacked in a store- room over planks in tiers comprising not more than ten in each in such a way that air keeps circulating. Detoxification of aflatoxin can be achieved by filtration at oil mills. Ground nut oil exposed to sunlight for an hour removes nearly 90% of aflatoxin. Chemicals such as chloride, peroxide, sodium bisulphate can detoxify aflatoxin in groundnut.

Yield

By adopting good agronomical practices, it will be possible to obtain about 15-20 quintals of pod s per hectare from bunch type and 20-30 quintals per hectare from spreading type.

Chapter 10
SOYBEAN (Glycine max L. Merril)

Soybean (*Glycine max* L. Merril) is an important pulse crop rich in food value. It is a cheapest, richest and easiest source of best quality protein and fat. It is more considered as oilseed crop owing to its multiplicity of uses as food and industrial products, it is called a 'wonder crop or miracle crop'. It is the number one oilseed crop of the world which contains 40% protein and 20% oil. Soybean protein is rich in the valuable amino acid lysines (5%) in which most of the cereals are deficient. The seeds contain good quality protein rich in lysine and oil is having considerable amount of essential fatty acids (Omega-6 and Omega-3). It also contains phytochemicals known as isoflvines which protect human body against chronic diseases such as cancer, diabetes, osteoporosis and blood pressure. Soybean, being leguminous crop, improves the soil fertility by fixing atmospheric nitrogen and also through leaf fall at maturity. Soybean is a food that is nearly perfect as cow's milk, but at the same time rich in iron and Vitamin-C (when sprouted). A large number of Indian and western dishes such as bread, kachori, pastries, high-protein food for children, food for diabetic, milk, biscuits, sweets, fermented food, khoa, paneer rabdi, powdered food material, chocolate, ice cream, protisnacks, nutrinugget, green pods as vegetable, canned seed vegetable, salad, dry seed-roasted, boiled, cooked, soysauce, soysoup etc. can be prepared from its seed/flour. It is widely used for manufacturing of edible oil, vanaspati ghee, salad oil, butter, glycerine, oil for light, explosive, varnish paints, soap, lubricating oil, printing ink, celluloid, plywood material, tape joint, typewriter ribbon, rice cream, vitamins, antibodies, medicine and cosmetic material etc. It can be used as forage, hay, silage etc. Its forage and cake are excellent nutritive foods for livestock and poultry.

Origin

Soybean is reported to have been originated in Eastern Asia especially in China around 2800 B.C and were used as food long before the existence of written record. The wild ancestor of the soybean is *Glycine soja* (previously called *G. ussuriensis*), a slender twining vine legume native to central China and Korea. Japan is the focal point from where soybean goes to other countries. In India the cultivation of soybean was first started at Nagpur (1822).

Area and distribution

Soybean is one of the important crops of the world. The United States of America have become the world leading producer. The USA, Brazil, Argentina, China and India are the world's largest soybean producers and represent more than 90% of global soybean

production. Soybean production in India at present time is restricted primarily in Madhya Pradesh, Maharashtra and Uttar Pradesh.

Classification

Classification of soybean is done according to form, size, shape and colour of its seeds and maturity period as given below.

- **Manchurian classification**

This classification is based on colour of seed. Soybeans have been divided into three groups according to this classification.

(A) Yellow group

1. Yellow seeds with light hilum
2. Yellow seeds with golden hilum
3. Yellow seeds with brown hilum

(B) Black group

1. Large black seed
2. Small black seed
3. Flat black seed

(C) Green group

1. Epidermis of seed green but embryo yellow
2. Epidermis as well as embryo green

- **Martain classification**

This classification is based on shape and size of soybean seed.

1. Soja elliptica
2. Soja spherica
3. Soja compressa

- **Hertz classification**

This classification is based on shape of pods

1. Soja platycarpa
2. Soja tumida

- **American classification**

This classification is based on maturity period of crops.

Climatic requirement

Soybean grows well in warm and moist climates from sea level to an elevation of 3,000 m. Temperature of 15-32^{o}C is optimum for germination. For growth and development, the optimum temperature range is 26.5-30^{o}C. Lower temperatures tend to delay the flowering. It has been observed that low temperatures reduce the oil content, whereas higher temperatures during seed formation increase the oil content in seed. At temperatures >42^{o}C, nodulation is hampered severely. If the temperature is less than 18^{o}C, there will be no pod setting. A relative humidity of 70-75% is optimum for pod formation. The crop cannot tolerate frost and water logging. It is grown in areas of 400-750 mm annual rainfall. It is a short day plant and requires a photoperiod of 13-14 hours provided that temperatures are also favourable.

Soil requirement

Soybean can grow in well drained loam, sandy loam and clay loam soils. The soil pH should be 6.5-7.5. Acidic and alkaline soils inhibit the germination of seed. Water logging is injurious to the crop.

Varieties

Bragg: It is an introduction from U.S.A. It is suitable for Bihar, Delhi, Haryana, Madhya Pradesh, Maharashtra, Orissa, Punjab, Uttar Pradesh and West Bengal. Plants are medium tall (90-100 cm.), erect, branched with six or seven upright branches. Leaves and pods are covered with brown hairs. Maturity period is 110-115 days. The seeds are bold, yellow with black hilum .The oil content in the seed varies from 23-25 percent whereas protein content varies from 42-45 percent. The average yield is 1625-1875 kg/ha.

Lee: It is an introduction from U.S.A. Plants is dwarf (40 cm.), erect and branched. Pods and leaves are covered with brownish hair. Maturity period is 110-115 days. Seeds are light yellow in colour with black hilum. Oil content in seed varies from 23-25 percent. Average yield is 1500- 2000 kg/ha.

Clark- 63: It is an introduction from U.S.A. Plant are dwarf (70 cm.), leaves and pods are covered with light yellow to brown coloured hairs. Maturity period is 90-95 days. Seeds are yellow with dull luster and black hilum. Oil content in seeds varies from 18- 20 percent The average yield is 2500-3000 kg/ha.

PK 416-Seeds are medium sized and ovule is yellow in colour. This variety is tolerant to yellow vein mosaic virus, r*hizoctonia* blight & bacterial leaf spot. This variety gives average yield of 25-30 q/ha in 120 to 125 days.

PK 472- Plants are with dark green leaves. Seeds are bold, smooth, yellow and non-shattering. This variety is tolerant to yellow vein mosaic virus, r*hizoctonia* blight& bacterial leaf spot. This variety gives average yield of 25-30 q/ha in 120 to 125 days.

PK 564- Plant stems are strong. Seed is medium sized. This variety is tolerant to yellow vein mosaic virus, r*hizoctonia* blight& bacterial leaf spot. This variety gives average yield of 25-30 q/ha in 120 to 125 days.

Punjab- 1: Plants are taller than Bragg and more branched with bushy habit. Leaves and pods are covered with brownish hair. Seeds are yellow with black hilum. Maturity period is 120-130 days. Average yield is 2000-2500 kg/ha. Seed oil content is 20-22 percent. It is suited for Punjab, Gujarat and parts of Rajasthan.

Ankur: Plants of this variety are tall (120-130 cm). Seeds are small, a bit flat and yellow in colour with light brown hilum. Maturity period is 125 days. Average yield is 2500-3000 kg/ha. Oil contenting seed varies from 19-20 percent and having resistant to rust.

Alankar: Seeds are round and yellow with light black hilum. Maturity period is 120 days. Average yield is 2500-3500 kg/ha. Oil content is 20-21 percent.

Shilajeet: Plants are dwarf (50-70 cm.). Seeds are bold with oil content of 20-22 percent. Maturity period is 105 days with average yield of 2000-2500 kg/ha.

PK- 262: Plants are semi dwarf. Seeds are bold and yellow in colour with oil content 22 percent. Crop gives average yield of 3000-3500 kg/ha in 130 days.

Cropping system

In north India, it has tremendous scope as an intercrop in pigeonpea, maize, cotton and upland rice. In southern part of the country, soybean has a good scope as intercrop in cotton, sorghum, pigeonpea, groundnut and sugarcane. In central India, it has been found very remunerative on the fallow lands in *Kharif*. Soybean-gram/ wheat/ potato/ tobacco/ maize/ mustard/ toria, Soybean-potato-wheat and Soybean- wheat-groundnut are some common rotations followed in north India

Sowing time

Time of sowing plays an important role in soybean cultivation. The last week of June to first fortnight of July is optimum sowing time. In northern and central India, last week of June is the optimum time of sowing under irrigated conditions. Soybean is also cultivated as *rabi* crop and the seed is sown in October and November. The summer crop is sown in middle of February or middle of March.

Field preparation

The seed bed should be well pulverized, free from clods and perennial weeds, and well leveled. The land should be prepared by ploughing 4-5 times followed by planking after each ploughing. Generally one deep ploughing with mould board plough followed by 3-4 light ploughings by desi plough will ensure the proper tilth.

Seed rate

Soybean crop needs about 70-80 kg/ha seed during kharif season (timely sown) and 100-120 kg/ha seed during spring and summer seasons (late sown). Intercropping with other crops either in alternate rows or 2 rows of soybean between two rows of main crop would require 60% of the seed rate. The seed rate also depends on seed size. Small seeded varieties require 55-60 kg/ha seed whereas medium and bold seeded varieties require 70-75 kg/ha and 80-90 Kg/ha, respectively.

Sowing method

Soybean is cultivated as pure crop, inter crop and mixed crop. The seeds are sown by different methods. Pure crop should be sown by seed drill or behind the plough. Soybean can be planted at spacing of 45 cm row to row and 4-5 cm plant to plant. A seeding depth of 5 cm is optimum. Shallow depth may be justified to crust prone areas and deeper in sandy soils. Rainfall immediately after sowing results in crust formation inhibiting seedling emergence. Crust breaking by light racking is desirable under these situations.

Soybean has a good scope as intercrop in pigeonpea, cotton and upland paddy in northern India and in sorghum, cotton, sugarcane, pigeonpea and groundnut in southern India. Soybean is planted with the companion crop in the alternative rows or two rows of Soybean with one row of companion crop. Paired row method utilizes the resources more efficiently with higher yield.

Seed treatment

To get rid of seed borne diseases, seeds must be treated with Thiram or Captan @ 2g/kg seed or *Trichoderma viridi* @ 5 gm. per kg of seed. For higher yields, seeds must be treated with *rhizobium* and PSB culture. The inoculation of seed with *Rhizobium* culture is most important when the crop is cultivated first time in any land. The seed should be inoculated with *Rhizobium japonicum* strains of soybean culture to overcome the problem of poor nodulation. The inoculated seeds are stored under shade till the time of sowing. Sowing should be finished within two hours of inoculation. *Rhizonbium* culture, if not available at the planting

time, the seeds should be sown after mixing with soil collected from 15 cm deep soil of land which was under soybean cultivation for consecutive 2-3 years.

Fertilizer requirement

An application of 25 kg N/ha as a starter dose will be sufficient to meet the nitrogen requirement of the crop in initial stage. A response of higher nitrogen application has been observed in fields deficient in nitrogen. Apply 80 kg P_2O_5/ha to meet the phosphorous demand of the crop at the time of sowing. In K deficient soils, basal application of 40 kg K_2O/ha is recommended. To correct K deficiency in a standing crop, 0.5% foliar spray of KCl is recommended. Soybean requires S for oil synthesis. In areas with low S availability, 20 kg S/ha is necessary. Application of 20 kg $ZnSO_4$ /ha recommendation is made for all soybean growing zones.

Water management

The crop requires about 600-650 mm rainfall. Soil deficient in moisture requires pre-sowing irrigation for the good germination. Irrigation at active growth stage is required; however there should not be any moisture stress at the end of flowering to pod initiation stages. In rainfed crop prolonged dry spells, requires protective irrigation .The spring or summer crop of soybean requires assured irrigation facilities.

Weed management

To avoid weed competition during initial stage, soybean field should be kept weed free for the first 30-40 days after sowing. Two manual weeding, 15-20 and 30-45 days after sowing are sufficient for controlling weeds. During rains, hand weeding may not be possible. In such circumstances pre-plant incorporation of fluchloralin @ 0.75-1.00 kg/ha or pre-emergence application of pendimethalin @ 1 kg/ha or metribuzin @ 0.75 kg/ha have been found effective to control annual grasses and broad-leaved weeds. Response of application of post-emergence herbicides quizalofop-ethyl @ 50 g/ha 25 days after sowing (DAS) or imazethapyr @ 75 g/ha at 15-20 DAS in 800-1000 litre water per hectare area also control the grasses satisfactorily.

Disease management

Bacterial blight: Small reddish-brown spot surrounded by water-soaked margin with yellow holes appears on pods. Cool and moist conditions are favourable for bacterial blight. **Bacterial pustules:** yellow pustules appear on leaves which later changes to reddish brown with marginal yellowing. In case of heavy infection, defoliation may occur. Warm and moist

conditions are favourable for bacterial pustules. Using of disease free seed, practicing crop rotation and growing of resistant variety (Alankar, Ankur, Bragg, Durga etc.) will help in controlling the disease. The seed should be treated with Cerasan or Captan @ 3.0 g per kg of seed or *Trichoderma viridi* @ 5 gm per kg of seed before sowing. The crop should be sprayed twice with Copper Oxychloride 50 % WP (Blitox) or Streptocycline (500 ppm) at an interval of 10 days depending the severity of the disease.

Downy mildew (*Pernospora Sp*): Small chlorotic spots appear on the upper surface of the leaves which later turn greyish to dark brown with downy growth on the lower surface of the leaves. For control, the seed should be treated with Captan @ 3.0 gm per kg of seed before sowing. Spraying the crop with Copper Oxychloride 50 % (Blitox, Phytolan etc.) @ 5.0 g. per litre of water has been found effective in controlling the disease.

Dry root rot (*Macrophomina phaseoli* (Tassi) Goid): Small, round or irregular black sclerotia appears below the epidermis on the affected stem and root. The plant wilts within a week. On examination of the stem, dark sunken lesions are seen on the stem and dry rot symptoms appear on basal stem and main root. In advanced stages, dark sclerotial bodies may be seen on the affected roots and basal stem. Seed dressing with Thiram or Captan @ 3.0 g or *Trichoderma viridi* @ 5.0 g per kg of seed, crop rotation and field sanitation including cutting down the diseased plants and burning them and drenching the infested soil with fungicide will help in reducing the inoculum.

Yellow mosaic (*Virus*)**:** Yellow mosaic is an important virus disease, it is transmitted by white fly. The affected leaves become yellow with a slight crinkling and reduction in size. The plants are stunted in growth and set a few pod only. Regular spraying of the crop with a mixture of Methyl demiton 25 EC (Metasystox 25 EC) @ 1.5 ml per litre of water starting from third week or onwards at an interval of 10-15 days keep the white fly population under control and the crop becomes free from the incidence of yellow mosaic virus.

Insect management

Stem borer beetle (*Oberea brevis* Gahan. *Syn* : *Melanagromyza sojae* Zehnter.): A small pale brown longicon beetle whose grub bores into the stern of growing plants. As a result, drying of leaves and withering of plants occur. Adults feed on leaves by making multiple punctures, which appears as white spots on leaves. It can be controlled by spraying the crop with Monocrotophos 36 SL (Nuvacron etc.) @ 1.5 ml, Phosphamidon 40 SL (Sumidon etc.) @ 1.5 ml, Methyl Parathion 50 EC (Metacid, Paratox etc.) @ 1.0 ml/litre of water.

Bihar hairy caterpillar *(Spilosoma obliqua* Wallker.) : The caterpillar feeds gregariously on the foliage causing the whole plant defoliated in case of severe attack. The insect can be controlled by spraying the crop with Dimethoate 30 EC (Rogor etc.) @ 1.5 ml, Monocrotophos 36 SL (Nuvacron etc.) @ 1.5 ml, Methyl demiton 25 EC (Metassystox etc.) @ 1.5 ml/litre.

Tobacco caterpillar *(Spodoptera* Fab.): The larvae of this insect are voracious feeder and causes damages to the foliage. They feed on the surface of the leaves and ultimately skeletonise them. They are nocturnal in habit and cause damage of the foliage at night. They hide themselves under the clods at the base of the plant during day time. The insect can be controlled by spraying the crop with Dimethoate 30 EC (Rogor etc.) @ 1.5 ml, Monocrotophos 36 SL (Nuvacron etc.) @ 1.5 ml, Methyl demiton 25 EC (Metassystox etc.) @ 1.5 ml/litre.

Gram pod borer (*Heliothis armigera* Hubn.): The caterpillar makes holes in the pod and feeds on the ripening grains. The Caterpillar, as it grows, bores into green pods and destroys the seeds completely. It can be controlled by dusting the crop with Carbary 10 % @ 20 kg/ha or Spraying the crop with Methyl Parathion 50 EC (Metacid 50 EC) or Monocrotophos 36 SL (Nuvacron etc.) @ 1.5 ml. per litre of water The insecticide is to be applied at the fruiting stage and it may be repeated at the interval of 10 days.

Harvesting

The plant is harvested when the leaves turn yellow and finally drop and only the pods remain on the stalk. There is a thumb rule for harvesting soybean crop i.e. the crop should be harvested after it has fully matured. Harvesting is done either by cutting the plants close to the ground with sickles or pulling the plants. The harvested plants are carried to the threshing floor and dried in the sun about a week. It can also be threshed by wheat thresher after some adjustments. A moisture content of 13-14% is ideal for threshing with thresher.

Yield

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

Soybean is miracle/unique crop: Soybean accounts 50% of total oilseed production in the world. It contains about 40% protein and 20% oil. It is used in several ways in daily life and for its versatile use it is called as unique crop in the world. It can be used as-

1. The fruit, seed oil and oil cakes are used for human consumption for its higher protein content.
2. Produced milk from soybean seed is used as cow milk in China and also for the preparation of various milk products.
3. Used in preparation of coagulated products like paneer.
4. Fermented products like soysauce, cheese etc. are prepared.
5. Used preparation of bread, biscuit cake, etc.
6. Produced high protein granules for children.
7. Plants can be used as fodder for hey making and silage.

Chapter 11

Sesame (*Sesamum indicum* L.)

Sesame (*Sesamum indicum* L.) is a member of the family Pedaliaceae, which comprises of sixteen genera and about sixty species of which several can be crossed with *S. indicum*. A few of them are cultivated for their seeds. Sesame is also known as '**benniseed, gingelly and til**'. It is probably the most ancient oilseed crop grown all over the world. The crop spread early through West Asia to India, China and Japan, which themselves became secondary distribution centres. The Portuguese introduced sesame to Brazil where it is known as '**gingelim**'. Slaves are considered to have introduced sesame to North America by the end of seventeenth century and in the southern states it is known as '**benne**'.

Origin: Ethiopian area in Africa is generally accepted as the origin of cultivated sesame (*Sesamum indicum* L.) with considerable argument in favour of Afghan-Persian region or even a polytopic origin.

Genome Group: The genus sesame can be grouped into three on the basis of chromosome number.

Group I – The cultivated species *Sesamum indicum* L., has 13 pairs of chromosomes (2n=26). *S. capense, S. alatum, S. grandiflorum and S. schenkii* are also belonging to this group.

Group II–has 16 pairs of chromosomes (2n=32). *S. laciniatum, S. angolense, S. malabaricum and S. prostratum* are under this group.

Group III – *S. occidentale S. trifoliatum and S. radiatum* have 32 pairs of chromosomes (2n=64).

Interspecific hybridization has been widely studied and some crosses have produced viable seeds. Polyploidy can be induced chemically by colchicine treatment. The growth rate and general vigour of tetraploids can exceed that of diploids. The tetraploids plants are taller with longer leaves, larger flowers and capsules. These are now considered in breeding and selection programme for developing new varieties suited for specific conditions.

Climatic requirement: Sesame is considered as a crop of the tropics and subtropics but its cultivation can further be extended to the temperate zone by breeding suitable varieties. The crop is mainly distributed between 25 ^{0}S and 25 ^{0}N. It is normally grown below 1250 m altitude, but some varieties are found under cultivation up to 1500 m and up to 2000 m in Nepal.

It normally requires fairly hot conditions during its growth periods for high yield. A temperature of 25-27 ^{0}C encourages rapid germination, initial growth and flower formation. Temperature below 20 ^{0}C for any length of time delayed germination and seedling growth and below 10 ^{0}C inhibited germination and seedling growth. A frost-free growing period of about 150 days required for its good yield.

Sesame is basically a short day plant with 10-hour day length in 42-45 days for flowering. But many varieties have become adapted to various light periods with wide yield variations. It is reasonably drought resistant, but resistance develops when root system established well. Sesame produces an excellent crop in regions having 500-650 mm rainfall and can be grown in regions with rainfall ranging from 300 to 1000 mm. For high yield, rainfall should be distributed over the period of its growth approximately in the following proportions- 35% germination to first bud, 45% first bud to flowering and not more than 20% from flowering to maturity. Heavy rain during flowering will drastically reduce yield. Cloudy weather at flowering also affects seed setting and productivity. Rainfall at harvest reduces yield by increasing infestation of diseases and prolonging the period of capsule drying. The crop is extremely susceptible to water-logging. Heavy rain at any time during growth will greatly increase the disease incidence and plant mortality.

Soil: Sesame can be grown in a variety of soil types. But sandy-loam, fertile, well drained soils are ideal for its good growth and high yield. It is extremely susceptible to salinity and salt concentrations that have little effect on sunflower and cotton are fetal to the crop. It preferred soils with neutral in reaction (pH 6.5-7.5). But can produce good yield on slightly acidic to slightly alkaline soils (pH 5.5-8.0). The sesame field should be at higher level as compare to the surroundings for quickly disposal excessive rainwater after or during heavy rainfall. Undulated topography of the field also preferred for easy drainage.

Cultivation: Sesame is cultivated both as a pure crop and a mixed crop with groundnut, cotton, tobacco, pigeon pea, jower, mung etc in *kharif* season. It is also grown as pure crop during both *kharif and* pre-*kharif* season. The productivity of *kharif* crop is quite low as compare to that of pre-*kharif* crop due to high infestation of diseases in *kharif* season.

Crop varieties (State wise):

State	Varieties
Andhra Pradesh	Gowri, T 85, No-128
Bihar	Kanke white, M-3-1, M-2-3, M-3-3, B-14
Gujarat	Murg-1, Purva-1, Patan-64, Patan-65
M P	G-5, T-4, G-35, No-128, N-32
Maharashtra	N 128, T 85, Chanda-8, N 58-2
Orissa	Vinayaka, Kalika, Kanak
Rajasthan	Pratap, T 5, T 13, T 22,
Tamil Nadu	TMV-1, TMV-2, TMV-3, KRR-1, KRR-2
U P	T 4, T 5, T 10, & 12, T 13, T 22
West Bengal	B 9, B14, Tilottama (B 67), Rama (I S 5), Krishna, Madhavi, Gowri, Pratap, kanchan

Most of the varieties take 80-95 days to mature during all the seasons (*kharif*, pre-*kharif* and *rabi*) season. Productivity varies from 350-400 kg/ha during *kharif*, 600-800 kg/ha in *rabi* and 800-1000 kg/ha during pre-*kharif* seasons. Oil content varies from 40-50%.

Land Preparation: Soil should be pulverized well. About 2-3 crosswise ploughing is required for sowing the crop in sandy loam type of loose soils and 3-4 ploughing are needed to make fine tilth of the silty loam field. During ploughing weeds and plant residues of previous crop should be cleaned thoroughly and care should be taken so that soil contains adequate moisture to ensure good germination of the crop. However, excess moist condition of the soil during sowing should also be avoided.

Season and sowing: Sesame is mainly a *kharif* season crop. This crop is usually sown early in the season as compare to other *kharif* crops. Time of sowing depends on the onset of monsoon in *kharif* season. In mixed cropping, the time of sowing of the crop will be governed by the sowing of the main corp.

Sowing time of sesame in different regions in India:

Southern India: In south India during *kharif* season it is sown on 2nd half of May when monsoon starts.

Eastern India: In eastern India it is sown on 1st part of June as rainfed crop in kharif season.

Central India: In central India sesame is sown on 2nd half of June as a kharif crop.

Northern India: In northern India it is sown on 1st part of July in kharif season.

Sesame is also grown as a **pre-*kharif* crop** in different regions in India. The **pre-*kharif* crop** is generally sown on end of February to 1st half of March in central and eastern India when

temperature raises 20 ^{0}C or above. But in south India where temperature does not fluctuate much it is sown on January. In the **south another crop can also be grown *rabi* crop** which is sown on October.

Method of sowing: In mixed cropping, the seed is sown either in parallel rows alternating with the main crop or broadcast in the entire field. It is generally broad cast in case of **pure crop** and in the north it is also sown in lines behind the plough or with the help of seed drill. At optimum plant density no significant difference in yield was observed between **line sowing and broadcasting**, but for better intercultural operations line sowing is preferred.

Seed rate: In Mixed cropping – 1.0 – 1.5 kg seeds/ha.

In Pure cropping- 4-5 kg seeds/ha.

Seed treatment: Sesame seeds must be treated with any of the fungicides like Agrosan G N, Tafason, Aratan 6, Mancozeb 75% WP, Carbendazin 50% WP, Dithane M-45 or Indofil-4-45 to protect them from infection by seed borne and soil borne diseases. Any one fungicide @ 2.0-2.5 g/kg of seeds is generally used for seed treatment. The Seeds are soaked with spraying of water and then mixed thoroughly with fungicide before sowing.

Spacing: During *kharif* 35-40 cm row to row and 15-20 cm plant to plant spacing is recommended. But during pre- *kharif* season 30 cm row to row X 10 cm plant to plant spacing is followed. **Optimum plant density** for *kharif* season is 20-25 plants/m^2 and that for pre- *kharif* season is 30-35 plants/m^2.

Depth of sowing: 2.0-2.5 cm depth of sowing was the best for sesame seeds. Both shallow (1.5 cm or less) and deep (3.0 cm or more) sowing should be avoided for better emergence and uniform crop stand.

Manuring: FYM 5-7 t/ha should be applied 10-15 days before sowing and mixed thoroughly with soil during ploughing. In addition to this 20-30 kg N/ha should be given at sowing and mixed thoroughly with soil by final ploughing in rainfed *kharif* crop.

For irrigated *kharif* crop in addition to organic manuring 30-40 kg N, 20 kg P_2O_5 and 20 kg K_2O/ha should be applied to obtain high yield. ½ N and full dose of P and K should be applied at sowing and remaining N need to be applied at 25-30 DAS after weeding and thinning. After topdressing irrigation should be applied. But in sandy type of light soil topdressing should be given after irrigation to avoid nutrient loss through percolation and flashing. *Rabi* and pre-*kharif* crop require higher dose of fertilizers for high productivity. Here 5-7 t/ha of organic manure + 60-80 kg N, 30-40 kg P_2O_5 and 30-40 kg K_2O/ha need to

be applied to get high yield. N and K may be applied in two equal splis-1/2 at sowing and remaining 1/2 at 25-30 DAS before or after irrigation as the case may be.

Intercultural operation

Thinning: Thinning and weeding are the most important cultural operations done in sesame cultivation. If the seeds germinate properly about 80-100 plants/m^2 appear in the field. These excess plants must be removed from the field to facilitate good growth necessary for obtaining high crop yield. Huge number of plants has to be thinned out to maintain optimum plant density. First thinning is generally done at 10-15 DAS when the weak and abnormal plants are uprooted leaving the healthy plants in the field. At 1st thinning 10-15 % more plants are kept so that if some plants die the extra plants cover up the gap. Final thinning is done 10 days after 1st thinning when the extra plants if present at close distance are removed to maintain optimum plant density. During final thinning the weeding has also been done.

Weeding: To get good harvest, the crop should be kept free of weeds at early stages of growth. Several weeds are infested the sesame field particularly during *kharif* season and causes considerably yield loss. About 15-20% yield loss was noted in many cases and in some cases complete failure of the crop due to smothering the field by weeds may occur. Normally the weeds are controlled by hand weeding. One hand weeding at 10-15 DAS and another at 25-30 DAS can control the weeds very effectively and keep the sesame field clean and produce good yield of *kharif* crop. One weeding at 20-25 DAS may be very effective in controlling weeds in pre-*kharif* crop. Application of alachlor 1.5 kg/ha at 1 DAS in 500 liters of water effectively controlled weeds in sesame field and recorded quite high yield comparable to that of weed free check.

Irrigation: *Kharif* sesame is generally grown under rainfed condition in India. However, if dry spell occurs coinciding with flowering or capsule setting, one irrigation under such condition can provide 10-15% more yield. Pre-*kharif* crop requires irrigation due to scarcity of rain water. Here, irrigation must be given at critical growth stages like seedling (10-15 DAS), branching (25-30 DAS), peak flowering (45-50 DAS) and capsule development (65-70 DAS) stages. **If there is any rain, it will curtail down the irrigation requirement. Irrigation in sesame field is given by boarder and strip method and 5-7 cm ha water is applied per irrigation.**

Plant protection

Insect-pests: Tiger-moth (*Amsacta moorei*), stem borer (*Oberea sesami*), hawk- moth (*Acherontia styx*), leaf roller (*Antigastra catalaunalis*) are important insect-pests found in

sesame field. They may be controlled by spraying Chlorpyriphos 2.5 ml/l, Dimecron 40 EC 1.5 ml/l at initial stage of infestation.

Diseases: Among the diseases leaf spot (*Cercospora sesami*), stem rot (*Macrophoma sesami*), charcoal rot (*Macrophomina phaseolina*), root rot (*Thielaviopsis basicola*) and blight (*Phytophthora nicotiana* var *sesami*) are important. They should be prevented by following suitable crop rotation, seed treatment, using disease-free good quality seeds. Phyllody the most destructive disease of sesame caused by mycoplasma like organism transmitted through leaf-hoppers. So attack of leaf-hoppers should be controlled by spraying insecticide. The infested plants at early stage may be uprooted and burnt. Crop rotation must be followed.

Harvesting: Sesame is normally takes 80-95 days to mature. At matuity, leaves and stems tend to change from green to yellowish then reddish tint. Capsules ripen irregularly from the lower stem upward, the topmost often being half mature at cutting. The drying period before threshing allows the seeds to ripen without loss from mature capsules. The plants should be cut before all capsules are mature to avoid loss of seed yield due to shattering. Harvesting should be done early morning hours of the day at a relatively low temperature and high humidity to avoid shattering of seeds. Immediately after harvesting, the crop should be brought to the threshing floor and stacked in the floor for 2 days then spread over the floor in sun for drying and threshing. Threshing is done by beating the upper parts of plants with sticks or by run over of animals. Immediately after threshing the seeds should be cleaned and dried again to reduce moisture content to around 7% for storing or marketing.

Yield: 8-10 q of seeds per ha.

Use of Sesame

Use of Sesame Seed: 77.7% of Sesame seeds are used for oil extraction, 20% seeds is used for domestic purpose and 2.3% used for seed purpose.

Domestic use: Sesame seeds are used either normal or fried for the preparation of various types of foodstuffs, sweets, cakes, pastry etc. It is also used in most of the family functions. Parched seeds are sprinkled on a variety of dishes and served on ceremonial occasions.

Use of oil: Sesame oil used as edible vegetative fat, fixative in the perfumery and scented hair oil. Low quality oil is used for lubrication, lightning purpose and preparation of soap, resin and paints.

Use of cake: Sesame cake is used for cattle feed, poultry feed and raw quality cake is used as organic manure. Decorticated sesame cake used for the preparation of adhesive, poultry feed and baby food.

Oil Extraction and oil quality:

Oil extraction: Oil from Sesame seeds is extracted by **(i) *Ghani,* (ii) Expeller, (iii) Hydraulic and Solvent extraction** methods.

Oil quality: Sesame produces excellent quality of oil and due to this it has been called '**queen of oilseed crops'**. The chief fatty acids in sesame oil are oleic and linoleic that make it conducive for human consumption. It contents unsaponifiable matter including 'sesamol' and 'phytosterol'. The high resistance of normal and hydrogenated sesame oil to oxidation is partially due to 'sesamol' present in it. It also contents minor substances like 'sesamin' and 'sesamolin' that have been found to be effective synergists for pyrethrin, a potent insecticide.

Chapter 12
FORAGE CROP

INTRODUCTION

The crop- livestock interaction is very strong. 46% area of the total geographical area in India is under cultivation but only 5.1 % (8.4 m ha) area of the total cropped area under forage cultivation.The fodder production in the country is not sufficient to meet the requirements of the growing livestock population and also the forage offered to animal are mostly of poor quality.India has a very huge population of livestock. As per all India census estimate, total livestock population (excluding poultry, dogs and rabbits) in the year 2012 was over 548 million.Among the livestock products, milk is the most important.Although India has very large population of livestock, the productivity of milk and other livestock product per animal is very low compared to other many countries in the world. The growth attained in livestock sector hitherto has been attributed largely to increase in animal numbers and to a little extent on productivity enhancement. Owing to problem of severe shortage of fodder and feed, the future growth of livestock has to be sustained primarily on enhancement of animal productivity and not on increase in number of animals. The deficit gap of availability vis-à-vis the requirement of green fodder is huge at 696.40 million MT (63.50 %) and 143 million MT (23.56 %) for dry fodder (2014).One of the main reasons for the low productivity of our livestock is malnutrition, under-nutrition or both, beside the low genetic potential of the animals. It is evident that the country is highly deficient in respect of availability of green fodder.

Role/Importance of fodder

Fodder plays an important role in economizing the cost of production of livestock products especially of milk. Fodder comprises a major protein of dairy ration of milch animals and therefore cultivation of nutritious and high yielding fodder is inevitable. Profitable livestockfarming depends mainly on adequate availability of fodder with reasonable price. With increasein number of animal population & shrinking land resources, the problem to provide adequatefeed and forage become so acute.

1. Feed & fodder cost constitute about 60-70% of cost of milk production. Thus cultivatedfodder has an important role in meeting requirement of various nutrients & roughage toproduce milk most economically.
2. Feeds given to animals not only meet nutrient requirement but fills the rumen to satisfythe animal.

3. In view of microbial digestion system, feeds have to meet requirement of cattleproduction and microbes to promote digestion.

4. Fodder crops provide all the critical elements like highly digestible protein, carbohydrates, fats and minerals. Green fodders are a very good source of B-carotene (precursor of vitamin A).

5. Fodder cultivation has been traditional in most parts of the country. Since generationsfarmers cultivate certain varieties and crops for fodder production and area allocation tothese crops depending upon availability of land, water and requirement for own livestock.

Conservation of Forage Crops

Cost optimization is thought out at every stage of dairy farming. Labor shortage is giving ways tofarm mechanization. All of them have opened door for new technologies, which can reducecost and increase farm productivity & profitability. Silage-making is one of the technologies that empower farmers to provide quality roughage throughout the year using forages, crop residues, agro-industrial by-products, which can be a waste otherwise. Silage-making is practiced to store and preserve green fodder, when it is available in excess, for later use during scarcity period. In livestock farming, hay-making is the primary method of foragepreservation. However, silage-making can replace hay making as the technique of choice inIndia, as it is less dependent than hay-making on specific weather conditions and can beextended to a great variety of forage and fodder crops and locally available agro-industrial byproducts.

Chapter 13
SORGHUM (*Sorghum bicolor* L)

Sorghum is most important fodder crop for livestock because of its wide adaptation, rapid growth, high green and dry fodder, ratoon ability and drought tolerance. Sorghum besides an important food crop of world is also valued for its fodder and stover. Sorghum fodder is suitable silage and hay making and thus can supplement the fodder supply during lean season. The dry stover forms important feeding stock for animals especially in dry areas. It is suitable for cultivation in areas that are too dry for maize. Livestock relish its fodder due to sucrose content in its straw. The crude protein and fibre content of fodder is 7-10% and 25-35%, respectively. It is cultivated for fodder purpose in the country over 2.6 m ha mainly in the states of western Uttar Pradesh, Haryana, Punjab, Gujarat, Rajasthan and Bihar. It meets over 2/3 of the total forage demand of *kharif* season.

Origin and History

Cultivated sorghum probably originated in East Central Africa, in or near Ethiopia or sudan because of the great diversity of types growing in that region. Sorghum (*Sorghum bicolor* L.) belongs to the family *Poaceae*. It is the world's fifth most important cereal fodder crop of arid and semi-arid tropics being high biomass productive and water efficient. It is known under a great many names**:** milo, guinea corn in West Africa, kafir corn in South Africa, durra in Sudan, mtama in eastern Africa, **jowar in India** and kaoliang in China.

Soil and its preparation

Well drained sandy loam to loam soils with a pH range of 6.5 to 7.5 are ideally suited for its cultivation. The field should be thoroughly prepared and levelled to make weeds free sowing. Better crop stand is obtained on well-prepared soils. One ploughing with soil turning plough followed by two harrowing (crosswise) and planking is sufficient to get a good seed bed. The crop can't tolerate longer water stagnation hence, provision of good drainage is essential.

Sowing time

Single or double cut varieties are sown with the onset of monsoon in June-July. Multi cut types are sown during March-April in areas with irrigation facility which provides four cuts till September-October in northern India. However, in southern India, where minimum

temperatures do not fall below 15^0C, it is grown during *Rabi* season also in the month of October-November. For summer sowing of multi cut types, mid-March to mid-April is the best period, while for monsoon season crop, sowing should be done preferably between 25th June and 10th July.

Seed rate and sowing method

The crop is sown in rows of 30 cm (single cut) to 45 cm (multi cut) apart with a plant to plant spacing of 15 cm. The seed is sown at a depth of 2-5 cm. For sorghum 50-60 kg/ha and sweet Sudan grass 30-35 kg/ha seed is sufficient. The crop must be planted in rows at 25-30 cm apart.

Cropping system

Sorghum being the very exhaustive crop should be rotated with legume like chickpea. For higher and quality fodder production, intercropping of sorghum with legumes is advised. Its intercropping with cowpea (normal rainfall areas) and guar (low rainfall areas) in 2:1 ratio is promising. For intercropping, erect genotypes of legume are ideal.

Varieties

The varieties with less menace of leaf diseases and stem borers are ideal for fodder purpose.

Varieties	Areas of cultivation	Green fodder (t/ha)
Single cut		
PC-6, PC-9, PC-23, HC-136, HC-171, HC-260 (Early to medium duration)	Whole country	35.-50
U.P. Chari-1, UP Chari-2, Pusa Chari-1, MP Chari	U.P., Maharashtra, A.P. & Tamil Nadu	35-45
HC-136, Raj, Chari-1, Raj Chari-2 Long duration	Whole country	37-50
Double cut		
CO-27	Tamil Nadu	45-65
AS-16	Gujarat	40-60

Single cut varieties

Raj chari-1: Resistant to stem borer and is non-lodging. Green fodder yield is 45 t/ha.

Raj chari-2: A selection from local type of Udaipur region. Resistant to stem borer with highdigestibility. Green fodder yield is 33 t/ha.

UP chari-1: It is not suitable for high rainfall areas. Very low in HCN and can be fed toanimals at any growth stage.

UP chari-2: It is not suitable for high rainfall areas. Suitable for late sown conditions too.Green fodder yield is 38 t/ha.

usa chari-1: It is resistant to lodging, drought and pests. Highly responsive to fertilizers.Green fodder yield is 33 t/ha.

Multicut varieties/ hybrids:

PCH 106: It has profuse tillering and quick regeneration capacity and provides 3-4 cuts.Yields up to 65 t/ha of green fodder

Meethi Sudan: It provides 55-60 t/ha of fodder in 4 cuts. It is tolerant to drought and waterlogging. The stems are sweet and thin with profuse tillering.

Dual purpose varieties/ hybrids:

CSV 15: It is a single cut variety with 45 t/ha of green fodder yield. Its stems are tall, sweetand juicy. It is resistant to leaf diseases and drought.

CSH 13: A hybrid suitable for taking single cut of fodder. It is resistant to leaf diseases andyields about 45-50 t/ha of green fodder.

Fertilizer requirement

The field should be manured with 10 t FYM/ha to meet requirement of secondary and micro nutrients. In single cut varieties, basal application of 60:30:30 Kg N: P2O5: K2O per hectare should be given at sowing time followed by top dressing with 30 Kg N/ha, one month after sowing. In low rainfall and rainfed areas, 60 Kg N/ha is applied at sowing time. In case of two cuts and multicut, dose of 60:60:60 Kg& 70:30:30 kg N: P2O5; K2O/ha, respectively, as basal should be applied. Top dressing of 50 kg N/ha should be done after each cut. For better crop performance, 30-35 days stage. If crop suffers due to dry spell, spraying of 2 % urea solution should be done. In sulphur deficient soils (below 10 ppm available S), the application of 40-60 Kg S/ha is advantageous not only for improving biomass production but quality f the fodder also.

Irrigation management

Sorghum as a rainfedkharif crop needs no irrigation. However, at times of drought irrigation 35 DAS is advantageous. In summer, the crop requires 5-6 irrigations at 10-15 days interval depending on soil and climate.

Weed management

Weeds at early stages of crop growth compete for water and nutrients, and finally leading to heavy yield losses. One hand weeding 15-20 DAS is necessary and later on weeding should be done depending upon the requirement of the crop. However, inter culturing becomes difficult during rainy season. For chemical weed control apply atrazine @ 500g/ha between 7-15 days after sowing using 625 L of water.

Disease and insect-pest management

Sorghum is infected by number of insects and disease pathogens. Some of the important diseases are Anthracnose, Sooty stripe and Zonate leaf spot. Among insects, shoot fly, stem borer and sorghum midge are important. In forage sorghum, use of chemicals for control of insect-pest diseases may not be safe option. Therefore, field samitation, use of healthy seed and seed treatment with Thiram @ 3 g/Kg seed is recommended. To avoid diseases and pests, resistant varieties are to be grown. Summer sown crop is very susceptible to shoot fly and it may be controlled by Carbofuran 3G @ 3-4 Kg/ha applied in treanch at sowing time. To avoid attack of stem borers, crop should be sown during July as it is not attacked by the borers during rainy season.

Harvesting

Single cut varieties are harvested at 50-100% flowering stage. In multi cut varieties, the first cut is taken 55 days after sowing and the subsequent at 40 days interval. In multi cut varieties, first cut should be taken 8-10 cm above ground level so as to facilitate profuse tillering.

Hydrocyanic acid (HCN) or Dhurin

Young sorghum plants contain poisonous chemical. The crop at early stages contains hydrocyanic acid (HCN) or Dhurin. HCN in excess of 200 ppm concentration is toxic to animals. Hence, harvesting should not be done prior to 45 days from sowing. Heavy nitrogen fertilization and water stress (drought) increases HCN content. Silage or hay making removes the toxin. In summer, an irrigation before harvest may be effective in reducing HCN. For hay making, pre-flowering is ideal stage for harvest. At this stage, the biomass is soft and rich in nutrients. Danger of HCN poisoning is greatest at immature stages of sorghum growth and decreases with maturity.

Chapter 14
Napier Grass *(Pennisetum purpureum)*

Introduction

The hybrid Napier for fodder is highly valued for its abundant herbage yield, palatability and good herbage quality. It contains 8.5-10.2% CP, 28-34.5% crude fibre and 10-11.5% ash on dry matter basis. It is a triploid grass and thus does not produce seeds. It provides nutritious

and palatable fodder all the year round. It grows faster and produces more herbage and the stems are hard. It is triploid grass and thus does not produce seeds. The oxalate contain of some of the varieties may be high (> 3%). It can be mitigated if harvested at longer intervals (45-60 days). The grass is ideal for green fodder, silage and hay. Legumes fodder may be mixed with grass in the ratio of 1:2 to produce balanced silage. A combination ofNapier grass with berseem, Lucerneor cowpea provides good quality palatable fodder for cattle. It is considered as a soil restoring crop also as grass leaves the soil richer in organic matter.

Origin and history

Napier grass is native of Rhodesia in South Africa, where it is found growing extensively. It is presumed that this plant has been used as a fodder for the first time in Rhodesia. The name napier grass is given in the honour of Col. Napier, who first drew the attention of the Rhodesian Department of Agriculture in 1909 to the fodder value of this grass. It was introduced in India in 1912 from South Africa.

Climatic Requirements

It grow well at high temperatures, can withstand to drought conditions for fairly long spell. It grows in areas with rainfall of over 1000 mm but it cannot tolerate the flooding /water logging. The optimum temperature is 31^0 C but it performs well in areas having temperatures above 15^0 C. light showered alternated with bright sunshine are very congenial to the crop. It is a tropical grass which can withstand drought for a short spell and regenerate with rains.

Soil Conditions

It can grow on almost all type and fertility status of soils but being exhaustive species, well drained clay loam soils are preferred. The crop can bear soils acidity to limited extent (pH-5.5).

Varieties-

Varieties	Area of cultivation	Green fodder yield (t/ha)
IGFRI Hybrid Napier No. 3 and 6	Central India, north-east hills and northern hills	80
Pusa giant & NB 21	Whole country	100-160
Co 1, Co 2 and Co 3	Tamilnadu, Karnataka, AP and Gujrat	120-170
IGFRI 7	Hilly, sub humid, and sub temperate India	140-170
PBN 83	Punjab	125-170
IGFRI 10	Whole country	150 -180

Field preparation

It is a long duration crop; hence periodical tillage activities like other crops are not possible after the crop occupies the field. Generally 2-3 ploughing followed by planking is required to obtain the fine tilth.

Sowing method and Time

It is propagated by stem cuttings with two buds called rooted slips. About 25000 to 40000 rooted slips or stem cuttings/ha are needed. Planting can be done at any time of year except during winter months. February planting is most suitable in areas where assured irrigation facility is available. Under rain fed conditions July-August planting is preferred. Stem cuttings are placed into the soil at an angle of 45^0, so that one node is pushed into the soil and one remains above the soil surface. Rooted slips are prepared by uprooting a clump, dividing it into rooted slips with small stem. They should be planted in to field with a spacing of 60x50 cm for sole cropping and 100x50 cm for intercropping. Irrigation should be done just after the planting of crop.

Nutrient management

Apply NPK fertilizers as per soil test values along with recommended FYM/compost. In absence of soil test results, 20-25 t FYM should be well mixed in soil at the time of land preparation. At sowing time a basal dose of 60kg N, 50 kg P_2O_5 and 40kg K_2O/ha should be applied in bands prior to planting. Subsequently 20kg and 10kg N should respectively be top dressed just after and 20 days after the cut. Alternatively, the crop may be fertilized with 40 kg N just after the cut.

Water management

The crop should be planted in well moist soil condition. The crop needs regular irrigation at an interval of 15-18 days in March to May, at 10-12 days interval I summer months. During monsoon seasons the irrigation is rarely needed in event of long monsoon failure.

Weed management

The gap filling may be done after 20 days of planting. Regular hand weeding/hoeing and ensures good aeration and crop growth as well as control weed growth.

Harvesting & Threshing

First cut at 60-65 days after planting and subsequent cuts are obtained at 30-40 days interval. At least 6-8 cuts are possible annually. In order to encourage quicker regeneration from the basal buds, stubbles of 10-15 cm are to be left out at harvest.

Chapter 15
Cowpea - (*Vigna unguiculata*)

Cowpea (*Vignaunguiculata* L.) belongs to family Leguminoceae. It is also known as Lobia, black eye pea, kaffir pea, marble pea, China pea and southern pea. In north India, it is grown during kharif and summer seasons, while in south it is grown all the year round. Cultivation of cowpea is recommended for irrigated areas. It is generally grown in mixture with pearlmillet, sorghum etc. to enhance the green fodder yield and supplement the nutritive value of non-leguminous fodders. The crop is recommended for feeding the dairy cattle to maintain a good flow of milk during summer. Cowpea makes good hay and its seed is used as concentrate in animal feeds. The crude protein content in cowpea fodder ranges between 16-21%. The nutritive value of fresh biomass of cowpea (dry matter basis) is 12.5% digestible crude protein (DCP), 62.0% total digestible nutrients (TDN), 2.7 M cal/kg of digestible energy (DE)

Origin

It is native of central Africa where almost all the wild species are found.

Climate requirement

Cowpea is best suited for moderately humid tropic and sub-tropics up to an elevation of 1500m. Frost, excessive heat and prolonged water logging are, however, not conducive for its growth. The optimum temperature for its growth is 27^{o}C, and the minimum is 15^{o}C. It requires average soil temperature >19^{o}C for 3 days from sowing to emergence, that limits its cultivation in north during winter.

Soil and its preparation

Cowpea can be grown on variety of soils. The plants prefer light soils. Loam and sandy with good drainage are most suitable for god crop growth. Field should be prepared by two cross harrowing and planking so as to get a levelled and weed free sees bed for a quick germination and faster initial growth.

Varieties

Varieties	Areas of cultivation	Green fodder (t/ha)
EC-4216	North zone	30-35
UOC-5286	Whole country	35-40
IFC-8503, EC-4216	North, West and Central India	30-40
UPC-5187	North zone	30-45
FC-8	Tamil Nadu	30-35
UPC-4200	North-East region	30-35
GFC-1, GFC-2, GFC-3, GFC-4	Gujarat	25-35
Sheweta	Maharashtra	35-40
Bhundel lobia-1	Whole country	30-35
Bhundel lobia-2	North west zone	35-40
Upc-618, UPC-622	North-west, North-east and Hill zone	35-45

Sowing time

In irrigated areas, sowing can be done during summer while in rainfed areas; it can be done after commencement of rains. Its sowing time extends from March to middle of July. In southern region, sowing of crop for fodder may be done throughout the year.

Seed rate and sowing method

A seed rate of 35-40 kg/ha is sufficient for its proper plant population. The sowing should be done in lines at an inter row spacing of 25-30 cm. The seed should be shown with seed drill or behind the plough at a depth of 2-3 cm.

Nutrient management

Cowpea is a leguminous crop and has capacity to fix atmospheric nitrogen. However, for good growth 20 kg N and 60 Kg P_2O_5 / ha should be applied at the time of sowing for good crop growth. In sulphur deficient soils (below 10 ppm), 20-40 kg sulphur per hectare is recommended for quality fodder biomass production.

Water management

Normally the *Kharif* season crop does not require irrigation except in case of long dry spells in which the crop should be irrigated at an interval of 10-12 days. But summer crop requires 6-7 irrigations at 8-10 days interval.

Weed management

In general, *Kharif* crops are densely infested with weeds due to conducive situation for growth. In cowpea, the weed problem is severe in early stages. After 30 days the crop covers the land area and thus, problem of weed infestation is minimized. One manual weeding or hoeing with weeder cum mulcher at 3 weeks crop stage is effective to check weed growth.

Pre-plant soil incorporation of Trifluralin or Fluchloralin @ 0.75 kg a.i./ha has been found useful chemical weed management method to arrest weed growth.

Diseases and Insect management

Mosaic virus disease: It is a serious seed borne disease of cowpea. The symptoms appear aschlorotic patches on cotyledons, that later cover entire foliage. The secondary infection spreads through aphids. Selection resistant varieties, use of healthy seeds, control of aphids and rouging of infected plants are useful in its management.

Jassids(*Empoascakerri*): Both nymphs and adults suck sap from leaves in dry weather.Affected leaves turn yellow and fall off. Spray 0.03% Monocrotofos or Phosphamidon is effective. It is also controlled by spray of 200 ml of Malathion 50 EC in 200 litres of water per acre. If the crop is grown for fodder, do not feed the treated crop to cattle within one week of spraying.

Flea/Galerucid beetle (*Madurasia obscurella*): The beetle feeds on leaves, buds and flowers.Severe attack can cause defoliation. Apply phorate 10 G kg/ha at sowing along with early sowing to avoid pest attack.

Hairy caterpillar (*Amsactamoorei*): The young larvae feed on lower surface of leaves andskeletonize them leading to severe yield losses. Collection and destroying eggs and larvae in early stages. Dusting 0.05% dichlorovos spray is recommended.

Cowpea stem fly (*Melangromyza phaseoli*): The maggots bore into younger stems andtunnels towards the base causing damage to stem. The affected plants wither and die. Clean culture, use of resistant varieties and 0.05%monocrotophos spray control stem fly.

Harvesting management

Rainy season crop is harvested after 55-60 days of sowing at 50 % flowering stage whereas summer crop requires few days and should be harvested after 70-75 days of sowing. Under irrigated condition, cowpea crop yielded 25-30 t/ha green biomass. But under rainfed condition only yield level are low i.e. 15-20 t/ha.

Chapter 16
CLUSTER BEAN or GUAR (*Cyamopsis tetragonaloba L)*

Clusterbean (*Cyamopsistetragonoloba L.*) is a multipurpose legume of papilionaceae family, which is valued for its gum, seed and fodder production besides for green manuring. It is also known as Guar in Hindi, which is the most drought tolerant crop. The fodder of clusterbean as well as its grain is quite nutritive, rich in protein, fat and minerals. The crude protein and crude fibre content varies from 15-18% and 25-30%, respectively. It is a very valuable fodder crop for the rainfed areas because it is tolerant to drought. It can be grown alone or mixed with sorghum, Bajra, etc. Its gum is highly mucilaginous, which is being used in various industries such as textiles, cosmetics, explosives, paper, food processing etc. Today clusterbean is one of the significant foreign exchange earner of the country. Clusterbean is grown on about 2 lakh ha in India mainly in the states of Rajasthan, Haryana, Gujarat, Punjab, Madhya Pradesh, Uttar Pradesh and Maharashtra.

Origin

According to Gillette (1958), the tropical Africa is its probable center of origin because of more occurrence of its wild species there.

Soil and its preparation

It is a soil restorative crop, especially suitable for light sandy or alluvial soil. The facility of adequate drainage is ideally suited for its growth. The field should be prepared by 2-3 harrowing to ensure a levelled and weed free soil surface.

Varieties

Varieties	Areas of cultivation	Green fodder (t/ha)
FS-227	Entire guar grown tract	30-35
HFG-110,HFG-156	Entire guar grown tract	25-30
Guara-80	North-West zone	20-30
Maru guar	Western Rajasthan	25-30
Bundle Guar-1, Bundel Guar-2, Bundel Guar-3	Entire guar grown tract	30-35

Sowing time

Under irrigated conditions, *summer* crop should be sown in March-April and rainy season sowings should be done in June-July with the onset of monsoon in north India conditions. However, in southern parts of the country winter sowings can be done in October-November.

Seed rate and sowing method

Sowing is done in 25 cm apart lines using a seed-rate of 30-35 kg/ha. In dry land semi-arid regions, where moisture stress is common, sowing is recommended in 30 cm apart rows with reduced seem rate of 25-30 kg/ha to have a low plant population. The seed should be sown with *Paira*under irrigated conditions and *Pora*in dry lands.

Nutrient management

It is a leguminous crop and has ability to fix atmospheric nitrogen. Therefore, only 20 kg N + 50 kg P_2O_5 /ha at sowing time should be applied.

Water management

Summer crop requires 3-4 irrigations, whereas, rainy season crop generally does not require any irrigation. However, if long dry spell prevails, one or two irrigation may be provided *Rabi* season crop in southern India needs 3-4 irrigations.

Weed management

Pre-plant soil incorporation of Nitralin @ 0.75 kga.i. /ha has been found effective. One operation with weeder cum mulcher at 3-4 weeks crop stage is very useful for checking weed growth.

Disease and Insect management

Bacterial blight (*XanthomonascyamopsidisPv. Cyamopsidis*): The disease appears as smallwater soaked lesions, which later become necrotic on leaves, and may also appear on flower and pods. It is a seed borne disease. Seed treatment with hot water at 50^oC for 10 minutes controls the disease. At the appearance of disease or at 8 weeks after sowing spray the crop with 75 g streptocyclin and 500 g copperoxicloride in 500 litre of water to save the crop from this disease. If needed repeat spray after 15-20 days.

Alternaria leaf spot (*Alternariacyamopsidis*): Dark brown round to irregular spots varyingfrom 2 to 10 mm in diameter, appear mainly on leaf blades. In severe infection, several spots merge together and the leaflets become chlorotic and usually drop off. If the plants are infected in early stages of growth, there may not be any flowering. Spray Dithane Z 78 (0.2%) at an interval of 15 days is effective in its control.

Insect management

Generally this crop is not affected by insects but sometimes aphid causes damage to the crop. To control aphid spray 500 ml malation 50 EC in 500 litre of water per hectare.

Harvesting management

The crop should be harvested at bloom to pod formation stage (60-75 days after sowing). A good crop of cluster bean yield 30-35 tonne green fodder yield/ha.

Chapter 17
COTTON (*Gossypium* spp L.)

Cotton (*Gossypium* spp L.) belongs to family Malvaceae. In hindi also known as Kapas. It is one of the most important commercial crop, grown for fibre world over. Fibre is used for making cloth, thread and other synthetic fibres. The fibre is almost pure cellulose. Cotton seed contains 15-25% oil which is used for making vegetable ghee or oil. Cotton seed cake after extraction of oil is good organic manure which contains about 6% N, 3% phosphorus and 2% potash. Cotton meals are good concentrated feed for cattle. The chemical composition of cotton is cellulose 91.00%, water 7.85%, protoplasm pectins 0.55%, waxes, fatty substances 0.40% and mineral salts 0.20%. Cotton has gossypol, a toxin that makes it inedible.

Origin and history

Cotton has been used as a fabric in India from time immemorial. The excavations of Mohen-jo-daro indicates a high degree of art in spinning and weaving with cotton at that time. It finds mention in the Rig-Veda, the oldest scripture of the Hindus. The cultivation of cotton spread from India to Egypt and then to Spain and Italy. Every evidence proves that India was the original habitat of cotton.

Gossypium hirsutum – upland cotton, native to Central America, Mexico, the Caribbean and southern Florida, (90% of world production).

Gossypium barbadense – known as extra-long staple cotton, native to tropical South America (8% of world production).

Gossypium arboreum – tree cotton, native to India and Pakistan (less than 2%).

Gossypium herbaceum – Levant cotton, native to southern Africa and the Arabian Peninsula (less than 2%)

Area and distribution

The important cotton growing countries are India, USA, former USSR, China, Brazil, Egypt, Pakistan, Turkey, Mexico and Sudan. Current estimates for world production are about 25 million tonnes annually, accounting for 2.5% of the world's arable land. China is the world's largest producer of cotton, but most of this is used domestically. The United States has been the largest exporter for many years. The five leading exporters of cotton in 2011 are the United States, India, Brazil, Australia, and Uzbekistan.

In India, the states of Maharashtra (26.63%), Gujarat (17.96%) and Andhra Pradesh (13.75%) are the leading cotton producing states, these states have a predominantly tropical wet and

dry climate. In nearly 65% of the area, cotton crop in entirely dependent on rainfall and supplementary irrigation facilities exist in 35% of the area. Maximum Productivity (774 kg/ha) is given by Gujarat state followed by Andhra Pradesh (748 kg/ha) against national average of 591 kg/ha. During 2009-10, the area, production and productivity of Haryana state was 5.07 lakh ha, 19.3 lakh bales each of 170 kg and 650 kg/ha, respectively.

Classification

Genus *Gossypium* includes 20 species of cotton including wild as well as cultivated species. The cultivated species have spinable lint while wild species have only short seed fuzz or smooth seeds. According to classification by Hutchison (1947), the following four cultivated species contain almost all the varieties of cotton cultivated in India.

Desi cotton		
Gossypium arboreum	(29%)	(n= 13)
Gossypium herbaceum	(21%)	(n= 13)
American cotton		
Gossypium hirsutum	(50%)	(n= 26)
Gossypium barbadense	(2000 ha)	(n= 26)

Classification according to staple length (Mean fibre length)

(i)	Superior long staple	>27 mm
(ii)	Long staple	24.5-26.5 mm
(iii)	Superior medium staple	22-24 mm
(iv)	Medium staple	19.5-21.5 mm
(v)	Short staple	19 mm or less

Climatic requirement

Cotton requires a mean annual temperature of over 16^{o}C and an annual rainfall of at least 50 cm distributed throughout the growing season. It is grown in tropical and subtropical conditions. For the successful germination of its seeds, a minimum temperature of 16^{o}C is required. The optimum temperature for vegetative growth is 21-27 ^{o}C. It can tolerate temperature as high as 43 ^{o}C but does not do well, if it falls below 21 ^{o}C. During fruiting phase, the day temperature ranging from 27 to 32 ^{o}C and cool nights are needed. If during fruiting period heavy showers of rain occur or heavy irrigation is applied, shedding of flowers and young bolls may result. Abundant sunshine during the period of boll maturation and harvesting is essential to obtain a good quality produce. Cotton plant cannot stand frost and hence its cultivation is restricted to an altitude of 1000 m only.

Soil requirement

Cotton is grown on variety of soils, ranking from well drained deep alluvial soils in the north to black clayey soils of varying depth in Central zone and in the black and mixed black and red soils in South zone. Cotton is moderately tolerant to salinity and is sensitive to water logging and thus prefers well-drained soils.

Cropping system

In northern India many rotations of crops involving cotton are feasible. Crops like wheat, chickpea, pea, linseed can be grown after harvest of cotton. Some of the important rotations are: Cotton-wheat, Cotton-berseem, Cotton-chickpea, Cotton-field pea, Cotton-linseed, Cotton-Sunflower etc. In southern India cotton-sorghum-ragi is an important crop rotation in irrigated areas. Intercropping with ragi, other millets or groundnut is also quite common in parts of Tamil Nadu, Karnataka and Andhra pardesh. In northern India mixed cropping or intercropping with sesamum, groundnut, castor, chilli, guar etc. is quite common.

Varieties

Variety	Sowing time	Plant Height	Ginning %	Fibre length (mm)	Maturity (Days)	Av. Yield (q/ha)	Remarks
American							
HS 45	Up to 15 May	120-160	34.0	22.5	180-190	21.0	Escape from pink boll worm. Wheat can be sown easily after harvesting.
H 974	15 May-20 June	130-140	35.0	23.0	160	18.61	Resistant to jassid, pink boll worm is less
HS 6	Up to 15 May	150-160	36.0	23.6	180-185	21.63	Resistant to jassid, pink boll worm is less
H 1098	Mid May-Ist week of June	130	35.2	22.7	165	21.0	Resistant to jassid, pink boll worm is less
H 1117	Early sown	150-160	35.5	24.1	175-185	19.18	Resistant to leaf blight
Desi							
HD 107	Mid April-Mid May, Early maturing	150	38.0	16.0	180	25.0	Pink boll worm is less, resistant to white fly
HD 123	Normal sown	150	39.2	14.7	165	22.91	Wheat can be sown easily after harvesting
AAH 1 (Hybrid)	Normal sowing	150	38.0	18.4	190-200	25.06	Tolerant to all diseases & insects

Hybrids							
HHH 81	Normal sowing	200	35.0	25.9	185	24-25	Pink boll worm is less
HHH 223	Normal sowing	150-160	35.2	22.5	175-180	21.24	Jassid resistant

The most popular Bt cotton varieties are RCH 134, RCH 314, RCH 317, Ankur651, MRC 7031 and Tulsi 4.

Field preparation

Pre-sowing irrigation is undertaken after harvest of wheat. The field is ploughed with tractor-drawn implements and levelled and planked before sowing. In Central and South zones, where cotton is a rainfed crop, deep ploughing is recommended to remove weeds. The field is prepared by repeated ploughing and harvesting with the onset of pre-monsoon rains. Crop is recommended to row ridges and furrows in dry lands for moisture conservation and weed management. In the red soils of South Zone, having poor moisture retention, field is given 2-3 harrowings followed by shallow ploughing and sowing is done on ridges. The availability of herbicides for weed control has opened up options for reduced tillage and residue management, which are more energy efficient and have an ameliorative effect on soil quality.

Sowing method

Row sowing: Sowing is done in rows as per recommendation of different cotton growing zones with the bullock drawn plough or seed drill in rows and the plant to plant spacing is maintained by thinning.

Square planting: In this system, uniform spacing between and within the rows is maintained. For planting in this system, two typed harrow is moved along and across the field and the seeds are dibbled on cross points. In this system plants get equal space for growth and development. Inter-culture is done along and across the rows.

Paired row planting: The plant population and the number of rows are equal in the normal and paired row planting. In case of paired row, distance between every two rows is reduced and thereby the space between the two pairs of rows becomes more than the normal spacing. This wider spacing, between the two pairs, helps in better aeration and light resulting in better fruiting also. It also helps in easy intercultural operation and other operations. In this planting intercropping with the early maturing and short statured legume like green gram, black gram etc. can be practiced.

Skip row planting: In this system after every two, three or four rows, one or two rows are not planted but the plants of such rows are adjusted in the other planted rows, thus

maintaining the desired plant population. This planting is useful to have inter crops that help ease in operation particularly in tall growing varieties.

Spacing

In Haryana for timely sown cotton spacing of 67.5 cm x 30 cm, 4-5 cm seeding depth and plant population of 50,000 plants/ha is recommended but under late sown condition plant to plant spacing should be reduced and a plant population of 67,000-70,000 plants/ha (25% more) is required.

Sowing time

The sowing time for cotton varies considerably in different cotton growing zones.

Zone	Optimum sowing time	
	Irrigated	Rainfed
North Zone (Punjab Haryana, Rajasthan)	15th April – 30 June	Bhiwani, Mahendergarh, Sirsa where sandy soil, sowing must be done in Ist fortnight of April to avoid sand deposits on plants.
Central Zone (Maharashtra, Madhya Pradesh, Gujarat)	15-25th May	With the onset of monsoon 1-15 June in South Gujarat and 15-30 June in Maharashstra
South Zone (Andhra Pradesh, Karnataka and T. Nadu)	15th April-15 May Jan.-Feb. in rice fallows of A.P. and T. Nadu	June in Karnataka

Seed treatment

Acid delinting: The process of removing the fuzz from the cotton seed by treating with conc. H_2SO_4 is known as acid delinting. Wash the seeds with water 3-4 times and then with lime water and fresh water and dry the seeds under sun. Treat the seed with following chemicals from 2 hrs before sowing for early and good germination along with healthy plants and better root proliferation. Treat the 6-8 kg acid delinted cotton seed with emisan 5 g, streptocyclin 1 g, succinic acid 1 g dissolved in 10 litre of water. For termite control 10 ml chloripyriphos + 10 ml water/kg seed be treated. For control of root rot 2 g Bavistin/kg seed be mixed.

Seed rate

Variety	Acid delinted seed (Kg/ha)	Non delinted seed (Kg/ha)
American varieties	15-20	20-25
Bt Cotton hybrids	2.125	-
American hybrids	3-3.750	4.375
Desi varieties	12.5 Kg	15

Fertilizer requirement

Zone	American	Hybrid	Desi
North	87.5 kgN+30 kg	175 kgN+60 kg	50 kgN+10 kg
	P_2O_5+10 kg	P_2O_5+60 kg K_2O+10	$ZnSO_4$ /ha
	$ZnSO_4$/ha	kg $ZnSO_4$/ha	
Central & South	NPK 40-20-20	180-60-60 kg/ha	

Time of application: Add full amount of P_2O_5 and $ZnSO_4$ at sowing. ½ N at square formation (July end) + ½ N at flowering. In hybrids, add full amount of P_2O_5 and $ZnSO_4$ at sowing. 1/3 N at sowing + 1/3 N at square formation (July end) + 1/3 N at flowering. Seed and soil treatment with *Azosprillium*.

Water management

Depending upon the location, soil type, climate and crop growth period, cotton needs 700-1200 mm of water to meet its water requirement. The requirement is low during first 60-70 days after sowing and highest during flowering and boll development. The first irrigation be delayed at least 40-50 days for better root development and to avoid excess growth. In general 3-4 irrigations are needed. Cotton is commonly flood irrigated, although irrigation by furrow method in more effective in water saving. Drip irrigation is becoming popular, particularly in hybrids in Central and South zones. On sandy-loam soils of North Zone, 3-5 irrigations are sufficient. In red sandy-loam soils of Tamil Nadu with low water holding capacity, 4-13 irrigations are necessary. Moisture stress at flowering and fruiting results in shedding of flowers and bolls and thereby reduce the yield. Last irrigation should be applied at 1/3 rd opening of bolls.

Use of hormones

(A) **Naphthalin acetic acid** (NAA): Two spray of NAA should be done. First spray should be done @ 125 ml/ha at the time of flowering (2^{nd} and 3^{rd} week of August) and second spray @175 ml/ha after 20 days of 1^{st} spray. This will help in reducing flower rotting and boll drop.

(B) **Cycocil**: To avoid excessive growth of American cotton, apply 80 ml cycocil / ha in 800 lt. of water at square formation.

Picking	
American cotton	In the month of October
Desi cotton	In the 3rd week of September

Picking should be done at 8-10 days interval.

Weed management

Cotton is susceptible to weed competition from sowing to complete canopy cover. Cotton yields are reduced by 50-85% with unchecked weed growth or their ineffective control. Weeds must be removed mechanically 2-3 times as per requirement. First weeding should be done before first irrigation. For chemical control of weeds spray Pendimethalin @ 1.5 kg a.i./ha in 600 lt of water just after sowing. This will control *Trianthema* (Santhi) and

Echinochloa sp. or before germination carry out dry hoeing followed by spray of Diuron @ 500 g/ha in 600 lt of water. Or 40-45 days after sowing carry out dry hoeing followed by spray of Stomp @ 3 lt/ha in 600 lt of water and apply irrigation. This will also take care of annual weeds.

Disease management

Angular leaf spot (*Xanthomonas axanopodis pv. malvacearum*): The bacterium attacks all the above ground plant parts, causing various types of symptoms. The disease may appear from the seedling rot to boll rot. On the leaves water-soaked lesions first appear that become angular, bound by vein lets and turn dark brown to black. The spot size may vary from 1-5 mm in size and often several spots may coalesce to form irregular black patches resulting in withering and drying of leaves. The infection may spread along the bigger veins and veinlet of the leaves and causes vein blight symptoms.

Wilt (*Fusarium oxysporum* f. sp. v*asinfectum):* The disease affects the plant at all stages of growth. There is drooping of leaves starting from the oldest leaves at the base and wilt proceeding upward. Defoliation and discoloration of stem may also be seen.Vascular bundles are filled with fungal hyphae.

Root Rot (*Rhizoctonia bataticola*): The disease spreads in the field in circles. If the affected plants are pulled out and examined, the entire root system shows rotting and decaying. In severe infection tap root remains attached to the plant and remaining root system (lateral and thinner roots) decays completely. The woody portions may become black and brittle, Often fungal sclerotia appear as minute black dots on the surface of the of the woody tissue and on the rotting bark.

Leaf Curl (*Cotton Leaf Curl Virus CLCV*): The disease causes thickening of small veins, accompanied by up word cupping and curling of the leaves and formation of enations on the lower surface of the leaves. The internodal length is reduced and plants remains stunted. The height of the plant is greatly reduced, there is smalling of leaves and fruiting bodies and plant look bunchy.

Integrated disease management

1. Seed treatment with Emisan-6 (5 g) and Streptocycline (1g) in ten liters water. This solution is sufficient for 5-8 kg seed and controls both internal and external seed borne infection.

2. In areas where root rot is problem, treat the seed with Bavistin @ 2.5 g/kg seed just before sowing.
3. For angular leaf spot, spray the crop with Streptocycline (15-20 g/ha) alternating with copper oxychloride i.e. Blitox (1.5-2.0 kg/ha) from last week of June or beginning of July at 15 days interval.
4. Follow crop rotation atleast for 3 years in areas where root rot is a problem.
5. Adjust sowing date so that the temp. of soil should not be high. Sowing of mung bean/ *moth* in alternating rows of cotton is helpful in checking the root rot.
6. Destroy the plant disease debris after harvest of the crop and give one deep ploughing in the month of June- July which will reduce the root rot inoculum.
7. Application of FYM increases the growth of antagonistic organism.
8. Desi cotton (*Gossypium arboreum)* have high degree of resistance to leaf curl.
9. Rouge out the leaf curl infected plants in the initial stage to prevent secondary spread of the disease.
10. Timely spraying of Ethion 50 EC@ 1.2 litre/ha or other systemic insecticide to control the white fly as vector to control the spread of leaf curl virus.
11. Spray the crop with Dithane M-45 @ 0.2% for the control of leaf spot diseases.

Insect management

Termites: At the seedling stage termites cut the plants from the ground level. The first sign of attack in the young plants is wilting/drying followed by the death of the plant. The infested plants can be easily pulled out and usually containing the termites on them. For control, don't use green manure or raw farm yard manure as these encourage the termite infestation. Remove the stubbles of the previous crop from the field which attract the termites. Use chloripyriphos @ 5 liter per hactare in the standing crop along with irrigation. Seed treatment with chlorpyriphos @10 ml chlorpyriphos+10 ml water per kg seed. After the seed treatment, dry it in shade for 30 minutes

Leaf Hopper (*Amrasca biguttula):* It remains active during July-August and increases with the intermittent rainfall. Both nymphs and adults cause damage by sucking the cell sap. The attacked leaves turn pale and then rusted red and leaves may turn to cup shape (down side) and dry up. For control spray the crop with 750 ml dimethoate (Rogor) 30 EC or 900 ml oxydemeton-methyl (Metasystox) 25 EC or formothion (Anthio) 25 EC or 100 ml

imidacloprid (Confidor) 200 SL or 100 g thiomethoxm (Aktara) 25 WG in 300-350 liter of water per hectare

Cotton White Fly (*Bemisia tabaci):* The insect damage during August- September in cotton and more population has been noticed in dry weather conditions. Damage is done by sucking the cell sap from the leaves resulting the loss of vitality of the plant. Cotton white fly also transmit the cotton leaf curl virus and the veins of diseased leaves got thickened and later on leaves becomes cup shaped (upside) and another leaf is emerged from the leaf. Control same as leaf hopper.

Spotted bollworm (*Earias insulana):* In the vegetative stage larval bore into the growing shoots and the affected shoots droop down. Later on, during the reproductive stage, larvae borer in to the flower buds, flowers and green bolls consequently shedding of the fruiting bodies takes place. The attacked bolls are tunneled and blocked with excreta. The infested bolls open prematurely and the lint is spoiled resulting in lower market value. For control destroy the alternative host plants mentioned under host range as these serves food source and also pests complete the life cycle in the absence of cotton crop and re infest the cotton in the ensuing crop season. Avoid the intercropping of okra with cotton, as the insect pests of cotton and okra are similar thus the okra crop serves the source of infestation. Avoid taking the ratoon crop because the insect-pests build up on rattoon crop a bit early and later on migrate to main crop (cotton). If there is infestation by spotted bollworm at vegetative stage, go for de topping of the infested growing vegetative shoots to manage the buildup of the pest population. For the control of spotted bollworm spray 2.5 litrer neem (Achook/Nimbecidin) or 1.5 litre carbaryl (Sevin/Carbavin/Hexavin) 50WP or fenitrothion (Folithion//Sumithion/Ekathion) 50EC or quinalphos (Ekalax) 25EC or lindane (Kanodane) 20EC or profenophos (Curacron) 50EC in 350-400 liter of water per hactare.

Pink bollworm (*Pectinophora gossypiella):* Larval stage damages the buds, flower and bolls. Soon after emergence, the larvae enter the flower buds, flowers and the bolls. Entry hole is closed down and larvae continue its feeding inside the bolls. The attacked bolls fall off prematurely. for management, remove previous year's refuge of cotton crop. Destroy the off-season cotton sprouts; alternative host plants and burn the plant debris from cotton fields to minimize incidence of insect pest. Deep ploughing of the fields in the end of February is also helpful in reducing the carryover of the pest. Spray the crop with insecticides suggested for the control of spotted bollworms.

American Bollworm (*Helicoverpa armigera)*: The newly hatched larva initiates feeding on the buds, squares, flowers and bolls of the cotton crop. The larvae make a circular hole on the fruiting bodies and as the larvae grow up half of the larval body remain outside and release the fical material outside. Fully damaged fruiting body shed down. During early season the larvae may also be noticed feeding on the succulent leaves. For management, destroy the weeds, which serves as the alternative host for the cotton bollworm. Encourage intercropping of cotton with bajra so that natural enemies of American bollworm may build up on intercrop which finally may take care of the pest. Deep summer ploughing to expose pupae to sunlight so that these may be killed due to desiccation as well as may be picked up the birds. Use recommended dose of fertilizers as the excessive use of nitrogenous fertilizer encourages the pest infestation. Spray 2.5-3.0 litre chloripyriphos 20 EC or quinalphos25EC or carbaryl 50WP or 1.5-2.0 litre ml triazophos in 500-600 liter of water per hactare.

Cotton semi-looper (*Anomis flava):* Young semi-looper feeds on leaves making small holes while grown up larvae feed on leaf lamina. Spraying of insecticides for spotted bollworm will also control the semi-looprers.

Aphid (*Aphis gossypii):* Adults are pale green while nymphs are of green color. Nymphs and adults of aphid cause damage by sucking the cell sap from twigs and leaves. Aphids also secrete the honeydew, which covers the dorsal surface of the leaves and on the leaves. Management practices under taken for sap-sucking pests would also take care of this pest also.

Cotton Grey Weevil (*Myllocerus undecimpustulatus):* Weevils are of grey Colour while grubs are white and legless. The pest remains active in cotton eco-system from April to October-November. The grubs feed on the roots while the adults feed on leaves, buds and flowers. Nibbling of the leaves, flowers and buds take place from the margins. Management practices applied for other cotton pests will also take care of this pest.

Causes of low yield of lint in India

The national average productivity of cotton lint in India is about 123 kg/ha although, the highest productivity of lint 230 kg/ha in the country has been obtained from NW PZ *i.e.,* states of U.P., Punjab, Haryana and Rajasthan. The reason for such lower productivity is

(i) Lack of ideotypes.

(ii) About 80% of the area under cotton is rainfed.

(iii) The fertilizer consumption and fertilizer use efficiency of cotton is very low due to lack of irrigation resources.

(iv) G. arboreum and G. herbaceum are known for their lower yields, longer duration and poor ginning qualities.

(v) The undesirable plant characters like bushy and spreading growth habits require wider spacing which results into less plant population per hectare.

(vi) Poor harvest index i.e. production of most of monopodial (vegetative branches) and lesser of fruiting branches.

(vii) Susceptibility of old plant types to numerous insect/pest and diseases.

(viii) Higher percentage of boll shedding due to formation of more abscisic acid (ABA) during square and boll formation stage.

(ix) Bad boll opening due to improper nutrition i.e. insufficient nitrogen and Ca supply during early plant growth period followed by deficient potash content during flowering stage.

(x) Excessive moisture or drought during square formation or during flowering results into higher boll shedding and poor yields.

(xi) Excessive nitrogen without an appropriate quantities of P and K causes heavy boll formation and high boll shedding.

Factors affecting the quality of cotton

1. **Genetic factors**: It is very distinct that the staple length, ginning %, fibre fineness etc. vary greatly with different cotton spp. It is further observed that most of the quality factors are superior in the fibres received from the flanks or the basal region (Chalazal end) to those fibres received from the apical region (micropylar end) of the same plant. It is also observed that a higher number of fibres/seed, higher ginning % and higher weight of individual fibres are obtained from lighter seeds of the cotton.
2. **Locality and season:** The quality of the same variety differs considerably when it is grown in different cotton growing regions. The growing season also has its impact on the quality characters of cotton *viz.* cotton grown during summer in South India gives longer, finer and more mature fibres than those which are obtained from the winter crop of the same area. These differences were probably due to higher atmospheric temperature and greater solar radiation in the former than in the latter case.
3. **Fertilizer:** The opinions differ about the impact of the fertilizers on the quality of fibre. According to some scientists there is no significant correlation between fibre quality and rate and source of fertilizer nutrient supply. But according to another group it is observed that the soil rich in organic matter content or when supplied with organic manures

produces better quality cotton fibres than the soil which is supplied with only inorganic fertilizers and organic matter is kept lower.

4. **Water management:** From the experimental findings it has been concluded that high humidity or water logging is always harmful to the cotton quality. But at the same time drought is responsible for immaturity, decrease in staple length and increase in roughness of the fibre. It is noticed that heavy rains before flowering result in shorter staples than rains after flowering which result in shorter staples whereas rains during boll formation stage help in increasing the fibre length.
5. **Picking:** The cotton picked earlier (in beginning) is of superior quality than the cotton picked up at later stages which is accounted for the age of plants and attack of insect/pest in the cotton crop. Apart from this presence of foreign materials such as leaves, stem, diseased or damaged cotton in the lot reduces the quality.
6. **Plant protection measures**: Presence of weeds, insect/pests and attack of diseases naturally lower down the quality. Hence the crop given a proper care and protection will always produce better quality cotton than those which are grown in neglected conditions.
7. **Type of seed used:** A seed keeps its genetic purity upto 3 years and from 4th year of its multiplication the degeneration rate becomes faster. Therefore, the type of seed, whether foundation seed (which is supposed to be the best) or certified seed or what type of seed is used for raising the crop is of greater importance for studying the cotton quality.
8. **Storage factors:** The cotton stored in open or under uncontrolled climatic conditions will degenerate very quickly and the quality would be exceptionally poorer than that stored under better conditions.
9. **The moisture regulations and cotton quality:** The fibres swell up by absorbing moisture when it passes through dry to wet state and they get elongated by 1.2 % longitudinally and by about 14% laterally. The extent of swelling increases with increase in temperature and relative humidity. These fibres shrink when they get dried, thus the moisture content in the atmosphere and store weakens the fibres and the colour, lusture etc. are also impaired. Therefore, a poor moisture regulation in the store is harmful to the quality of cotton.
10. **Other factors:** Such as sowing time, spacing, type of soil, hormonal treatment etc. have also their due share in the effect on the quality but are not of significant importance.

Bt Cotton

Genetically modified (GM) cotton was developed to reduce the heavy reliance on pesticides. The bacterium *Bacillus thuringiensis* (Bt) naturally produces a chemical harmful only to a small fraction of insects, most notably the larvae of moths and butterflies, beetles, and flies, and harmless to other forms of life. The gene coding for Bt toxin has been inserted into cotton, causing cotton to produce this natural insecticide in its tissues. In many regions, the main pests in commercial cotton are lepidopteran larvae, which are killed by the Bt protein in the transgenic cotton they eat. This eliminates the need to use large amounts of broad-spectrum insecticides. Bt cotton is ineffective against many cotton pests, however, such as plant bugs, stink bugs, and aphids; depending on circumstances it may still be desirable to use insecticides against these. The International Service for the Acquisition of Agri-biotech Applications (ISAAA) said that, worldwide, GM cotton was planted on an area of 16 million hectares in 2009. This was 49% of the worldwide total area planted in cotton. The U.S. cotton crop was 93% GM in 2010 and the Chinese cotton crop was 68% GM in 2009. Cotton has mainly been genetically modified for resistance to glyphosate (marketed as Roundup in North America) a broad-spectrum herbicide sold by Monsanto, the same company that sells some of the Bt cotton seeds to farmers. There are now a number of different cotton seed companies selling GE cotton around the world. GM cotton acreage in India continues to grow at a rapid rate, increasing from 50,000 hectares in 2002 to 8.4 million hectares in 2009. The total cotton area in India was 9.6 million hectares (the largest in the world or, about 35% of world cotton area), so GM cotton was grown on 87% of the cotton area in 2009. This makes India the country with the largest area of GM cotton in the world.

Chapter 18
JUTE *(Corchorus* sp.) 2n=14

Jute is cultivated for its bast (stem) fibre obtained from 2 cultivated species of *Corchorus capsularis* and *C. olitorius*. The fibre has great utility in both domestic and industrial uses. It is used for making various types of ropes, rugs, carpets, mats, coarse woolen fabric (druggets), cloth (hessians) and sacks to store foodgrains. It is also used in making coarse canvas for wrappings, wall covers; its blend gives good blanket and clothing. Of the various trade goods, sacking constitutes the major utility followed by hessians. *C. olitorius* and *C. capsularis* contribute to 78 and 10% of the total fibre sources of the country. The sticks are used as fuel and lighting material, and for making gun powder and charcoal. In paper industry, these are used as raw material for coarse paper and resin cloth. Resin bonded and pressed jute sticks make durable hard boards. The genus *Corchorus* has 2 cultivated species. *C. olitorius* L. is widely cultivated, and has originated from Africa (primary center of origin) with India or Indo-Myanmar region as its secondary center of origin. This species has been reported from Africa, Asia and Northern Australia. The other cultivated species *C. capsularis* is found in Indo-Myanmar and South China region, but not in Africa and Australia. It has originated from Indo- Myanmar region including South China. In India, nine species of *Corchorus* (7 wild and 2 cultivated) have been reported so far. *C. capsularis* is commonly distributed in north-eastern parts of India, and gradually becomes scarce towards west, whereas *C. olitorius* is more common in western and north-western India.

Geographic distribution

Jute is mainly cultivated in India and Bangladesh, Besides, these two countries it is also grown to some extent in China, Myanmar, and Nepal (Table 1)

Table 1. Area, production and productivity of Jute in major producing countries (2004)

Country	Area (m ha)	Production (m t)	Productivity (t/ha)
Bangladesh	0.437	0.800	1.831
China	0.036	0.068	1.889
India	0.820	1.900	2.317
Myanmar	0.030	0.026	0.867
Nepal	0.011	0.016	1.433

Source: FAO Production Year Book, 2004

In India, the most important jute producing state is West Bengal, contributing more than 75% of India's total production of 1.69 million tonnes (Table 2). Other states are Assam, Andhra Pradesh and Bihar

Table 2. Area, production and productivity of jute in important states of India (2004-05)

	Area (000 ha)	Production (000 bales)*	Productivity (kg/ha)
Andhra Pradesh	58.0	410.4	1274
Assam	134.5	1056.2	1414
Jharkhand	0.1	1.1	1980
Orissa	5.0	41.0	1476
West Bengal	569.0	7853.0	2484
India	773.9	9399.3	2186
		(1.69 mt)	

*Bale: 180 kg ***Source:*** *Fertilizer association of India, 2006*

Classification

Genus *Corchorus* has 2 species viz. *olitorius* (It is raised on well drained high lands only), and *capsularis* (It is more popular and widely grown). The plant has tap root system with numerous lateral branches. It is hardy in nature and can grow well both on high and low lands and is able to tolerate waterlogging conditions to some extent).Jute growing areas in India may be divided into the following 8 agro-climatic zones.

1. *Lower Bengal* (The Ganga Riverine Tract): This is primarily *C.olitorius* raising tract with JRO 632 as a standard variety. This tract includes 24 Pargana, Hoogly, Nadia and Murshidabad districts.
2. *Malda, Dinajpur*: Both species of jute (*C. olitorius* and *C. capsularis*) are raised in this tract comprising Malda and West Dinajpur districts.
3. *North Bengal and Brahamputra Valley New Alluvium*: This tract is spread into Cooch-Behar and Jalpaiguri districts of West Bengal, and Golpara, Kamrup, Nowgoan districts of Assam. This is mainly *C. capsularis* raising tract with JRC 321 in low lying areas, and JRC 212 in rest of the areas. On uplands, *C. olitorius* variety JRO 632 is also raised.
4. *Tripura, Cachora Area of Old Alluvium*: This tract is very small, but productivity is very high. *C. capsularis* is mainly grown in this tract.
5. *Kosi area – Purnea and Saharsa*: Purnea and Saharsa are important jute raising districts of Bihar. This is a *C. capsularis* raising tract but *C. olitorius* is also raised on a very small area.
6. *Muzaffarpur, Darbhanga area:* This is a *C. capsularis* growing tract.
7. *West Bihar and eastern Uttar Pradesh*: This tract includes Champaran district of Bihar, and Bahraich, Sitapur and Lakhimpur Kheri districts of Uttar Pradesh. This is *C. capsularis* raising tract.

8. *Cuttack-Balasore area*: This tract includes Cuttack, Balasore, Sambalpur and Puri districts of Orissa. This is mainly *C. capsularis* raising tract, but *C. olitorius* is also cultivated under upland conditions.

Botanical Description

Jute is a herbaceous annual plant. Although both the species of jute (*C. capsularis* and *olitorius*) are alike in general appearance, there are considerable differences between them as given hereunder.

Character	C. capsularis	C. olitorius
Stem	Conical, base diameter tapering sharply towards apex. Pigmentation varies from green to dark red with various intermediate shades. Periderm develops prominently at base. Technical height is more. Stem is branched or unbranched.	Cylindrical, base diameter tapering Gradually towards apex. Pigmentation is green or light red or deep red. Shades of colour are fewer. Periderm is abscent. Technical height is less than capsularis. Stem is branched usually.
Leaves	Leaves are dull. Tastes bitter owing to presence of glucoside corchorin, hence called *tita pat*. Leaves are lanceolate, oblong with coarsely toothed margin. Lower most pair of serrations enlarged and end in filiform appendanges.	Leaves with shining upper surface and rough under surface. Tasteless or slightly sweet, hence called *mitha pat*. Leaves are elliptic to ovate with smoothly serrated margin. Lower most pair of serrations enlarged and end in filiform appendages that are long and prominent.
Flowers	Small with 5 yellow-pale yellow sepals. Ovary is round; anthers have 20-30 stamens.	Larger (2-5 times that of *capsularis*) with 5-6 coloured or green sepals, ovary is elongated; anthers have 30-60 stamens.
Pods	Rounded, 1-5 cm diameter with flat tops, wrinkled with green, yellowish to copper coloured and 5 locular. The fruits are internally divided by 5 septa and dehisce into 5 segments	Cylindrical-long (6-10 cm long 0.3-0.8 cm diameter) green capsule with 5-6 locules.
Seeds	Copper coloured, 2-3 mm long with 7-10 seeds in 2 rows in each locule with transverse partition between seeds. Contains 35-50 seeds/pod with a test weight of about 2 g.	Bluish green to steel grey coloured with 25-40 small seeds/row with transverse partition between each seed. It contains 125-200 seeds/pod with a test weight of about 3.33 g.
Fibre	Ordinarily whitish, hence called white jute for trade purposes. The fibre layers are more (10-24) with more fibre bundle/cross section (2573)	Frequently finer, stronger and more lustrous than capsularis with yellowish or greyish fibre (tossa jute). The fibre layers are less (8-19) with less fibre bundles/cross section (2181).
Roots	Less deeper, having more lateral roots and is tolerant to water logging. Root:shoot ratio is less (1:7)	Deeper with less number of lateral roots and less tolerant to water logging. Root:shoot ratio is more (1:12).

Climate

Jute is a crop of humid tropical climates. It thrives well in areas with well distributed rainfall of 2,500 mm spread over vegetative growth period of the crop with no cloudiness. Locations

with a mean rainfall of <1,000 mm, incessant rainfall and waterlogging are not suitable for its cultivation. For better growth, a mean maximum and minimum temperature of 34°C and 15°C and a mean relative humidity of 65% is required. Temperatures below 15°C and above 43°C during growth are not suitable for jute crop. *C. olitorius* can not withstand waterlogging, however, *C. capsularis* can withstand water logging, but its fibre quality is impaired with prolonged water stagnation. At a temperature below 10°C no germination occurs in both the species. *C. capsularis* can withstand higher temperature at germination (up to 32°C), while *C. olitorius* is sensitive to such high temperatures.

Soil and its preparation

Jute can be raised on all kinds of soils from clay to sandy loam, but loamy alluvial are best suited. Laterite and gravel soils are not suitable for this crop. The new grey alluvial soils of good depth, receiving silt from the annual floods are the best for jute cultivation. A soil pH of 5.0-7.4 is within the tolerable limit of soil reaction. Soils with acidic pH (<4.5), effective soil depth <50 cm, electrical conductivity >2 dS/m and exchangeable sodium percentage >15 are not suitable for the crop. The crop is raised successfully on old alluvial soils of Bihar, mild acidic soils of Assam, Orissa, and light alkaline soils of *tarai* districts of Uttarakhand. It has been observed that clay loam for *C. capsularis* and sandy loam for *C. olitorius* are most suitable soil types. Jute seeds being small require very fine tilth. The land can be prepared by ploughing and cross-harrowing 3-5 times followed by planking. In acidic soils (pH <6.0), incorporation of 1-1.5 t/ha of lime, 30-40 days before sowing is necessary for better crop performance. Soil moisture between 21-45% is considered ideal for proper germination.

Sowing

Time of sowing

C. capsularis sowing starts from late February, whereas that of *C. olitorius* in early April and continues up to mid June. In Bihar and Uttar Pradesh, sowing is done up to mid July as per the onset of monsoon. In lowlands, February sowing is ideal, as it helps in avoiding waterlogging in early crop growth phases. In mid-lands and uplands, March-April sowing is preferred. For *capsularis*, March-April and for *olitorius* April-May is the optimum sowing time.

Method of sowing

Broadcast sowing is the most common method. Owing to the small size of seeds, small quantity of seed is required. To ensure even distribution of seed, they are mixed with 3-4

times well powdered soil and broadcast cross-wise. Immediately after sowing, the soil is harrowed and planked for covering the seeds. In broadcast crop, weeding is difficult and cumbersome owing to uneven distribution of plants. Hence line sowing behind a plough or using seed drill are preferred for ease of interculture.

Seed rate and spacing

Seed rate varies with method of sowing and species to be grown. For broadcast sowing, 6 and 10 kg seed/ha of *olitorius* and *capsularis* are required. Line sowing needs 4 and 6 kg seed/ha only.

The seeds are sown in row 20 cm (*olitorius*) and 30 cm (*capsularis*) apart. The plants within the row should be thinned manually at 2 stages. First thinning is done 20 days after sowing (DAS), when the plants are of 5 -10 cm. At this stage, plants are thinned to a distance of 5 cm. In second and final thinning 35 DAS, when plants are 12-15 cm height, and are thinned to a distance of 10 cm. Thus the optimum population varies from 3.33 (*capsularis*) to 5.0 lakh/ha (*olitorius*).

Varieties

The important varieties of jute for different states are given below.

State	Recommended varieties	
	Corchorus olitorius	Corchorus capsularis
Assam	JRO 524 (Navin), JRO 632 (Baisakhi tossa), JRO 7835 (Vasudev), JRO 66, JRO 8432, JRO 128 (Surya), JRO 878, JRO 36E, S 19, Subala	JRC 212 (Sabuj sona), JRC 321 (Sonali), JRC 7447 (Shyamali), UPC 94 (Reshma), Hybrid C (Padma), JRC 1108, Bidhan Pat 3 (D-110), Bidhan Pat 1, Bidhan Pat 2, Fanduk, D-154, UPC 7716, C-80, CIN 178, CO 234
Bihar	JRO 524, JRO 7835, JRO 66, JRO 8432, JRO 128 (Surya), JRO 632, JRO 878, JRO 36E, S 19, Subala	JRC 212, JRC 321, JRC 7447, KTC 1 (Rajendra Sada Pat), UPC 94, JRC 698, Bidhan Pat 3 (D-110), Bidhan Pat 1, Bidhan Pat 2, Fanduk, D-154, C 80, CIN 178, CO 234
Orissa	JRO 524, JRO 632, JRO 878 (Chaitali tossa), JRO 7835, TJ 40 (Mahadev), KOM 62 (Rebati), JRO 878, KOM 9	JRC 212, JRC 7447, UPC 94, JRC 4444 (Baldev), KC 1 (Jaydev), JRC 1108, Bidhan Pat 1, Fanduk, JRC 321
Uttar Pradesh	JRO 524, JRO 3690 (Sabitri), JRO 66, JRO 8432, JRO 128 (Surya), JRO 632, JRO 878, JRO 7835, JRO 36E, S 19, Subala, Co 234	JRC 212, JRC 321, JRC 7447, UPC 94, JRC 1108, Bidhan Pat 3 (D-110), Bidhan Pat 1, Bidhan Pat 2, Fanduk, D-154, C 80, CIN 178, Co 234
West Bengal	JRO 632, JRO 3690, JRO 524, JRO 7835, JRO 878, JRO 66, JRO 8432, JRO 128 (Surya), S 19, Subala	JRC 212, JRC 321, JRC 7447, UPC 94, JRC 1108, Padma (Hybrid C), JRC 698, Bidhan Pat 3 (D-110), Bidhan Pat 1, Bidhan Pat 2, Fanduk, D-154, C-80, CIN 178, Co 234

Manures and Fertilizers

In general, the nutrient requirement of *capsularis* is more than that of *olitorius*. In soils with low organic carbon content, FYM application @ 5-10 t/ha, a month prior to crop sowing is recommended. The leaf fall from the standing crop and also root stubbles left in the soil after harvest results in recycling of handsome amount of nutrients besides organic matter in intensive cropping systems. The recommended doses of fertilizers are 20 to 60 – 20 to 30 –

20 to 50 (*olitorius*) and 40 to 80 – 40 to 50 – 60 to 80 (*capsularis*) kg/ha of N-P_2O_5-K_2O respectively. In heavy soils with low to moderate rainfall, all nutrients are applied as basal. In light soils and high rainfall situations, N is applied in 2 equal splits, ½ basal and ½ top dressing, i.e. preferably after weeding and thinning operations. Seed inoculation with *Azotobacter chroococum* and *Azospirillum brasilense* has been found promising to supplement part of N fertilizer. Foliar application of 20 kg N through urea solution with teepol as sticker at pre-flowering stage is promising. In acidic soils, P gets fixed; hence, their placement is better. K is usually applied as basal, but in leaching prone soils, split application is ideal. In acid soils and regions with high rainfall, calcium and magnesium deficiency is common. Liming of soil @ 2-5 t/ha, once in 4 years or Dolomite application (40 kg MgO) is found promising as it supplies both calcium and magnesium.

Water management

Jute is sensitive to both drought and waterlogging. The crop sown during the months of February-April requires irrigation till the onset of monsoon. At germination and knee-high stages, adequate soil moisture must be ensured by irrigation. In general, after pre-sowing irrigation, monthly irrigation till onset of monsoon may be necessary. During rainy season, the crop experiences water logging that adversely affect fibre quality. Provision of quick drainage in uplands will be beneficial to the crop. However, in lowlands, it may not be feasible.

Weed management

The crop suffers from heavy weed infestation in the initial 6 -8 weeks after sowing. Two-three hand weedings or mechanical hoeings are required to arrest weed menace. The first 2 manual weedings are combined with thinning operations at 20 and 35 DAS. The third weeding should be done 55-60 DAS. Due to continuous rains, sometimes manual weeding may not be possible. In such a situation, herbicide integrated with manual weeding is promising. Fluchloralin (pre-plant incorporation, 3-7 days before sowing) or pendimethalin (pre-emergence, 1-2 days after sowing) @ 0.75- 1.0 kg/ha combined with one hand weeding at 35DAS may effectively control the weeds. Recommended post-emergence herbicides for weed control include MSMA (mono sodium methane arsenate) @ 4-5 kg/ha and dalapon @ 6 kg/ha. They should be applied 20 days after sowing.

Cropping Systems

Jute can be intercropped with greengram and groundnut. Greengram is sown in lines 40 cm apart. After 1 month 2 rows jute variety JRO 878 or JRO 7835 are sown in between

greengram rows. Groundnut is sown in 60 cm rows in mid January (in eastern India only) and 2 rows of jute 'JRO 878' or 'JRO 7835' are sown in between groundnut rows in the end of March. In seed crop of jute , intercropping of urdbean is promising.

The following crop rotations are adopted in jute-growing areas.

Irrigated areas

Jute + greengram-paddy-potato	Jute-paddy-potato
Jute-paddy-gram	Jute-paddy-wheat
Jute-paddy-mustard	Jute-paddy-barley
Cowpea-jute-potato	Jute-paddy-berseem
Rainfed areas	
Jute-paddy-pulses	Jute-gram
Jute-paddy-mustard	Jute-mustard
Jute-paddy	Jute-wheat

Harvesting

Harvesting of the crop at pre-bud or bud stage gives best quality fibre; however, the yields are low. Hence, as a compromise between quality and quantity, early pod formation stage has been found best for harvesting. Harvesting is done by cutting the plants at or close to the ground level with sharp sickles. In flooded lands, the plants are uprooted. The harvested plants are left in the field for 2-3 days for the leaves to shed. Next, the plants are tied into bundles 20-25 cm of diameter and the branching tops are lipped off to rot in the field.

Retting of jute

Retting is an aerobic and anaerobic microbiological process by which the fibres in the bark get loosened and separated from the woody stalk. There are 2 processes of retting of jute. The bundles are kept in 30 cm deep water, and later placed side by side in retting water, usually in 2-3 layers and tied together. They are covered with water-hyacinth or any other weed that does not release tannin and iron. The float is then weighed down with seasoned logs or with concrete blocks or are kept emerged (at least 10 cm below the surface of water) with bamboo-crating. Clods of earth used as a covering material or as weighing agent produce dark (Shyamla) fibre of low value. Retting is best done in shallow canal with slow running clean water. The optimum temperature is around 34^{o}C. If fibre comes out easily from the wood on pressure from the thumb and fingers, retting is considered complete

Extraction of fibre

The fibre, extracted separately from each reed (stem) with fingers is sleek, clean and free from entanglement. By the beat- break-jerk method, 10-12 reeds are taken at a time, their

stiffer root- ends are beaten with a mallet to loosen the fibre. The bundle is then broken in the middle and the fibre is loosened. By gripping this loosened fibre in the middle, the broken bundle is jerked in water so that the sticks slip off. The fibre is then washed in clean water, rung and eventually spread to dry, preferably in shade or mild sun. The second method often leaves the broken sticks and make fibre somewhat entangled resulting in sticky fibre. The extraction of fibre from the green stem with a machine followed by a short period retting has also proved to be successful.

Yield

The national average is 1.3 tonnes of fibre/ha. However, with improved package of practices, it is possible to get 2.0-2.5 tonnes of fibre yield/ha from improved varieties. If the seed is produced, it may yield about 0.4-0.5 tonnes in case of white jute and 0.25-0.30 tonnes/ha in case of *tossa* jute.

100 yards of hessian	= 54 lbs of raw jute
4148 yards of hessian	= 1 tonne raw jute (5.55 bales raw jute)
1 tonne of sacking	= 1.11 tonne of raw jute (6.17 bales of raw jute)
1 tonne of hessian, sacking etc.	=1.05 tonnes raw jute (5.85 bales of raw jute).

Chapter 19
SUNHEMP *(Crotolaria juncea L.)*

Description: Sunhemp is a short-daygenerally 1 to 4 m in height plant. Stems up to 2 cm in diameter, cylindrical and ribbed. Leaves simple, spirally arranged along the stem; petiole up to 0.5 cm. Strong taproot, well developed lateral roots. Much branched and lobed nodules, up to 2.5 cm in length. Flowering is indeterminate. Seeds heart-shaped, with narrow end strongly in-curved, up to 6 mm long, dark brown to black. Due to cultivar and environment, seed weight is highly variable, ranging from 18,000 to 35,000 per kg (Chee and Chen 1992).

Use: It is a fibre as well as green manure crop and a minor fodder crop. Sun hemp is extensively cultivated for fibre or green manure and leaves are fed as a high protein supplement to other poorer feeds. In Sri Lanka dried leaves, bark and boiled seeds are fed to cattle. With restrictions, seed has been used as fodder in the former Soviet Union and southern Africa. It is showing promise as a forage legume for intercropping with upland rice. Leaves and stems are dried since animals do not eat sunhemp when it is green. Sun hemp should be cut for hay or ploughed in for green manure in the early flowering stage when it is 1.5-2.5 months old. Due to the shade of its dense canopy it is also used as a cover crop to suppress weed populations. The presence of pyrrolizidine alkaloids is typical of the genus *Crotalaria*. Nitrogen concentrations of about 3% in hay and 5-10% in seeds have been reported from the former Soviet Union, but normally they are lower. Seeds may contain about 40% starch while stems contain about 40% fibre. There are about 33 seeds/g (Chee and Chen 1992).

Toxicity: Reddy *et al.* (1999) revealed that, despite its toxicity, sunhemp hay can be safely incorporated at up to 45% level in rations of sheep under an intensive feeding system. Sheep will not suffer any adverse effects if forced to eat dried forage, but will suffer from toxicity if fed large quantities of seed. Sunhemp should not be fed to horses, and the intake of hay by cattle should be restricted to about 10% of their diet.

Origin: *Crotalaria juncea* is generally considered to have originated in India, where it has been cultivated since prehistoric times, but is now widely grown throughout the tropics and subtropics. According to some thought, it is originated from Brazil.

Geographical distribution: Uttar Pradesh having the highest area under sunhemp. Followed by MP, Maharastra, Rajasthan and Orissa.

Climate: Sunhemp is a tropical crop grown during kharif in north India and throughout the year in south India. A minimum of 400 mm rainfall with equal distribution during the crop period is ideal. Sunhemp is drought resistant and is adapted to hot, semi-arid and arid areas, yet can tolerate light frosts. It is not tolerant of salt, nor of sustained waterlogging. It is

photoperiod-sensitive and flowering occurs in response to short days; long daylengths favour vegetative growth and reduce seed-set.

Soil: Sun hemp has a wide range of adaptation to soil types. It grows on poor soils, but growth on such soils is improved by fertilization. For fibre production, light, loamy, well-drained soils are preferred; on low-lying clay soils it makes vigorous growth, but then the fibre is coarser and yields are lower.

Seed rate and spacing: The seed is usually sown by broadcasting @ 25 kg/ha. Row seeding (30 cm) requires a seed rate of 15 kg/ha.

Fertilizers: Generally phosphorus and potassium are applied through fertilizers @ 25 kg/ha as basal.

Growth and development: Sunhemp is fast growing. Seedlings emerge 3 days after sowing, and rapidly produce a thick ground cover that smothers weeds.Extensive cross-pollination occurs in sunhemp and self-pollination takes place after the stigmatic surface has been insect or mechanically stimulated.

Diseases and pest: Sunhemp is attacked by many diseases and pests, including viruses, fungi, insects and nematodes, but they usually cause little economic damage. In India, anthracnose, caused by *Colletotrichumcurvatum*, wilt caused by *Fusariumudam* and caterpillar larvae of the moth *Utetheisapulchella* can be serious. Pod-boring insects can reduce seed production. Beetles of the genus *Exora* can sometimes cause serious defoliation. Damage from insects is more severe if crops are planted in the same area for more than 3 consecutive years. Fungicide seed treatments and crop rotations are the most recommended and practiced disease control measures.

Harvesting: Pod formation stage (120-140 DAS) is considered optimum stage of harvest for fibre. The plants are cut with sickles and bundles are retained in the field for 2-3 days for the leaves to be shed. The process of retting and extraction of fibres are similar to jute. Fibre yield is around 400 kg/ha. However, a well managed crop can yield upto 1500 kg/ha.

The fibre is dull, yellow, somewhat coarse, strong and durable. Due to high cellulose content, low lignin, the fibre is used in the manufacturing of tissue paper and paper currency. In rural areas, it is used for making ropes, and nets. Sunhemp fibre is not used for textile purpose unlike Jute.

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