CROP PRODUCTION TECHNOLOGY-II (RABI CROPS)

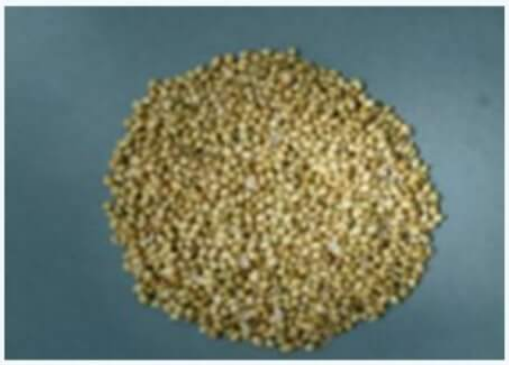
RABI CROPS

Wheat

Gram

Potato

Mustard



Coriander

Oat

Crop Production Technology-II (Rabi crops)

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SYLLABUS

Theory

Origin, geographical distribution, economic importance, soil and climatic requirements, varieties, cultural practices and yield of *Rabi* crops; cereals –wheat and barley, pulses-chickpea, lentil, peas, oilseeds-rapeseed, mustard and sunflower; sugar crops-sugarcane; Forage crops-berseem, lucerne and oat, Medicinal and aromatic crops-mentha, lemon grass and citronella.

WHEAT

Triticum aestivum L

Wheat is one of the leading food crops of world farming and occupies significant position among the cultivated cereals. Cultivation of wheat has been the symbolic of green revolution that is why some times green revolution is also termed as Wheat revolution. Wheat forms the main source of protein and calories to a large section of the Indian population. The story of green revolution in India are primarily a tale of wheat revolution. No other major crops in India have achieved as high a rate of growth in production as wheat has done. Wheat production has increased significantly from 6.5 million tonnes (1950-51) to more than 90 million tonnes (2014-15). This happened because of the spread of semi-dwarf Mexican wheat varieties along with spectacular increase in complementary dosages of inputs particularly fertilizers and irrigation. India is the second largest producer of wheat next to China in the world. Wheat is the second largest important grain crop after rice and contributed significantly to the food security of the nation.

Economic Importance

In India, wheat is popularly consumed in the form of chapatti, puries, dalia and upama by human beings and wheat straw by cattles. Wheat compares well with other important cereals in its nutritive value. Wheat grains contain more protein (about 12 to 13%) than other cereals. Wheat proteins are of special significance. Besides, their significance in nutrition, they provide characteristic substance known as Gluten, which is very essential for baking breads as it provides the structural frame work for the familiar spongy, cellular texture of bread and other products. Wheat grains is a staple food used to make flour for leavened, flat and steamed breads, biscuits, cookies, cakes breakfast cereals, pasta, noodles and for fermentation to make beer and other alcoholic beverages or bio fuel. The whole wheat can be milled to leave just the endosperm for white flour. The by product of this are bran and germ. The whole grain is a concentrated source of vitamins, minerals and protein, while the refined grain is mostly starch. Wheat protein is easily digested by nearly 99% human population. With a small amount of animal protein or legume protein added, a wheat- based meal is highly nutritious. Much of the carbohydrate fraction of wheat is starch. Wheat starch is an important commercial product of wheat, but second in economic value to wheat gluten. The principal parts of wheat flour are gluten and starch. These an be separated in a kind of home experiment, by mixing flour and water to form a small ball of dough, and kneading, it gently white rinsing it in a bawl of water. The starch falls out of the dough and sinks to the bottom of the bowl, leaving behind a ball of gluten.

Nutritive value of wheat

Much of the carbohydrate fraction of wheat is starch. Wheat starch is an important commercial product of wheat, but second in economic value to wheat gluten. The principal parts of wheat flour are gluten and starch. These can be separated in a kind of home experiment, by mixing flour and water to form a small ball of dough, and kneading it gently while rinsing it in a bowl of water. The starch falls out of the dough and sinks to the bottom of the bowl, leaving behind a ball of gluten.

In wheat, phenolic compounds are mainly found in the form of insoluble bound ferulic acid and be relevant to resistance to wheat fungal diseases. Alkyl resorcinols are phenolic lipids present in high amounts in the bran layer (e.g. pericarp, testa and aleurone layers) of wheat and rye (0.1-0.3 % of dry weight).

Wheat protein is easily digested by nearly 99% of human population (see gluten sensitivity for exception), as is its starch. Wheat also contains a diversity of minerals, vitamins and fats (lipids). With a small amount of animal or legume protein added, a wheat-based meal is highly nutritious.

The most common forms of wheat are white and red wheat. However, other natural forms of wheat exist. For example, in the highlands of Ethiopia grows purple wheat, a tetraploid species of wheat that is rich in anti-oxidants. Other commercially minor but nutritionally promising species of naturally evolved wheat species include black, yellow and blue wheat.

Several screening studies in Europe, South America, Australasia, and the USA suggest that approximately 0.5–1% of these populations may have undetected coeliac disease. Coeliac (also written as celiac) disease is a condition that is caused by an adverse immune system reaction to gliadin, a gluten protein found in wheat (and similar proteins of the tribe Triticeae which includes other species such as barley and rye). Upon exposure to gliadin, the enzyme tissue trans glutaminase modifies the protein, and the immune system cross-reacts with the bowel tissue, causing an inflammatory reaction. That leads to flattening of the lining of the small intestine, which interferes with the absorption of nutrients. The only effective treatment is a lifelong gluten-free diet

Origin and History

Bread made from wheat has, from ancient times, been referred as the staff of life. It continues to be, along with rice ,the most important food grain of te world. According to the well known studies of Vavilov, the north- western portion of the Indian subcontinent together with the contiguous region of Afghanistan was the centre of origin of the bread wheat i.e the most important group of wheat which are cultivated now throughout the world.. Archaeological investigation at Mohenjo-daro has shown that wheat of cultivated species being grown in that region about 5000years ago. In fact , wheat has been grown in India from pre-historic times and there was a time i the early ears of the century when wheat was exported from India. The cultivation of wheat dates back to more than 5000 years back during the era of Indus valley civilization where the original species was *Triticum Sphaerococcum* popularly known as Indian wheat has now disappeared and replaced by present day species- *Triticum aestivum* or the common Bread Wheat, *Triticum durum* or the Macaroni wheat and the *Triticum dicoccum* or the Emmer Wheat. During independence, the country was dependent on wheat import to meet the food demand of the country. Due to the lodging prone low yielding nature of Indian wheat under high fertility conditions, there remained a continuous need for a breakthrough in wheat production. The wheat received under PL 480 agreement continued to be the main base on which the large population of India was dependent. It was finally the dream of Dr. Norman E. Borlaug, the father of green revolution during mid sixties that came true to materialize the spurt of the Green Revolution in the Indo-Gangetic plains by which India became a wheat surplus country from a deficient one. This led

to the achievement of as hunger free world by then as India plays a major role in creating a global status of food security. The production level of Wheat in India had a quantum jump from 6.46 million tonnes from an area of 9.75 million ha in 1950-51 to more than 90 million tones from an area of about 30 million hectares during 2014-15.Currently, India is second largest producer of Wheat in the world after China with about 12%share in total world Wheat production. Now, India is surplus and in a position to export wheat in the International Market and can earn foreign exchange.

History of Wheat Production in India

Landmark varieties of wheat in India and their yielding ability

Variety	Year of release	Yield potential (Q/ha)
S 227	1965	33.7
C 306	1965	36.0
Sonalika	1967	45.5
Kalyan Sona	1970	46.0
WL 711	1975	46.8
UP 262	1977	44.0
WH 147	1977	45.1
HD 2189	1979	45.7
HD 2009	1980	45.8
Lok 1	1981	45.4
HUW 234	1984	35.3
HD 2285	1985	42.5
HD 2329	1985	47.1
UP 2338	1990	51.3
WH 542	1992	61.5
Raj 3765	1995	48.9
PBW 343	1995	63.0
HD 2687	1999	62.9
HD 2733	2001	61.5
GW 322	2002	61.0
DBW 17	2006	64.1

India became second largest wheat producing country during 1997-98, and achieved a record production of 76.4 million tons during 1999-2000. The total production increased to the magnitude of more than six folds from roughly 12.3 million metric tons in 1964-65 to an estimated 76.8 million metric tons in 2007-08. This feat was achieved as a result of a strong research back up that facilitated the development of improved high yielding varieties of wheat resistant to diseases with stable performance. Some of the major landmarks in wheat improvement at global level were the introduction of new dwarf plant type utilizing Norin 10 genes and spring x winter wheat hybridization culminating into recombination breeding leading to the development of 'Veery' germplasm (1B/1R), development and use of long spike buitre gene pool for improving spike length and grain number and finally the development and use of synthetic wheat for improving a number of traits like resistance to

biotic stresses, tolerance to a biotic stresses along with adaptability to varying environments.

Wheat varieties released in India during 1965-2007

The wheat programme since its inception (1965) has released 344 wheat varieties (291 bread, 46 durum, 4 *dicoccum* & 3 triticale) for cultivation under different production conditions in all the six wheat growing zones. The varieties have been released after very strict evaluation for yield advantage, disease resistance and the minimum required quality traits in order to provide the opportunity for varietal diversification to combat the threat of diseases and nutritional disorders.

Wheat & Triticale varieties released in India during 1965-2007

Species	Released by		Total
	CVRC	SVRC	
Bread wheat	199	92	291
Durum wheat	27	19	46
Dicoccum wheat	04	-	04
Triticale	02	01	03
Total	**232**	**112**	**344**

CVRC –Central variety release committee, SVRC – State variety release committee

Crop improvement:

Wheat has been cultivated for several thousand years in India. Wheat grains have been

found in the Mohenjadaro excavations. These have been identified as belonging to *Triticum aestivum*sub-species *sphaerococcum*, characterized by spherical shape and dwarf plant stature. From thedays of Mohenjadaro up to the dawn of India's Independence in 1947, the country developed the capacity to produce about 6 million tonnes of wheat. It was not sufficient to meet the demand, leading to large-scale importation of food grains. In addition to strengthening of research and organization of a national extension service, several measures to stimulate food production including land reforms, irrigation, and fertilizer production were initiated in the fifties. Production of wheat and rice through the High Yielding Varieties Programme (HYVP) in wheat, rice, maize, sorghum (jowar) and pearl millet (bajra).Wheat production rose to nearly17 million tonnes in 1968. After several thousand years, the stagnation in yield was broken in wheat. Since similar productivity improvement was also visible in rice, the phenomenon has been described as "Green Revolution".

Wheat crop has exhibited a robust growth trend since the onset of the Green Revolution in1968. In 2014 our farmers harvested nearly 90 million tonnes of wheat, while the wheat harvest at the time of our Independence was only 6 million tonnes. Much of the increase in wheat production has come from productivity improvement. Had this not occurred, we would have required nearly 74 million ha of area in contrast to the current actual area of about 30.00million ha. It is rightly described as "land saving agriculture", since the pathway of production improvement is higher productivity. "Forest-saving agriculture" may be even m more appropriate term, of forest area. Such phenomenal progress has been possible because of the introduction of mutually reinforcing packages of technology, services and public

policies through the High Yielding Varieties Programme introduced by the Government of India in 1966. Yield improvement in wheat is one of the most exciting adventures in the field of agricultural science not only in our country but in the entire world**.** B.P. Pal initiated the wheat improvement programme at the Indian Agricultural Research Institute (IARI), New Delhi. The emphasis of the programme of IARI was directed to achieve both disease resistance and yield. This ultimately resulted of resistance to stem, stripe and leaf rusts, and NP 824 possessing ability to respond to about 50 kg of nitrogen. In 1954, a research programme was started for developing non-lodging and fertilizer responsive varieties of wheat. With the earlier tall varieties it was difficult to get economic response to the application of mineral fertilizers and adequate irrigation water. Average wheat yields stagnated at less than 1 tonne per ha. This is why the breeding of non-lodging varieties was accorded a high priority during the fifties, when the country had taken to the path of expanding the area under irrigation and manufacturing of mineral fertilizers. Unfortunately, short and stiff straw was always associated with short panicles and fewer grains. The breakthrough came in March, 1961, when a few dwarf spring wheat strains possessing theNorin-10 dwarfing genes, developed by Norman E. Borlaug in Mexico, were grown in the fields of IARI. Their phenotype was most impressive. They had reduced height and long panicles, unlike the earlier hybrids between *T. aestivum* and *T. compactum* and *T.sphaeroccum* and the induced erectoides mutants in which short height was coupled with small panicles. In 1964, a National Demonstration Programme was started in farmers' fields both to verify the results obtained in research plots and to introduce farmers to the new opportunities opened up by semi-dwarf varieties for improving very considerably the productivity of wheat. When small farmers, with the help of scientists, harvested over 5 tonnes of wheat per hectare, its impact on the minds of other farmers was electric. The clamour for seeds began and the area under high yielding varieties of wheat rose from 4 ha in 1963-64 to over 4 million ha in1971-72. This was because of the bold decision taken in 1966 at the instance of C. Subramaniam, the then Minister for Food and Agriculture, to import 18,000tonnes of seed of the Mexican semi-dwarf varieties, Lerma Rojo 64A and Sonora 64.The introduction of Lerma Rojo 64A and Sonora 64 was followed by the release of Kalyan Sona and Sonalika, selected from the advanced generation material received from Mexico. Further, hybridization between Mexican strains and Indian varieties resulted in many high yielding and rust resistant strains in different parts of the country. Mutation breeding for changing the red grain colour of Lerma Rojo 64A and Sonora 64 led to the production of Pusa Lerma and Sharbati Sonora. Crossing the semi-dwarf *T. aestivum* material with*T. durum* varieties produced semi-dwarf *T. durum* varieties like Malavika. In all cases, attention was paid to disease resistance and *chapati* making quality of the grain. Above all, the dwarf wheats would never have expressed their yield potential, without appropriate agronomic practices such as shallow seeding and giving the first irrigation at the crown root initiation stage. Anticipatory research to avoid potential environmental problems was strengthened and a wide variety of high yielding strains possessing resistance or tolerance to the principal disease causing organisms were developed. This underlines the fact that agricultural scientists were fully a live to the need for conducting an action-reaction analysis while introducing new technologies. Such awareness led to intensified efforts in varietal diversification and to the pyramiding of genes for tolerance to biotic and a biotic stresses. This is why wheat

production had continued to show an upward trend during the last 35 years. The Indian wheat varieties Sonalika, WL 711, HD 2009 and HD2172 are also popular in other countries like Bangladesh, Pakistan, Nepal, Bhutan, Afghanistan, Sudan and Syria. In Sudan, wheat var. HD 2172,grown in 90% of the wheat area, has paved the way for self-sufficiency in food grains. The remarkable speed with which the high yielding varieties were identified from the initial Mexican material and later developed within the country was the result of the multi-location testing and inter-disciplinary research organized under the All India Coordinated Wheat Research Project of the Indian Council of Agricultural Research (ICAR).The coordinated wheat project is an outstanding exercise in meaningful, international and interdisciplinary cooperation. We salute B.P. Pal, who initiated both organized wheat breeding and coordinated varietal testing programmes in the country. Breeding efforts alone would not have borne fruit but for the outstanding support given by plant pathologists, agronomists, soil chemists and specialists in other disciplines. In short, the participants in the wheat research programme functioned like members of a symphony orchestra. Such harmony and cooperation led to historically path breaking results. Advances in wheat production also serve as an illustration of the value of fusion between political will and scientific skill. But for the political action taken by C. Subramaniam, scientific results might have just remained in the laboratory

Classification

Wheat belongs to the family Poaceae (Gramineae) and classified based on the chromosome number sets (genome) for each commonly recognised types, viz. Diploids(2n=14), tetraploids(2n= 28) and hexaploid (2n=42), (Linnaeus,1753 first classified wheat&Sakamura1918,reported).

Three species of Wheat namely, (i) *T. aestivum*, (ii*) T. durum* and (iii) **T. dicoccum** are being cultivated in the country, as per details given as under :

Sl. No.	Species	% Share of production	Major growing areas
01	***Triticum aestivum***	95%	Uttar Pradesh, Punjab, Haryana Rajasthan, Bihar, West Bengal, Assam Parts of Madhya Pradesh, Himachal Pradesh, Jammu & Kashmir
02	***Triticum durum***	4 %	Madhya Pradesh, Maharashtra ,Gujarat Southern Rajasthan and few locations in Punjab
03	***Triticum dicoccum***	1 %	Karnataka, Maharashtra & Tamil Nadu

Distinguished characters of *T. aestivum* (Soft Wheat) and *T.durum* (Hard Wheat)

Features	Wheat	
	Soft wheat	**Hard wheat**
Ear	Awned or awnless,cylindrical or spindle	Awned as a rule, Prismatic

Ear compactness	loose,space between spikelets	Dense, no space between spikelets
Awn	Divergent,length equal to ear head or shorter	Parallel,longer than ear head

From the stand point of the growing season two main types of wheat namely the Winter Wheat and the Spring Wheat are generally distinguished. These terms are mostly used in the western countries where the crops is raised in **"winter"** as well as in the "Summer". Varieties with a longer period of growth and with greater requirements of low temperature in the early stages of growth are sown in September-October and they pass the severe winter covered by snow, come in to ear in spring and matured during summer month of June and July. These are **"Winter Wheat".**

"Spring Wheat are characterised by their short growing period, they do not require very low temperature in early stages of their growth and are sown in April or May and harvested in August-September.

In India two features are combined in as much as short-duration varieties with spring type of growth are raised during the Rabi or winter season.

It is only in some hills in South India that where wheat is grown in winter as well as in summer but the area is very small. The duration, the time of wheat sowing and and harvesting vary considerably in India. The longest growing period is in the hills of Northern India,where it is grown or sown in the month of October and harvested in June-July. The plains, the period of growth is the longest in North-Western region becomes shorter towards the North-East and South . The duration of growing season is approximately 180 days in hills of North. The duration of 160 days taken in North-west, 120-140 days in UP, Bihar and western India and 100 days in peninsular India.

In Punjab wheat sowing begins in November and are over by the end of the month. Late sowing may extend up to the end of December. In UP and Bihar sowings are 15 days earlier than in Punjab. In central and western India sowing are completed by the end of October, while in Deccan region sowing is done in September

Botanical description:

Wheat plant can be divided in two different parts viz., root system and Shoot system

Root System:

Primary root system: It forms at the time of seed germination and arises at the depth where seed is planted

Secondary root system: It arises at the point above the primary root system as the principal organ of absorption as the young wheat seedling process to mature.

Shoot system:

It consists of all Plant parts visible above the ground. It is composed of stem, leaves and inflorescence

Stem: The stem of wheat plant is round or cylindrical. Stem and inflorescence may be called a **"culm".**

Leaves: Leaf consists of four parts

Leaf sheath: It is the basal part of leaf. It encircles the culm (stem) and protects the growing point and auxiliary buds from the weather and provides some supports to stem.

Leaf blade: The flattened, parallel portion of the leaf

Ligule: A membranous or cartilaginous fringe at the junction of the sheath and blade on the side of leaf next to culm. The continuation of the sheath through the collar is known as ligule.

Auricle: Lobes of leaf blade which extend downward on each side at the junction of the blade and sheath. These are horn like or claw-like appendages projecting from the collar of the leaf.

Inflorescence: The flowering portion of wheat plant which is called ear or head or spike

Rachis: The central zigzag axis is the rachis. Spikelets are borne on alternate sides of rachis,which gives it zigzag appearance.

Spikelet: Spikelet is composed of flowers called florets. The number of florets in a spikelet may vary from one to five.

Florets: The outer covering of a floret is made up of a lemma and palea. The lemma enfolds the palea near their attachment point. If an awn is present, it is attached to lemma

Kernel: Wheat has a caryopsis type of fruit. The typical wheat kernel is from 3-10mm in length and from 3-5 mm in diameter. The composition of wheat kernel is:

The germ is 2.5%. It is high in proteins and fats.

The bran accounts for 14% of the grain. It is a by-product of milling and is used in dairy and poultry feeds. Small amounts are used in breakfast cereals

The starchy endosperm constitutes about 83 to 84% of the kernel

Wheat production constraints:

- **Delayed sowing due to**
  - (a) Prevalence of long duration rice varieties.
  - (b) High moisture regime in depressed land.
  - (c) Poor farm mechanization.
- Broadcast sowing leading to improper placement of seed and fertilizers resulting in poor plant establishment and crop stand.
- Low seed replacement rate (SRR)
- Imbalanced fertilizer use.
- Lack of adequate irrigation resources.
- Narrow or short winter leading to high initial and terminal heat.
- Poor weed management.
- Low percolation of improved varieties.
- Lack of farm mechanization.

- Poor storage and marketing facilities.
- Socio-economic constraints.
- Fragmentation of land holding
- Poor consolidation of land
- In adequate extension linkage
- Non-replacement of organic sources of nutrient supplementation
- Poor rural marketing facility
- Illiteracy, unawareness and low risk bearing resource poor farmers

Technology for adoption:

- Timely planting
- Planting through zero till seed drill / normal seed drill (Line sowing)
- Seed treatment before sowing
- Balanced use of fertilizer (Organic & In-organic)
- Efficient use of irrigation water through sprinklers and light irrigation
- Frequent irrigation in case of abrupt rise in temperatures
- Replacement of most popular wheat variety PBW 343 with

  HD2733, CBW38, DBW39 and other improved varieties
- Adoption of Resource conservation tillage (RCTs)-Zero tillage, conservation tillage, FIRB(Furrow Irrigated Raised Bed Planting) etc.
- Practice of conservation agriculture (CA) for resource use efficiency
- Adoption of organic package of practices for quality assurance and value addition.

Distribution: The major wheat producing countries in the world are China, India, United States, Russia and France. In India the major wheat growing states are Uttar Pradesh, Punjab, Haryana, Rajasthan and Bihar with a highest productivity in Punjab (about45q/ha), Haryana(44q/ha), UP(31q/ha) and Bihar (27q/ha) with all India average of 30q/ha.

Area and production of wheat:

The Indian Scenario:

Wheat is grown in India in an area of about 30 Million ha. with a production of 95 Million tonnes. The normal National productivity is about 3.1 tonnes/ha. The major Wheat producing States are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, Maharashtra, Gujarat, Karnataka, West Bengal, Uttarakhand, Himachal Pradesh and Jammu & Kashmir. These States contribute about 99.5% of total Wheat production in the country. Remaining States, namely, Jharkhand, Assam, Chhattisgarh, Delhi and other North Eastern States contribute only about 0.5 % of the total Wheat production in the country.

The India's share in world Wheat area is about 12.40%, whereas it occupies 11.77 % share in the total world Wheat production. There is hardly any scope for expansion of area under Wheat. The main emphasis would be on increasing the productivity of Wheat by adopting the improved cultivation practices.

Wheat production statistics in India

Crop Year	Area(mha)	Production(mt)	Yield(kg/ha)
1950-51	9.75	6.46	0.66
1960-61	12.93	11.00	0.88
1970-71	18.25	23.83	1.31
1980-81	22.28	36.31	1.63
1990-91	24.17	55.14	2.28
2000-01	25.73	69.68	2.71
2007-08	27.70	78.56	2.80
2008-09	27.80	80.58	2.90
2012-13	30.00	93.51	31.17
2013-14	30.47	95.86	31.45
2014-15	30.37	90.78	29.89

Status of Wheat production in Bihar

Year	Area(m ha)	Production(mt)	Productivity(q/ha)
2010-11	**22.4**	**52.2**	**23.3**
2011-12	**22.0**	**48.5**	**22.1**
2012-13	**22.2**	**59.4**	**26.8**
2013-14	**22.6**	**62.3**	**27.6**
2014-15	**21.9**	**60.1**	**27.4**

Status of Wheat production in Bihar

The tremendous progress in area, production and productivity of wheat has achieved as compared to 1950 and India became the member of elite group of wheat exporting countries. About 95% of the wheat is produced in six states, viz. Uttar Pradesh, Punjab, Haryana, M.P, Rajasthan and Bihar.

Distribution: Wheat in India is cultivated in almost every state except Kerala, thus representing diverse crop growing conditions and situations. The wheat species grown on commercial basis in India are of spring type but cultivated during winter season. Based on growing conditions/agro climatic conditions and varying agro ecological production conditions, the country is broadly divided in to six wheat growing zones. The growing periods of wheat is variable from one agro climatic zone to another that affect the vegetative and grain filling duration leading to differences in attainable yield. The maximum wheat growing duration is in Northern Hill Zone and minimum in Penisular zone

Wheat growing season and cultural condition: Wheat is cultivated during winter season from mid October to April(except in higher hills of North India where harvesting of wheat is done in the month of May). Wheat is mainly grown under three production conditions, viz. Timely sown irrigated, Late sown irrigated and Timely sown Rain fed. Nearly 89% of the wheat area in the country is irrigated and most of it lies in North India.. Wheat cultivation in top three wheat producing states is supported by more than 95% area under irrigation, whereas Rajasthan and Bihar have more than 90% wheat area under irrigation conditions. The central peninsular and hilly areas of northern and southern regions of Gujarat, Madhya Pradesh, Maharashtra and Karnataka has comparatively lower coverage of area under irrigation and grow mostly rain fed wheat whose success largely depends on residual moisture build up from monsoon, limited availability of water for irrigation and casual winter rains. In recent years, a new situation of timely sown, restricted/limited irrigation has emerged in some of the areas of the central and peninsular parts where water for irrigation is not available in sufficient quantity and thus, the wheat crop is grown with one to two irrigations only.

Indian Wheat Growing Zones:

The entire wheat growing areas of the country has been categorized into 6 major zones as follows:

Sl. No.	Zones	States/regions covered	Approx Area (million ha)
01	Northern Hill Zone (NHZ)	Hilly areas of J&K(except Jammu, Kathua and Samba districts), Himachal Pradesh, Uttarakhand (excluding Tarai region) & Sikkim	0.8
02	North Western Plains Zone (NWPZ)	Punjab, Haryana,WesternUP(except Jhansi Div),Rajasthan (excluding Kota& Udaipur div), Delhi, Tarai region of Uttarakhand, Una & Paonta valley of HP, Jammu, Samba & Kathua districts of J&K and Chandigarh.	11.55
03	North Eastern Plains Zone (NEPZ)	Eastern UP(28 dist),Bihar, Jharkhand,West Bengal, Assam, Odisha and other NE states (except Sikkim)	10.5
04	Central Zone	MP, Gujarat, Chattisgarh, Kota & Udaipur Div of Rajasthan & Jhansi Div of UP.	5.2
05	Peninsular Zone	Maharashtra, Tamil Nadu(except Nilgiris & Palani Hills),Karnataka & Andhra Pradesh	1.6
06	Southern Hill Zone (SHZ)	Nilgiris & Palani Hills of Tamil Nadu	0.1

Important Zones for cultivation in Bihar -

Based on soil characterization rainfall, temperature and terrain four main agro climatic zones in Bihar have been identified these are:-

1. Zone-I : **North alluvial plain-** Consisting of districts viz. Saran, Siwan, Gopalganj, Muzaffarpur,Vaishali, EastChamparan, WestChamparan, Sitamarhi, Sheohar, Darbhanga, Samastipur, Madhubani and Begusarai.

2. Zone-II: **North east alluvial plain -** Consisting of districts viz. Purnia, Kishanganj, Katihar, Araria, Saharsa, Supaul, Madhepura and Khagaria.

3. Zone-III A: South East alluvial plain- Consisting of districts viz. Bhagalpur, Banka, Munger, Sheikhpura, Jamui and Lakhisarai.

4. Zone III B: South West alluvial plain- Consisting of districts viz. Patna, Nalanda, Rohtas,Bhojpur, Buxar, kaimur, Gaya, Nawada, Jahanabad, Arwal and Aurangabad

Varieties: The choice of the correct variety plays significant role in achieving optimum yield. The following considerations are important,while going in for selection of variety

1. Disease resistance
2. Fertilizer responsive
3. Lodging and shattering resistance
4. Desired maturity

The agro climatic conditions, local preferences and wheat based food habits, prevalence of diseases and pests, wheat based cropping systems availability of irrigation and related inputs factors have direct bearing on the types of wheat varieties to be developed for commercial cultivation in the country The Indian wheat improvement programme has significantly contributed to the release of more than 373 wheat varieties through Central variety release committee or state variety release committee for different agro climatic zones along with relevant production technology since inception of All India coordinated wheat and barley improvement programme in 1965. This included 316 bread wheat,49 durum, 05 dicoccum and 03 triticale varieties.

Wheat types	**Production conditions**			
	Normal sown	**Late sown**	**Rainfed**	**Sodic soils/others**
	North Western Plains Zone(NWPZ) Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions),Western UP (Except Jhansi division),Parts of J&K (Jammu and Kathua districts), HP and Uttarakhand (Tarai region)			
Bread wheat	DBW17, PBW550, PBW502 PBW343, WH542, UP2338, HD2687, HD2967	WH1021, PBW373, UP2425, RAJ3077, DBW16, RAJ3765, PBW590	PBW299, PBW175, WH533, PBW396	RAJ3077, KRL-19, KRL210, KRL213
Durum	PBW34, PDW215, PDW233 WH896, PDW291, PDW314			
	North –Eastern Plains Zone(NEPZ) Eastern UP,Bihar, Jharkhand ,Odisha,West Bengal,Assam & plains of NE States			

Bread wheat	CBW38, DBW39, KO307, NW1012, HD2733, HD2824, HD2967, K9107	DBW14, NW1014, HW2045, HD2985, NW2036, HI1563	HDR77, K8962, K9465, K8027, HD2888, MACS6145, C306	RAJ3077, KRL19, KRL210, KRL213
	Central zone(CZ) MP, Chattisgarh, Gujarat, Rajasthan (Kota and Udaipur division) and UP(Jhansi division)			
Bread wheat	GW190, GW273, DL803-3, GW322, GW366, HI1544	GW173, DL788-2, MP4010, HD2932, MP1203, HD2864	HW2004, JWS17, HI1500, HI1531, Sujata	Raj3077, krl-19, krl210, krl 213
Durum	HI8331,HI8498,MPO1215		HD4672, HI8627	
	Penisular zone(PZ) Maharashtra, Karnataka,Andhra Pradesh,Goa,Plains of Tamil Nadu			
Bread wheat	DWR162, MACS2496, GW322, Raj4037, NIAW917, UAS304, MACS6222, Macs6273	DWR195, HD2501, NIAW34, HUW510, HD2932, HI977, HD2833, PBW533, Raj4083, AKAW4627	K9644, HD2781, PBW596, HD2987	
Durum	MACS2846,HI8663,UAS415		AKDW2997	
	Northern Hill Zone(NHZ) **Western Himalayan regions of J&K (EXCEPT Jammu and Kathua distt.) , H.P(except Una and Paonta valley),Uttarakhand(except Tarai region), Sikkim and hills of West Bengal and N.E States**			
Bread wheat	VL738, VL804, HS240, HW5207	HS295,HS420	VL738, HPW42, HS365, VL829, VL832, SKW196,	HS375 (for summer sowing)
Triticale			DT46	
	Southern Hill zone(SHZ) **Hilly areas of Tamil Nadu and Kerala comprising the Nilgiri hills of southern plateau**			
Bread wheat	HUW318, HW1085, HW2044			

Wheat varieties recommended for North-East plain zone(NEPZ) including Bihar

Sowing conditions	Recommended varieties	Time of sowing
Timely sown irrigated conditions	HD2733. K0307,CBW38, DBW39, HD2967, Sabour Samrdhi (BRW3708), HD2824	15TH November to 25th of November
Late sown irrigated conditions	DBW14, HI1563, NW2036, NW1014, HW2045, HD2985, Sabour shreshtha (BRW934)	1st December to 15th of December.
Rain fed conditions	RW3016, HDR77,K8962, K9465, K8027, HD2888, MACS6145, C306, Sabour Nirjal (BRW37230)	Last week of October to 1st Week of November

Eastern UP, Bihar: Under timely sown conditions, varieties like HD 2733, HD 2824, HD2967, PBW 443, and HUW 468 need to be promoted by curtailing UP 262 and HUW 234. Similarly under late sown conditions, varieties like DBW 14, NW 2036, HW 2045, NW 1014, K 8962, HI1563 and HD 2643should be promoted.

Intensify Varietal Spread in NEPZ: In contrast to NWPZ, a large number of genotypes have been notified for the NEPZ but the variety released in 1984 i.e. HUW 234 is still in great demand. The average life of a wheat variety in NEPZ is about 12 years and it is

mainly due to poor seed replacement. The north-eastern region is catching attention in release of new wheat varieties but the seed demand of new varieties is quite low. The developmental agencies will have to play a significant role in popularizing the improved

wheat varieties.

Non-traditional wheat growing areas: Some areas in Jharkhand, Orissa, West Bengal, Tamil Nadu and Andhra Pradesh should be looked into for increase in the wheat acreage. Suitable varieties falling in that zone need to be tested at farmer's field

Major crop sequences/rotations followed in various states and suggested crop sequence by SAUs/ICAR:-

1. Rice-vegetable pea-winter maize,
2. Rice-wheat-green gram,
3. Rrice-vegetable pea-wheat for one year rotation and
4. Pigeon pea -wheat-rice-wheat and rice-mustard- green gram-rice-wheat for two year rotation.
5. Rice-Wheat,
6. Maize-Wheat,
7. Cotton-Wheat,
8. Soybean-Wheat,
9. Groundnut-wheat,
10. Tur-Wheat,

11. Urd-Wheat,

12. Jowar/Bajara-Wheat,

13. Sugarcane -Wheat,

14. Rice-Rice-Wheat,

15. Fallow-Wheat, Toria-Wheat,

Rotation:

It is not desirable to grow wheat year after year on the same piece of land.
The rotations followed in wheat care:

i) Mung/urd/soyabean (kharif) -wheat (rabi)
ii) Paddy/bajri/jowar (kharif) - wheat (rabi)
iii) Groundnut/sesamum (kharif) - wheat (rabi)
iv) On irrigated lands wheat is rotated with cotton, sugarcane and mustard.

Mixed Cropping:

1. Usually 12 different types of crops are sown mixed with wheat.
2. Among these gram, linseed and mustard are very commonly grown mixed with wheat.
3. Mixed cropping in dry cultivation is followed to safe guard the crop stand.
4. Mixed cropping with legume (gram) improves the nitrogen status of the soil.
5. It is done either by mixing wheat seed

Soil and climate:

Soil: Wheat is grown in a variety of soils of India. Soils with a clay loam or loam texture, good structure and moderate water holding capacity are ideal for wheat cultivation. Care should be taken to avoid very porous and excessively drained oils. Soil should be neutral in its reaction. Heavy soil with good drainage is suitable for wheat cultivation under dry conditions. These soils absorb and retain rain water well. Heavy soils with poor structure and poor drainage are not suitable as wheat is sensitive to water logging. Wheat can be successfully grown on lighter soils provided their water and nutrient holding capacity are improved. In India the wheat growing areas can be mainly divided into five soil divisions,

1. The Gangetic alluvium of Uttar Pradesh and Bihar

2. The Indus alluvium of the Punjab and Haryana

3. The black soil regions of central and southern India comprising Madhya Pradesh and parts of Maharashtra and Karnataka

4. The hilly regions of the Himalaya and elsewhere

5. The desert soils of Rajasthan.

Field/ land preparation:

Wheat crop requires a well pulverized but compact seedbed for good and uniform germination. With 3 to 4 ploughings, repeated harrowing, cultivation and planking before sowing to produce firm seedbed are considered desirable for raising a good crop of wheat.

Very timely cultivation to conserve moisture in the soil is essential under rain fed condition. In the black cotton soils, blade harrow *(bhakar)* is used instead of the plough. For field prepration 1 to 3 ploughings with an iron plough may sometimes precede the use of *bhakar.* Pre-sowing irrigation *(palewa* or *rauni)* of field, followed by cultivation and planking to prepare a fine well pulverized seed bed. Recently zero-tillage and minimal tillage sowing practices using a specially designed zero-till seeding-cum-fertilizer drill have been recommended to save the time required to prepare proper seedbed under the rice-wheat rotation, particularly when medium long and long duration varieties of rice (or basmati types are grown and the fields get vacated very late in November and December. Such practices can be followed even for timely sown wheat to reduce expenditure on field preparation. However, these are successful when weeds are not a serious problem or when these are controlled with the use of herbicides.

Land preparation by use of different technologies like RCT: As a general rule wheat crop requires a well pulverized but compact seed-bed for good and uniform germination. In irrigated areas wheat is usually sown after Kharif crops like, maize, Jowar, Bajara, Paddy, Urd, Moong(Green gram) etc.. After the harvest of previous crop, the field should be ploughed with disc or mouldboard plough. Where tractor is available one deep ploughing followed by two or three harrowing with disc or times and 2-3 planking should be given to prepare a well pulverized seed bed. Where bullock are the source of power, deep ploughing followed by two to three harrowing or four to five inter-cross ploughing with local plough should be done. Planking should be done after each ploughing.

Avoid powdery seed bed. One pre-sowing irrigation 7-10 days before seeding is necessary to ensure good germination. In case where previous crop was sugarcane, toria, tur etc., the pre-sowing irrigation for wheat may be given in the previous standing crop so that field may become available for its preparation and sowing, soon after the harvest of the previous crop. One light cultivation and levelling is required before sowing. Delay in sowing because drastic reduction in yield in late sown wheat. In certain areas crops are attacked by white ants and gujhia weevil..

In rain fed areas field preparation should be done with great care as conservation of moisture is dependent on it. Field are usually prepared by giving one deep ploughing with iron plough followed by two or three times local plough and planking. In these areas ploughings should be done in the evening time and furrows should be kept open whole night to absorb some moisture from dew. Planking should be done after each ploughing early in the morning. Planking should be done after each ploughing.

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Climate requirement:

Wheat crop has wide adaptability. It can be grown not only in the tropical and sub-tropical zones, but also in the temperate zone and the cold tracts of the far north , beyond even the 60 degree north altitude . Wheat can tolerate severe cold and snow and resume growth with the setting in of warm weather in spring .It can be cultivated from sea level to as high as 3300 meters.

The best wheat are produced in areas favoured with cool, moist weather during the major portion of the growing period followed by dry, warm weather to enable the grain to ripen properly. The optimum temperature range for ideal germination of wheat seed is 20-25^0 C though the seeds can germinate in the temperature range 3.5 to 35^0 C. Rains just after sowing hamper germination and encourage seedling blight. Areas with a warm and damp climate are not suited for wheat growing. During the heading and flowering stages, excessively high or low temperatures and drought are harmful to wheat. Cloudy weather, with high humidity and low temperatures is conducive for rust attack. Wheat plant requires about 14-15^0 C optimum average temperature at the time of ripening . The temperature conditions at the time of grain filling and development are very crucial for yield. Temperatures above 25^{0}C during this period tend to depress grain weight. When temperatures are high, too much energy lost through the process of transpiration by the plants and the reduced residual energy results in poorer grain formation and lower yields. Wheat is mainly a rabi (winter) season crop in India.

The optimum temperature requirement for wheat at different physiological stages

Growth stages	**Temperature Requirements**
Germination	20to25^{0}C mean daily
Tillering	15-16^{0}C
Accelerated growth	20 to 23^{0}C mean daily
Proper grain filling	23 to 25^{0}C mean daily
Ripening	25-30^{0}C

Seed and Sowing:

Seed: Selection of Seed: Only healthy seeds of right variety suitable for a particular locality should be selected for sowing. There should not be any mixture of seeds of other varieties of weeds. The seed should be purchased from a reliable source. Always use certified seed . If seed is not treated, treat with vitavax/ thiram @ 2.5 g/kg of seed.

Sowing: Different method of sowings: Wheat is sown by four methods:

1. Drilling: In this method seed is sown by seed drill or ferti-seed drill. With the help of this implement seeds drop at uniform depth and results in uniform germination and regular stand. Seed bed should be fine and well leveled free from clods and weeds for the use of seed drill or ferti-seed drill.

2. Behind Local Plough:-This method consists of dropping the seeds by hand into the furrows that have been opened with local plough. When seeds is dropped in furrows by hand, it is called **Kera** method and when it is dropped through a Pora or Nai orHazara a special

attachment with local/desi plough it is called **Pora** method. In this method seeds are dropped at a depth of 5-6 cm and germination is satisfactory.

3. Dibbling: This method is used in case where supply of seed is limited. Sowing is done the help of a small implement known as Dibbler It is a wooden or Iron frame with pegs. The frame is pressed in the field and lifted and then one or two seeds are dropped by hand in each of the hole. It is not a common method because it is a very time consuming process.

4. Broadcast Method: In this method the seeds are broadcast and then worked in by harrowing in order to cover them. However, the seeds are not uniformly distributed in the field. This method of sowing is very insufficient and should not been encouraged. Germination of broadcast seed is relatively poor and the plant stand is often irregular. Wastage of seed also results because most of the seed is left on the surface where they cannot germinate and may, therefore, be picked up and eaten by birds.

Sowing by different Resource conservation technologies (RCT)

1. **Laser land leveling**: This is precursor resource conservation technology that is a must for the proper implementation of other RCT's for greater productivity and profitability. This technology increases productivity, increases area under crop, saves water and other inputs, enhances factor productivity and reduces costs of production.

2. **Surface seeding**: This RCT is specifically suited to single crop *diara* lands of eastern parts of India where soil remains wet after rice harvesting. The technology requires no tillage, broadcast dry or soaked seed under saturated condition, scope in areas where soil remains wet after rice harvesting and doubles the cropping intensity.

3. **Zero tillage**: The main features of the technology are; zero tillage drill is simple and affordable, direct drilling in untilled condition, advances sowing time realizing higher yields, saves more than 90% fuel energy and time, similar yield at lower cost in comparison to timely sown wheat with conventional tillage and better management of herbicide resistant biotypes of *Phalaris minor*

4. **Bed Planting:** The Furrow irrigated raised bed system (FIRBS) accommodate 2-3 rows of wheat on raised bed with 75-90 cm spacing between beds. The furrows in between the beds are used for irrigation purpose. The method helps in saving of water upto 40% without loss of yield.

Time of sowing:

Time of sowing is one of the important aspects in obtaining good yields of wheat. It has a marked influence on the yield of wheat. The time of sowing varies widely over the wheat growing areas. It depends mostly on soil temperature, irrigation,

facilities and duration of wheat varieties. Rain fed wheat generally sown in the 2nd fortnight of October and beginning of November. The normal time for sowing of high yielding dwarf varieties in irrigated areas starts in the beginning of November. Long and medium duration varieties should be sown in the 1st fortnight of November and short duration varieties should be sown in the2nd fortnight of November. If a variety is sown later than its normal time of

sowing there is adverse effect on its yield. Under specific circumstances wheat is sown in the month of December too. In late sown wheat only, short duration varieties should be sown because there is comparatively less reduction in their yields as compared to late and medium duration varieties. When wheat is sown in the month of December there is a drastic reduction in yield(table-1).November onwards delay is sowing by each day causesreduction of 56 kg per ha per day in north eastern parts of the country and 41.6 kg per day per ha in north-western and central parts of the country.

It has been reported that because of extremely high temperature on either ends of the season with narrow temperature growing window that most appropriate time of sowing for maximum yields was found to be 15-25thNovember. Seedling earlier or later than this stipulated period resulted diminution in yield (17-38%) as well as quality of wheat. However, the wheat can be grown till 10th December after which the crop become uneconomical

Seed rate & spacing:

Seed rate varies with variety used depending upon its seed size, germination percentage, tillering ability, time of sowing, moisture content in the soil at the time of sowing and method of sowing. Usually, a seed rate of 100 kg per ha is sufficient under favourable conditions of normal sowing (Timely sown irrigated condition) . For varieties with bold grains and under late sown conditions, seed rate should be increased to 125 kg per ha .In case where wheat is to be sown by dibber, a seed rate of 25-30 kg per ha is sufficient. For normal sown crop a spacing of 20 Cm between rows is recommended. When sowing is delayed a closer spacing of 15-18 Cm should be adopted.

Depth of sowing:- Depth of sowing is a very important aspect in successful cultivation of high yielding dwarf varieties of wheat. The coleoptiles length of high yielding Mexican dwarf varieties is about 5 cm. Therefore, seeds of these varieties should be covered not by more than 5 cm oil to ensure uniform and good germination. Seeds of semi-dwarf (one gene dwarf) varieties could be sown at the depth of 5-6 cm but seeds of three dwarf varieties should not be sown deeper than 4 cm. similarly, in late sown crop, seed should be sown shallow (about 4 cm deep)as deep sowing delays the emergence of seedlings by 2-3 days and heading by 5-6

Some facts regarding Sowing Time, sowing direction, sowing depth

1. The sowing time of wheat depend upon temperature, type of cultivation i.e. dry or irrigated and duration of wheat varieties.
2. In Bihar optimum sowing time is 15 th November to 25th November.
3. Early October sowing when day temperatures are high results in mortality of seedling due to foot rot or root rot disease.
4. While late sowing in last week of November of December give low yield. However the right time of sowing of wheat is early winter when freezing of coconut oil starts.

Sowing Direction:

Basically wheat is a long day crop but in winter day period is short hence sowing direction should be such that would allow maximum interception of sunlight and promote. During

winter direction of sun over India is south-south-east to west-north-west. Therefore, sowing is done in north-east or north-south direction to get higher yield.

Sowing Depth:

1. Wheat seed should be placed in a moist zone for better germination and establishment of seedling.
2. Under rain fed condition when crop taken on residual moisture sowing is done at 8 to 10 cm depth.
3. Under irrigation condition the sowing is done at 3 to 5 cm depth after pre-sowing irrigation.
4. Dwarf Mexican wheat varieties have a very short coleoptiles and hence sown only up to 5 cm depth.

Growth stages of wheat:

Pre-establishment stage:

a. **Pre-emergence** (up to 5DAS): Sprouting of seeds by giving rise to seminal roots and coleoptiles
b. **Emergence (**6 DAS): Appearance of coleoptiles from germinating seeds above the surface

Vegetative stage:

a. Seedling (up to 30 DAS): The young plants establish larger root system in this stage. This stage may be further differentiated as one leaf, two leaves, three leaves and four leaf stages
b. Crown root initiation (22 DAS);: This coincides with three to four leaf stage in the plant. At this stage the roots emerge from the crown disc.
c. Tillering (35-45 DAS): Plant develop crown and branch out in to tillers from their base at soil surface
d. Jointing (65 DAS): This is the stage at which plant start elongating when the nodes start developing above the crown node

Reproductive stage:

a. Booting (75 DAS) : In this stage the uppermost leaf swells out in to flag holding the spike in it.
b. Heading (85 DAS) : The spike starts emerging out from the flag leaf sheath at this stage
c. Flowering/Anthesis (95 DAS): Anthesis of florets and fertilization of ovaries take place at this stage

Post anthesis stage

a. Grain filling (105-135DAS): The ovaries, after fertilization, start elongation, start elongation
b. Maturity stage: Colour of glumes changes and kernels become fairly hard at this stage. There are two stages of maturity. i.e. Physiological and harvestable maturity days.

Nutrient management

- Recommended doses of the fertilizers (NPK) should be used
- Nitrogen use efficiency is more when fertilizer is placed by drill

- 1/3rd N application at sowing and 2/3rd at first node stage.
- Supplementing inorganic fertilization (NPK) with Zn and FYM increases the wheat yield.
- Application of K is necessary as soil is getting depleted of Kcontent due to intensive cultivation
- Micronutrient deficiency appears under light soils under intensive cropping especially in Rice-wheat cropping system.
- In sulphur deficient soils, SSP, Cosavet -90 WDG (10 kg/ha) or gypsum (250 kg/ha) can be used
- Zinc sulphate should be applied @ 25kg/ha once in rice-wheat system or 2-3 foliar spray of 0.5% zinc sulphate (21% zinc) at 15DAS
- In Mn deficient soil, spray 0.5% manganese sulphate solution 2-4 days before firstirrigation and two to three sprays afterwards at weekly intervals on clear sunny day.

Manures & fertilizer:

Manures and fertilizers both play important roles in wheat cultivation. Use of manure improves the general physical condition and structure of the soil and its capacity to hold water. A liberal quantity of bulky manure should be applied in the field available. About 10 to 15 tons of well rotted FYM or compost should be applied 4 to 6 weeks before sowing and worked well into the soil. However manures by themselves cannot meet, the high nutrient requirements of plant, which are also in short supply. It, therefore, becomes necessary to supplement manures with chemical fertilizers to get high yields. The high yielding dwarf varieties of fully exhibit their yield potential only when supplied with adequate quantities of nutrients at proper time. A crop of wheat yielding 50 quintals of grain per ha. Removes 100 to 150 kg nitrogen, 70 to 80 kg phosphorus and 125 to150 kg potash from the soil. The response of a given variety of wheat to application of fertilizer, however , varies from field to field and from locality to locality.

The time and placement of fertilizer is another area where significant progress was made. It was demonstrated that 150 kg nitrogen, 60 kg phosphorus and 40 kg potash per hectare were required for optimum productivity. The N was to be applied in two or three split doses of 60 kg as basal and the remaining 60 kg at first irrigation or 75 kg N as basal and remaining 75 kg N in two equal split at first and second irrigation and full phosphorus and potash to be applied as basal. Recently, the new wheat varieties have responded up to 180 kg N/ha with optima dose around 150 kg/ha. In the Indo-Gangetic plains, application of zinc @25kg/ha in rice-wheat system was found to increase the yield substantially. Recently, the use of sulphur has been found beneficial for enhancing the productivity as well as the grain protein content of wheat. Response to Mn (pockets in the Indo-Gangetic plains) and boron (eastern and far eastern region) has also been realized.

Our soils universally deficient in nitrogen but the status of phosphorus and potassium differs from place to place depending on native nutrients store and previous fertilization history of the field. Fertilizer dose for wheat should, therefore, be related to the fertility status of the soil as indicated by soil tests. In case soil testes recommendations are not available the

general guideline for fertilization of high yielding dwarf varieties grown under different agro-climatic conditions laid down by the all India coordinated wheat improvement project should be followed.

Fertilizer recommendation of North-Eastern Plains Zone (NEPZ) including Bihar

Sowing conditions	Recommended dose of fertilizers	Time of application
Rainfed	60+ 30+20kgNPK/ha	Entire dose should be applied as basal application.
Timely sown irrigated	150+60+40 kg NPK/ha	½ N at basal and remaining dose should be applied in two equal split at first and second irrigation. Full dose of P and K should be applies as basal
Late sown irrigated	120+60+40 kg NPK/ha	½N at basal and remaining ½ N at first irrigation. Full dose of P & K should be applied as basal

Note: Fertilizer recommendation should be based on soil test value, However if soil test value is not available than recommended dose as mentioned above should be applied. If there is deficiency in micro nutrients like zinc (Zn) orboron (Bo) then 25 kg $ZnSO_4$ 10-15 kg Borax should be applied at the time of final seed bed preparation. If Zinc or Boron deficiency symptoms are observed in standing crop than 5kg $ZnSO_4$ + 2.5kg slacked lime dissolved in 500-600 litres of water should be sprayed.

Fertilizer management

Bio-fertilizer; 100kg seed Pkts of PSB before sowing will inprove the wheat nutrition as INM. If the wheat is sown after legumes or fallow then 25% dose of nitrogen can be reduced. In case of light soils, nitrogen can be supplied at three times instead of two times. In light soils, if the deficiency of nitrogen is observed then 3% Urea to be sprayed at tillering stage should be treated with

Salient Features of Fertilizer Application of Wheat Crop

1. The response of wheat to organic manure is less as compared to fertilizers but it helps in improving structure of the soil and moisture holding capacity
2. The irrigated wheat crop with Mexican varieties gives good response to N but lower response to P and K.
3. The response to the application of nitrogen along with the phosphorous is better than the application of N and P alone.
4. Different agro climatic regions show different response to fertilizer.
5. Indo-Gangetic alluvial soil gives better response to fertilizers than black cotton soil of Maharashtra.
6. The response to the fertilizer is also depend upon time of sowing spacing, seed rate, method of fertilizer application, variety etc

7. Drilling of fertilizer at 6 cm depth below the seed gives better response than broadcasting.
8. Different type of Nitrogenous fertilizer give more or less equal response but in some cases ammonium sulphate nitrate has proved better than others.
9. . Foliar application of urea in addition to part application on through soil at sowing give good response in case of rainfed wheat.

Water Management: Generally 5-6 irrigation are applied to wheat crop in the absence of winter rainfall. However under Bihar condition 3-4 irrigation is adequate.The first irrigation should be applied at CRI stage (22DAS). In case of late sowing wheat first irrigation should be delayed to 4 weeks after sowing. Irrigation at CRI should not be avoided in wheat crop. Depending upon the irrigation availability the following irrigation schedule should be followed

Available number of irrigations	**Irrigation application (DAS)**
Two (2) at CRI and heading	22, 85
Three (3 at CRI, boot and milk	22, 65, 95-100
Four (4) at CRI, tillering, boot and milk	22, 45, 65. 95-100
Five (5) at CRI, tillering, jointing, milk and dough	22,45,65,85, 110

Adequate soil moisture is required for normal development of the wheat plant at all the stages of growth. The crow root initiation stage and heading stage are crucial stages when plant suffers most due to moisture stress .The following schedule of irrigation should be followed for dwarf varieties of wheat: In case of dwarf high yielding varieties ,a pre-sowing irrigation should be given and crop sown when the field becomes fit for operation.

1st irrigation: The 1st irrigation to the standing crop should be given 20-25 DAS (CRI stage). In cooler regions like hilly tracts and in late sown wheat, it is desirable to apply 1s irrigation approximately 25-30 DAS. Delay in giving this irrigation should be avoided as it would result in upsetting the synchronous tillering in dwarf high yielding wheat varieties, abnormal heads, poor root system and finally poor grain yield. It is the most crucial stage for irrigation.

2nd Irrigation: At tillering stage, within 40-45 DAS.

3rd irrigation: At late jointing stage, within 70-75 DAS.

4th irrigation: At flowering stage, within 90-95 DAS. Irrigation at this stage is also important because during this period plants suffer most from soil moisture deficiency. The grain number and grain size are reduced considerable.

5th irrigation: At dough stage, within 110-115 DAS.

The total number of irrigations required will vary depending upon soil type, winter rainfall, amount of water applied per irrigation.

Under limited supply of water the following schedule of irrigation should be adopted for best utilization of available quantity of water.

1. Where only **one irrigation** is possible, give it at crown root initiation (CRI) stage (20-25 DAS).
2. Where **two irrigations** are available, 1st irrigation should be given at CRI stage and 2nd at Boot or flowering stage.
3. Where **three irrigations** are a possible, 1st irrigation should be given at CRI stage and 2nd at late jointing (boot) and 3rd at milking stage.

These recommendations strongly stress the importance of irrigation at CRI stage. It has been found that each week delay in 1stirrigation from CRI stage results in yield reduction of 200-300 kg per hectare.

Area under irrigated wheat has increased with popularization of the Mexican wheat. At present, nearly 95% of the area sown to wheat in Punjab and Haryana has assured irrigation. The agronomy group has demonstrated that irrigating wheat at crown root initiation stage (CRI) which is approximately 21days after sowing is most crucial. If water is available subsequently, it was advised to utilize the irrigation during tillering and at flowering stages. Using the FIRB technology, it had been demonstrated that water saving to the extent of about 30 percent could be achieved for wheat cultivation

Weed management

Among biotic stresses, weeds play an important role in deciding productivity of any crop. Unfortunately, they are more resistant to a biotic stresses and their nutrient absorption capacity is also better than the wheat crop. In the past, weed control measures were developed in individual crops and very little work has been done to control weeds in a cropping sequence. Therefore, there is a need to focus on integrated weed management and succession of weeds in a cropping sequence. Besides, physical, cultural and chemical means, biological weed control in wheat crop using plant pathogens, especially in the form of myco-herbicides needs to be focused in future. If the rate of current use of herbicide continues, then in future we have to be cautious about ground water contamination, food safety, health hazards, protection of endangered species and herbicide resistant weeds. Therefore, an understanding of weed succession and weed dynamics in relation to various cropping systems, agro-techniques, soil and climate of the agro-ecological system is essential and need following strategies.

- Evaluation of alternate herbicides and herbicide mixtures for resistance inactivation
- Molecular basis of herbicide resistance and identification of markers
- Improving the efficiency of herbicides by using adjuvant /surfactants/proper Spray techniques/synergistic herbicide mixtures
- Integration of effective non-chemical measures like competitive varieties, crop rotations, tillage practices, residue retention, etc. With chemical measures
- Exploiting the feasibility of biological control, *i.e.* myco-herbicides
- Studies on weed succession and weed dynamics in relation to various cropping systems and tillage techniques.
- Studies on chemical weed control for companion and intercropping systems

• Identifying the possibility of allele-pathic wheat cultivars for weed management

• Studies on weed biology for the efficient weed management

Weeds emerge with the emerging crop seedlings and if not controlled in the early stages of crop growth these may cause reduction in yield varying from 10-40 % depending upon the intensity and kind of weeds present in an area. When field is generally infested from both dicot and monocot weeds.

The pre-dominant weeds associated with wheat crop are: *Anagallis arvensis* (Krishana neel), *Argemone mexicana* (Satyanashi),Asphodelus tenuifolius (Piazi), *Avena ludoviciana* (Jangli Jai), *Cannabis sativa* (Bhang), *Carthamus oxycantha* (Pohli), *Chenopodium album* (Bathu), *Cirsium arvense* (Kateli), *Convolvulus arvensis* (Hirankhuri), *Cornopus didymus* (Pitpapra), *Euphorbia jelioscopia*(Dudhi), *Fumaria parviflora* (Gajri), *Lathyrus aphaca* (Matri), Malva parviflora (Gogisag), Medicago denticulata (Maina), *Malilotus alba* (Metha), Phalaris minor(Mandushi/Gulidanda), Poa annua (Poa ghas), *Polygonum plebejum* (Raniphul), Polypogon monspeliensis (Lomar ghas), Rumex retroflex (Jangli palak), Spergula arvensis (Bandhania), Vicia sativa (Chatri/Gegla).

The major dicot weeds are: *Chenopodium album*, *Fumaria purviflora*, *Cirsium arvense Anagalis arvensis , Melilotus alba, and Melilotus indica,Vicia sativa, , lathyrus* spp.,etc.,
Monocot weeds include: *Phalaris minor,Avena fatua, , Polypogon monspllensis, Cyperus rotundus and Cynodon dactylon.*

Phalaris minor is the major weed of wheat in rice wheat system. Sometimes its population is so high (2000-3000 plants / m^2) that farmers are forced to harvest the wheat crop as fodder. Isoproturon (Arelon) was recommended for the control of *Phalaris minor* in1980s. It remained effective for almost a decade. However, sole dependence on this herbicide resulted in the development of resistance to Isoproturon in *Phalaris minor*.

In zero tillage fields, the intensity of *Rumex* and *Malwa parviflora* is increasing and may become a problem in the coming years. Therefore, we must remain vigilant regarding weed flora shift due to changes in tillage practices.

Weed Management Practices in Wheat

Various practices of weed management can be grouped into three broad categories namely cultural and preventive; physical or mechanical; and chemical weed control. These practices are discussed below;

Cultural and Preventive

Cultural practices such as time and method of sowing, crop density and geometry, crop varieties, dose, method and time of fertilizer application, time and method of irrigation have pronounced effect on crop-weed interference. Some of these factors are listed below:

Use clean wheat seed that is free from weed seeds. Go in for early sowing of wheat (before 15 Nov.).Adopt closer row spacing (18cm).Adopt criss-cross sowing to increase population density of the wheat plants. Place basal dose of fertilizer 2-3 cm below the seed.

Sowing of wheat on FIRBS reduces weed population. Pull out weeds before seed setting. Keep blinds & irrigation channels free from weeds. Introduce either berseem or oat

for fodder, as a crop rotation, sown once in three years. Stimulate emergence of *Phalaris* by giving light irrigation followed by weed control with non-selective herbicides like glyphosate or cultivation followed by sowing of wheat. Zero tillage offer a way to manage *Phalaris* but continuously practising zero tillage invites problem from other weeds. Grow fast growing and robust varieties of wheat.

Mechanical Control

It involves the removal of weeds by various tools & implements including hand weeding &pulling. It is not feasible where weeds resemble morphologically to crop ego P. minor & *Avena ludoviciana* before flowering in wheat. Also, mechanical weed control becomes difficult in broadcast sown wheat. However, mechanical control can be practiced effectively when wheat is sown on FIRBS as this system facilitates tractor mounted implements usage.

Chemical Control

Chemical weed control is preferred because of less labour involvement and no mechanical damage to the crop that happens during manual weeding. Moreover, the control is more effective as the weeds even within the rows are killed which invariably escape because of morphological similarity to wheat, during mechanical control. The following weedicide schedule has been found effective in controlling the Isoproturon resistant population of *Phalaris minor.*

Pre-emergence

As pre-emergence, only Stomp 30EC (Pendimethalin) is available which can be applied @ 3300 ml/ha (1000 g a.i/ha) at 0-3 days aftersowing in 500 liters of water /ha. Care must be taken to have fine tilth for better performance of pendimethalin. It controls bothgrasses and broadleaved weeds.

Post-emergence

During the last 3-4 years a number of herbicides were found effective against even the resistant biotypes of *Phalaris minor*. Out of thefour new herbicides found effective against Phalaris, two namely Sulfosulfuran and Metribuzin were effective against both grassy andnon-grassy weeds, whereas clodinafop and fenoxaprop were specific to grassy weeds. Application of Metribuzin should be done carefully as this chemical is not safe at double the recommended dose. Also its application is risky if hot and windy weather prevails and rainfall occurs immediately after its spray / application. The herbicides that are to be applied as post emergence after first irrigation at 30-35 days of sowing or 2-3 leaf stage of *Phalaris minor* are;

Both Grassy and Broad Leaved

1. Sulfosulfuran @ 25.0g a.i./ha in 250-300 liters of water /ha.
2. Metribuzin @ 175 g a.i./ha in at least 500 liters of water /ha.
3. A mixture of Sulfosulfuran at 25g/ha and metsulfuron methyl @ 4 g/ha in 250-300 liters water /ha.

4. Combination of 2,4-0 and isoproturon can also be used for the control of mixed weed population in resistancefree area.

Only Grassy Weeds

1. Clodinafop @ 400 g/ha (60g a.i./ha) in 250-300 liters of water / ha.

2. Fenoxaprop-ethyl @ 80-120g a.i./ha in 250-300 liters of water / ha.

Only Broadleaf Weeds

1. 2, 4-D @ 500 g a.i./ha in 250-300 liters of water /ha.

2. Metsulfuron methyl @ 4 g a.i. / ha 250-300 liters of water /ha.

Some Useful Hints

Precausions:

- Spray the herbicides, both pre and post emergence, when there is sufficient moisture in the soil.
- Spray the post-emergence herbicides when Phalaris minor is at 2-3 leaf stage.
- Spray on clear and sunny days only when the leaves are dry.
- Use only flat fan nozzle especially for Fenoxaprop.
- Remove *Phalaris minor* before seed setting and use as fodder.
- Ensure complete coverage of the field.
- Do not use Sulfosulfuran in mixed cropping system of wheat and mustard or other crops.
- Never apply these post emergence herbicides by mixing with sand, urea or soil.
- Do not mix Clodinafop and Fenoxaprop with 2,4-D

Generally weeds are eradicated with the help of hoe, khurpi etc. However, now-a-days it has become difficult due to labour cost and unavailability of labour. Now a number of chemical weedicides are available that control the weeds in wheat rather effectively.

Most common and effective herbicide to kill all the broad leaved weeds in wheat field is 2,4-D. It is available in market under different trade names and each formulation has different amount of active ingredients.2,4-D should be sprayed in wheat fields 32-35 DAS. This period may be extended to the maximum by one week. But after 40days of sowing, spray of 2,4-D is not beneficial because by that time weeds have already done the damage to the crop, secondly,after40 days weeds become woody in nature and are not likely to be killed easily with the recommended dose of 2,4-D. When 2,4-D is sprayed between 25-30 days , the ears of wheat have been found to suffer from malformation. Malformation adversely affects the uniformly of seed size and thereby reduces their value as grain and seed. Gappy spikelet result in reduction in total number of grains per head and finally lead to reduced grain yield. While spraying 2,4-D avoid drift of spray in the adjoining crop fields, because aslight drift of 2,4-D may spoil the pulses crop like pea, gram, lentil and mustard. It is desirable to spray 2,4-D when wind velocity is minimum.

To control *Phalaris minor* spray Tribunil or Isoproturon at the rate of 2kg per ha in 400-600 l of water 32-35 DAS. Spray of Isoproturon will also control wild oat if it is present in wheat field.(Source: Modern Techniques of Raising Field Crops- Chhidda Singh)

Plant Protection-

As a consequence of intensive farming, new pest problems are being encountered. The insects survive on the harvested rice stubbles or migrate from the adjoining crop of rice. It is therefore, necessary to develop a technique for removing the rice stubbles and other crop residue to avoid pest build up. There is a need for a continuous monitoring of this pest over NWPZ and NEPZ and understand the insect ecology better. In view of the environment friendly control measures, neem products and *Pasteuria* etc. can also be synthesized for the control of nematode

Major Diseases & Insect-Pests

Wheat crop suffers from several diseases which reduce its yield and quality. The major diseases of wheat in India are, three rusts -leaf, yellow and stem rust, Karnal bunt, foliar blights, powdery mildew and loose smut. Diseases of limited importance include headscab, foot rot and flag smut; these diseases though of lesser importance, may be important in certain pockets.

Leaf Rust /Brown Rust(*Puccinia recondita tritici.)*

Distribution: Throughout wheat growing regions of India.

Development: Pathogen over-summers in low and mid altitudes of Himalayas and Nilgiris. Primary infections develop from wind deposited urediospores in eastern Indo-Gangetic plains in middle of January where it multiplies and moves westwards by March.

Management: The presently recommended varieties in most of the wheat growing zones are rust resistant.

Stripe Rust /Yellow Rust *(Puccinia striiformis tritici)*

Distribution: Hills, foothills and plains of north western India and southern hills zone(Nilgiri hills of Tamilnadu).

Development: Spreads through air-borne urediospores, when temperature are 1020°C but the spread is checked above 25°c. Pathogen survives in the cool temperatures of hills (Himalayas and Nilgiris) and the primary infection takes places by middle of January in the foot hills and sub mountainous parts of north western India.

Also, infection comes from across the western border, hence the probability of evolution of new races increases in this area. Yellow rust from Nilgiri hills cannot come out of the zone due to high temperatures in the Peninsular and Central India.

Management: Most of the presently recommended varieties are resistant. Major emphasis is on host resistance and cultivation of resistant varieties is the main strategy of management.

Stem Rust /Black Rust (*Puccinia graminis tritici)*

Distribution: Mainly in Peninsular and I Central India, may occur in traces in Northern India too' were the infestation comes late.

Development: Develops from air-borne urediospores, needs free moisture and temperature above 20° C for spread. It can cause severe grain losses if infection is early. The pathogen perpetuates in Nilgiri hills during off season and becomes airborne. If Peninsular and Central

India experience rainfall during November then epidemics are severe. Late infections cause less damage in north India.

Management: The presently recommended varieties in most of the wheat growing zones are rust resistant, hence the old susceptible varieties be avoided.

Karnal Bunt *Tilletia indica (=Neovossia indica)*

Distribution: Parts of Northern Plains, especially Punjab, parts of northern Haryana, foot hills of J&K and HP, tarai area of Uttranchal, in lesser severity in Rajasthan, Bihar and UP. The states of Gujarat, Maharashtra, Karnataka and several parts of M.P. are free of KB.

Development: Seed and soil-borne; infection occurs at flowering by means of soil-borne inoculum. The degree of disease development depends upon the weather conditions prevailing during spike emergence to grain filling stage of crop. If the rains occur during the month of February in north Indian plains(disease - prone areas), the disease is likely to come with higher severity.

Management: Among the present day varieties, PBW 502 is resistant while the others show various levels of susceptibility. For management of this disease, one spray of Propiconazole (Tilt 25EC@ 0.1 %) should be given at the time of anthesis. Integration of one spray of propiconazole with one spray of bioagent fungus, *Trichoderma viride* (0.4% suspension) gives almost cent per cent disease control. The bioagent spray should be done before earhead emergence (Crop growth stage 31- 39 on Zadoks scale), followed by the spray of chemical at start of earhead emergence (crop growth stage 41 -49 on Zadoks scale). Twosprays of *T. viride,* at these two critical growth stages also give non chemical control of the disease which is almost similar to one spray of propiconazole. Chemical control should be adopted mostly in seed production plots.

Black Point (*Alternaria alternate)*

Development: Disease causes blackening of embryonic region of the seed (black point), discoloration of areabeyond the embryonic region (black discoloration *(Caused by Aalternata, Curvularia lunate, Epicoccum sp., Bipolaris sorokiniana, etc.)* and eye-spot symptom (B. *sorokiniana).* The warm and humid weather at grain filling or near maturity favors this disease.

Management: This disease is of minor importance. Only when the disease percentage is high, it causes concern to the trader and the consumer. The discoloured seeds are mostly shrivelled and they are separated out during processing.

Loose Smut *(Ustilago segatum (U. tritici)*

Distribution: North Indian plains and northern hills zone.

Development: It is a seed borne disease; infection occurs during *Loose Smut* flowering through wind-borne spores. The infection remains dormant inside the otherwise healthy looking seed but the plants grown from such seeds bear infected inflorescence. Infection is favored by cool, humid conditions during flowering period of the host plant attracted much attention. Treat the seed with fungicides like carboxin (Vitavax 75WP @ 2.5g / kg seed), carbendazim (Bavistin 50WP@ 2.5g / kg seed), tebuconazole (Raxil 2DS @ 1.25g / kg seed)

if the disease level in the seed lot is high. If it is low to moderate, treat the seed with a combination of *Trichoderma viride* (@4 g/ kg seed) and half the recommended dose of carboxin (Vitavax 75WP@ 1.25g / kg seed).

Foliar Blights*(Bipolaris sorokiniana* (Spot blotch), *Pyrenophora tritici repentis* (leaf blotch or tan spot), *Alternaria triticina*(Alternaria leaf blight)

Distribution: Mainly in eastern India but also occurs in Peninsular and Central *Foliar blights* India.

This disease complex is emerging as a problem in the north western India too.

Development: The disease requires high temperature and high humidity. This disease is more severe in latesown crop and causes substantial yield losses through formation of shrivelled grains. Most of the varieties are susceptible or moderately susceptible. The disease can be controlled through one spray of propiconazole (Tilt25EC @ 0.1 %).

Powdery Mildew *(Erysiphe graminis tritici)*

Distribution: Mainly in the cooler areas and hilly region; foot hills and plains of north - western India and the southern hills (Nilgiris).

Development: Powdery mildew can easily be diagnosed by the white, powdery patches that form on the upper surface of leaves and stem. With age, the patches turn dull dirty white and may have small black specks embedded. This disease can spread to all above ground cool to moderate temperatures. Low light intensity, which accompanies dry weather and a dense crop canopy favours this disease.

Management: Present day varieties are not resistant to powdery mildew. Hence, the disease severity is more in some pockets. Avoid excessively dense, stands by using adequate seed. For chemical control, one spray of propi-conazole (Tilt 25EC@ 0.1 %) on disease appearance (which usually occurs during early March in northern plains) is highly effective.

Head Scab *(Fusarium graminearum)*

Distribution: Parts of Punjab, especially in the sub mountainous regions. Bread wheat suffers lesser damage than thedurum. It was first recorded in severe proportion in some parts of Punjab during 1995-96 crop season and again during 2004-05 crop season.

Development: Disease development is favoured by cool, moist weather with high humidity. Spores are produced oncrop debris and reach the leaves through rain splash or wind. Apart from ear head infection, it can cause seedling blight and foot rot leading to lodging. In severe cases, it can cause shrivelling of grains and low-test weights. At present, it is a disease of limited importance but has the potential to emerge as a major problem due to the production of toxins.

Management: Bread wheat are more resistant than durum. However, no resistant varieties are available. Hence, vigilis needed for this disease.

Source: Krishi Seva . com

Distribution: It is found mainly in some parts of northern India especially the states of Bihar, Jharkhand,eastern UP and Chhatisgarh.

Development: These nematodes are spread through seed galls in the seed lots during planting and harvesting. Wet weather favours larval movement and infestation. The nematode invades the crown and basal stem area, finally penetrating floral primordia. This leads to formation of nematode galls in ear heads.

Management: Use of clean seed (free of galls) is the only method to prevent this disease. For removal ofgalls, the seed lots are floated in 2 - 5 per cent brine solution. The galls, which float on the surface, can beeasily separated and destroyed away from the fields. The seed thus cleaned should be washed with fresh water and used forplanting.

Aphids *(Sitobion avenae, Rhopalosiphum padi* and various other species)

Distribution: All wheat growing areas, especially in NWPZ and Peninsular India.

Development: The aphids exist in different stages, *viz.,* winged (alates), wingless (apterous) sexual and asexual forms. The rapid spread takes place through asexual reproduction where females give rise directly to nymphs rather than eggs. Infestation usually occurs during second fortnight of January till crop maturity.

Management: When feeding in sufficient numbers, they can cause considerable damage, but under normal conditions, losses are not much. Chemical pesticides are recommended for this pest in wheat if the level of aphids per tiller crosses 10 during vegetative phase and during reproductive phase. However, there is need to keep watch on this pest. The spray of imidacloprid @ 20 g a.i. per hainitially on border rows and if infestation is severe then in entire field will give good protection against this pest. Generally, natural enemies present in the field help in controlling the population of this pest.

Quality of Wheat:

Determinants of wheat quality

Quality is a complex term. The dictionary meaning of quality refers to the degree of excellence, relative nature or character. However, it is difficult to describe a given lot of wheat as poor, good or excellent quality and the definition of grain quality is something like that of moving average. Grain quality is essentially a relative term and should be defined in context of the purpose e.g. a particular type of wheat grain may be very suitable for preparing biscuits but the same grain is ot suitable for producing good breads thus grain X gives high quality biscuits but bad quality bread and so on. In fact, the simplest definition of the quality of a grain or plant product is in terms of its suitability.

Incase of cereal grains, the physical and chemical differences in the grain are the basis for the differences in their quqlity or suitability for an end use.The various products made from wheat are given. Quality characteristics of wheat can be categorized into two class based on these determinants

Physical characteristics of quality:

1. Test weight
2. Vitreous
3. Colour
4. Yellow berry

5. Grain hardiness
6. Thousand kernel weight
7. Flour extraction rate or milling recovery percent

Chemical characteristics of quality

The structure of a mature wheat kernel is shown in the figure. The proximate composition of chemical constituents and their distribution in different kernel parts is given

Proximate composition of cereal grains (g/100g)

Cereal	Protein	Fat	Soluble carbohydrate	Mineral matter	Cruide fibre
wheat	10.5-16	1.8-2.9	74-79	1.8-2	2.5-3.0
Maize	10.0-12% (Up to 16% in QPM	306-9	74-80	1.6-2	2.1-3.5
Rice(milled)	9.8	0.5	89	0.6	0.3
Barley	11.8	1.8	78	3.1	5.3
Oats	14.9	7	80	2.1	1.3
Sorghum	12.4	3.6	79.7	1.7	2.7

***Nx5.7 for wheat: Nx5.95 for rice, Nx6.25 maize, barley, oats, sorghum**

(Source: kent. N.L., 1982)

Percentage of the total constituents of wheat in the main morphological parts

Part	Weight (g/100g of grain)	Constituents					
		Starch	Protein	Dietary fibre	Crude fibre	Lipid	Mineral matter
Bran	15	0	20	70	93	30	67
Endosperm	82	100	72	27	4	50	23
Germ.scutellum)	3	0	8	3	3	20	10

(Source: kent. N.L., 1982)

Tranditional products made from different species of wheat in india

Type of wheat	Products
Bread	Chapati/Roti/Phulka, Tandoori Roti, Rumali Roti, Naan, Kulcha, Bhatura, Pizza, Puri, Kachori, Samosa, Matthi, Namakpara,Papad, Prantha, Paysam, Balusai, Jalebi, Ghewar, Phirni,Sawaian Chikki,, Vattayappam, Palappam,Shahitoast, Sattu, Noodles, Laddu etc.
Durum	Chapati, Parantha, Dhebra, Bhakri, Porridge(salted&sweet), Rawa Idli, Rawa Puttu, Khich di Etc.
Dicocum	Culadi Ki Laddu, Godi Huggi, Sweet Pan Cake, Madel etc.

Released bread wheat varieties recommended as suitable for different end uses

Sl. No.	End product	suitable varieties

1.	**Chapati**	C306, Raj1482,WH147, HD2402, UP262, WH416, SUJATA, GW496, PBW226, PBW175, Raj3765, K9107, NW1014, LOK1, GW273, GW322, HW2004, HD2285, HP1731, HI1500, HD2833, K0307, HD2888, HI1531, HD2987, MACS6145, DL788-2, Raj4037, PBW527, PBW53
2.	**Bread**	HI977, PBW226, K9107, HD2285, GW120, GW190, DWR195, NI5439, HS240, VL738, PBW396, HD2733, GW496, HD2189, DWR162, MACS2496, LOK1, HD2864, HD2932, NIAW917, MACS6222, MACS6273, UAS304, Raj4083, AKAW4637, HD2781, PBW533
3.	**Biscuit**	Sonalika, PBW373, UP2425, HUW234, VL829, PBW496, PBW175, HS277, NW2036

(Source: compilation from Annual Progress Reports, Quality, DWR, Karnal, India)

1. Physical Quality:

The wheat grain should be amber coloured, bold, longish-oval in shape and lustrous.

2. Nutritional Quality:

Wheat grain contains proteins, starch, fat, minerals and vitamins. But the nutritional quality is judged on the basis of protein content wheat grains and classified as low protein (> 8% protein), medium protein (8 to 12% protein) and high protein (< 12% protein).

3. Milling Quality:

The milling quality is judged by the easiness in milling and yield of flour obtained after milling.

4. Chapatti Making Quality:

The flour should be medium strong and have a high water absorbing capacity. The dough should be non sticky, pliable, elastic and extensible. While baking chapatee should puff fully and taste sweetish.

5. Bread Making Quality:

The flour should have a high water absorbing capacity and the dough must be of good elasticity and stability. After baking it should produce loaf of a large volume, good internal crumb, structure, golden brown crust.

6. Biscuits Making Quality: For biscuits flour should be soft and weak or pliable but non elastic.

7. Rawa or Suji Making Quality:

The hard wheat is more suitable for rawa or suji because of their strong gluten.

8. Straw Quality:

The straw should be soft and palatable.

Nutrition Quality of Wheat

i) Wheat grain contains proteins, starch, soluble sugars, cellulose, fat, minerals like P and Fe and vitamins like thiamin and riboflavin.

ii) On the basis of protein content wheat grains are classified into three categories.
a) Low protein content : below 8% protein.
b) Medium protein content : 8 to 12% protein.
c) High protein content : above 12% protein
iii) Specially gluten and lysine percentage of the proteins decides the quality of wheat.
iv) Gulten content is very important because it largely affects the quality of bread and other pastry products.

Flour Quality for Chapatti and Bread

Flour Quality for Chapatti:

i) The flour should have a high water absorbing capacity.
ii) It should make a dough which is not sticky, pliable, elastic and extensible.
iii) While baking chapatti should puff fully and rapidly.
iv) Chapatti should be palatable and sweetish in taste.
v) It should have a good keeping quality.
vi) The flour should have about 13 to 14% protein of which 3% is lysine.
vii) The sedimentation value should be 25 to 35ml.
viii) The sedimentation value should be 120 to 150 min.
ix) Total sugar content should be 2.5 p.c.
x) Diastatic activity between 200 to 300 mg maltose per 10 gm. Flour.

Flour Quality for Bread:

i) The flour should have a high water absorbing capacity.
ii) The dough should have good elasticity, stability and baking quality.
iii) After baking it should produce loaf of a large volume, good internal crumb, structure, golden brown crust.
iv) 90% variation in the bread is due to its protein contents.
v) The gluten percentage in the flour largely affects the quality of bread.

Harvesting, threshing storage: harvesting and threshing methods (manual/ mechanical), storage-moisture content , drying, chemical used for storage pests.

Harvesting and threshing: High yielding dwarf varieties of wheat should be harvested when the leaves and stems turn yellow and become fairly dry. To avoid loss in yield crop should be harvested before it is dead ripe. when harvest is not done in time, grain maybe lost die to damage by rain, birds, insects, shattering and lodging. Timely harvesting ensures optimum grain quality and consumer acceptance. The right stage for harvesting is when there is about 25-30% moisture in grains. Harvesting is normally done with serrate edge sickles by hand. Bullock driven reapers are also used occasionally. Combines are also available which can be harvesting, threshing and winnowing wheat crop in single operation . After harvesting the crop by hand, it is dried and three to four days on the threshing floor and then threshing is done by trampling bullocks or thresher attached to bullocks. Now-a-days power driven stationary threshers are becoming more popular because these are easy in operation and hasten the process.

Source: Modern technique of raising field crop

Quality seed production of wheat

Wheat is a one of the important cereal crop and India is the second largest producer of wheat in the world after China. Seed has played a crucial role in agriculture since ancient times. In modern agriculture also quality seed is an essential input that helps in exploiting the full potential of a variety. The seed that reaches to the farmers should have high genetic purity as well as high physical, physiological and health quality. In India farmers select and save the seed for next year sowing so therefore the seed supplied to the farmers should be of best quality. Therefore best practice to produce quality seed should be followed.

Climate:

Wheat is grown over a wide range of latitudes ranging between 600 N to 600S and altitudes ranging from sea level to an elevation up to 3,500 m in the tropics and sub tropics. The ideal condition for vegetative period is cool and moist weather and during grain formation warm and dry weather. The optimum temperature for germination is between 20-22° C and for vegetative growth ranges from 16-22^{O}C. During the grain development period wheat requires a mean maximum temperature of about 25^{O}C for at least 4-5weeks.

Land selection:

Selection of appropriate site is very essential for quality seed production. The seed production for wheat crop should be taken at well drained, clean, productive and levelled land that is properly crop rotated. The previous cropping history of the field should be known to avoid contamination from volunteer plants, noxious weed and soil borne diseases.

Selection of variety:

The recent variety having more demand and adapted to particular environment should be selected

Sowing Method:

Sowing with seed drill is recommended but not essential. However row planting has an advantage over broadcasting as it requires less seed, facilitates mechanized weed control, easy inspection and rouging of off-types.

Sowing Time in different wheat zones of India:

The sowing time for irrigated timely sown in different zones is as follows:

1. Northern Hills Zone: First fortnight of November
2. North Western Plains Zone: First fortnight of November
3. North Eastern Plains Zone: Second fortnight of November
4. Central Zone: 10 to 20th of November
5. Peninsular Zone: Second week of November
6. Southern Hill Zone: Last week of November month to first week of December.

Seed Rate:

The optimum seed rate for wheat seed production varies with location, time of planting and method of planting. For most of the condition 100kg/ha seed is optimum.

Fertilizer application:

Fertilizer application for the wheat should be based on soil testing results. A well balanced supply of Nitrogen, Phosphorus and Potash is essential and for proper and efficient seed production as it has influence on seed development and seed quality. On an average 150Kg Nitrogen, 60Kg Phosphorus and 40Kg Potassium for a hectare is the recommendation if soil testing results are not available.

Water management with minimum and optimum limits with time of applications:

Wheat crop requires 40 cm (400 mm) of water to complete its life cycle. Wheat crop needs irrigation when available soil moisture falls below 50-60 per cent of the field capacity. In general this crop requires 4-6 irrigations depending upon rainfall, soil type, tillage practices and water use by the genotype. For optimum wheat productivity, irrigation scheduling is the important aspect because deficits of water as well as excess application of water adversely affect the production. Depending upon the availability of irrigation water, it should be applied at critical growth stages of crop which are **Crown Root Initiation (20-25 days after sowing**), tiller completion /late tillering (40-45 days after sowing), late jointing or booting (60-65 days after sowing), flowering or heading (80-85 days after sowing), milking (100-105 days after sowing) and dough stage (115-120 days after sowing). **Crown root initiation and flowering or heading** are the most critical stages to moisture stress. Therefore, enough moisture must be ensured at these two stages of wheat crop.

Isolation distance:

Wheat seed field should be isolated from all sources of contamination (Genetic, physical and pathological) is one of the fundamentals of seed production. The minimum isolation distance from different contaminants is summarized in table below.

Contaminants	**Minimum distance(meters)**	
	Foundation seed	**Certified seed**
Fields of other varieties	3	3
Fields of the same variety not conforming varietal purity requirement for certification	3	3
Fields of wheat, triticale and rye with infection of loose smut disease in excess of 0.1.% and 0.50% in case of foundation and certified seed respectively	150	150

The specific requirement for foundation and certified seed production is summarized below.

Factor	Maximum permitted (%)	
	Foundation seed	Certified seed

Off-types	0.05	0.20
Inseparable other crop plants	0.01	0.05
Plant affected by seed borne (loose smut)disease	0.10	0.50

Seed Standards:

Factor	Maximum permitted (%)	
	Foundation seed	Certified seed
Pure Seed (minimum)	98 %	98 %
Inert matter maximum	2 %	2 %
Other crop seeds (maximum)	10 /kg	20 /kg
Total weed seeds (maximum)	10 /kg	20 /kg
Objectionable weed (Hirankhuri and Gulli danda) seeds (maximum)	2 /kg	5 /kg
Seeds infected with nematode galls of ear cockle and tundu disease(maximum)	None	None
Seeds infected with Karnal bunt (maximum)	0.05 % (by number)	0.25 (by number)
Germination (minimum)	85 %	85 %
Moisture (maximum)	12 %	12 %
For vapour proof container	8 %	8 %

Crop Management:

Crop management should be optimal and similar to that of grain crop. However small differences are there:

Use lower seed rate to increase multiplication factor

Proper spacing to facilitate rouging and inspection

Maintaining the species and variety purity

Controlling diseases that are seed transmitted.

Diseases and pest management in wheat seed crop

Seed Treatment: Seed should be treated with vitavax 75 WP or bavistin @ 2.5 g per kg seed before sowing.

Karnal Bunt disease: Healthy seed should be used. Seed should be treated with thiram 2.5 g per kg seed.

Smut disease: In the month of May-June when sunlight is very bright hot treatment should be given before storing the seed. Seed should be soaked in water for 4-6 hours and spread on floor in strong sun light to control this disease.

Rust disease: As soon as yellow rust is observed in the field, one spray of Propiconazole 25EC @ 0.1 per cent or Tebuconazole 250 EC @ 0.1 per cent should be given to control the disease. One ml of chemical should be mixed in one litre water and thus 500 ml of fungicide mixed with 500 L of water should be sprayed in one hectare wheat crop. Farmers should spray the crop preferably in the afternoon and when weather is clear (no rain, no fog etc.). Resistant genotypes should be grown.

Termite: Termite attacks the crop in early stage. Seed treatment is must to control this pest. For 1 quintal of wheat seed 500 ml Chlorpyriphos 20 EC in 5 litre of water used for seed treatment.

Aphid: Spraying of Imidacloprid @ 0.4 ml per litre water on border rows for control of aphids as soon as aphids are spotted.

Weed control

Metsulfuron @ 4.0 g or 2,4-D @ 500 g or Carfentrazone @ 20 g per hectare should be applied to control the broad leaved weeds in wheat crop. Pre emergence application of Pendimethalin @ 1 litre per hectare is also quite effective in controlling broad leaved weeds. For grasses sulfosulfuron 25 g, clodinafop 60 g, pinoxaden 40 g, and fenaxoprop 100g per hectare should be applied. Sulfosulfuron is effective against both grassy and broad leaved (non grassy) weeds whereas, clodinafop, fenaxaprop and are specific to grasses.

Roguing:

Removing undesirable plant is another fundamental of seed production. These undesirable plants include off types of genetic variants of the same variety, other varieties of wheat, noxious weeds and infected plants with seed borne diseases. This practice is carried out to maintain the genetic purity of the variety, and to keep the seed crop free from seed borne diseases.

Harvesting, cleaning and storage:

Mechanical harvesting is common practice of seed production fields. The critical factors to be considered during harvesting are seed moisture content, mechanical damage and cleanliness of equipments. After seed crop is harvested, the seed has to be dried and cleaned. During seed processing the raw seed received is cleaned in a series of steps from pre-cleaning, drying, air screen cleaning, length separation, gravity separation, seed treatment and bag weighing. After cleaning the seed is send for bulk storage.

Varietal purity and identity of seed is ensured through field inspection of growing crops. Land requirement, isolation distance and seed source are confirmed. The presence of off types, other varieties, other crops, and seed borne diseases are determined based on inspection of representative samples that are compared with the standards. Seed crop that meet minimum field and seed standards are accepted for certification.

Source: C.N.Mishra, Satish Kumar and Raj Pal Meena

BARLEY

Hordium vulgare L.

Barley (*Hordium vulgare* L.) commonly known as Jau belong to family Poaceae. Barley is the world's fourth most important cereal crop after wheat, rice and maize. It is a major source of food for large number of people living in the cooler semi-arid areas of the world. In India, it is staple food of the hill people and also used for food and feed purposes in other plain parts of the country as Rajasthan, Punjab, Haryana, Uttar Pradesh and Madhya Pradesh. In India barley has been traditionally considered as poor man's crop because of its low input requirement and better adaptability to harsh environments like drought, salinity/alkalinity and marginal lands. It is mainly used as cattle food and industrial raw materials for malting and brewing. In the modern time, it is popularly being preferred as medicinal food in urinary and as well as diabetic problems. Barley can be utilized as as a source of green fodder under water scarcity conditions, as it is very fast growing crop with high biomass in the early stages and requires less water.

Barley is grown in areas which have limited irrigation facility, or marginal, sub-marginal lands or area affected by salinity/alkalinity. Barley is also used for malt production, which is principally used in brewing industry and proving itself as a good source of better rural livelihood. The effect of different production factors, of which cultivar choice, planting date, planting density, fertilization, irrigation, weed management and availability of quality seed are the most important, and reflected in the yield and the malting quality of the crop.

The malt barley crop has specific crop production requirements which are as follows:

It is very hardy crop and can be cultivated in adverse agro-environment like drought, salinity, alkalinity etc. in plains and hilly areas under rain fed and irrigated conditions. The carbohydrates present in barley help in the regulation of the glucose level due to high fibres content which is five times more than that of the other whole grains. Barley grain are rich in Vitamin B, Vitamin E and folic acid. Its' feed helps in reducing the body weight, as it makes a food appetite suppressant, making one feel filled and satisfied. Barley is a good source of protein and 60% produce in India is used as a feed for the livestock. Barley contains about15% water, 6.7% of gum, 3.2 % of sugar, 60% of starch and 2.2% of fat. A wide variety

of barley products are known to be suitable for human consumption. These include porridge, muesli, cookies, barley flakes, breads, pasta, etc. The energy rich drinks like Bourn vita, Boost, Horlicks, Maltova etc. are prepared from malt extracts of barley. The parched grains of barley are consumed in many parts of Uttar Pradesh, Rajasthan and Haryana. Barley is malted in alcoholic beverages like beer, wine, etc. The by-products of malted barley are also used in the form of animal feed. Barley straw is used to make the bed for the livestock, making paper, fibre board, etc.

Barley usages

Barley grain is used as feed for animals, malt for industrial uses and for human food. Barley straw is used as animal fodder in many developing countries including India. Barley straw is also used for animal bedding and as cover material for hut roofs. Barley is also used for green forage and either directly fed to the animal or used for silage. It also has immense potential as quality cereal especially for nutritional and medicinal point of view.

In developed countries barley is considered as a functional food and used in many bakery products and recipes. In India, its utilization as food crop (mainly hull less type) is restricted to the tribal areas of hills. The barley products like “Sattu” (in summers because of its cooling effects on human body) and Missi Roti have been traditionally used in India. However, barley is predominantly consumed as food crop in the semi-arid regions of Africa (Morocco, Algeria, Libya and Tunisia), Middle East (Saudi Arabia, Iran, Iraq and Syria),highlands of Nepal, Ethiopia and Tibet, Andean countries of South America (Peru and Chile) and in some Asian countries (China and North Korea

Malt is the second largest use of barley and malting barley is grown as a cash crop in a number of developed and developing countries including India. Among cereals, barley is most preferred for malt, as its husk protecting the coleoptile (acrospires) during germination process and provides aid in filtration, firm texture of grains and its amylase activity makes it unique for malt recovery. Malt is used mostly in beer, hard liquors, malted drinks and flavourings in a variety of foods. Barley malt can also be added to many food stuffs such as biscuits, bread, cakes and desserts (Akar *et al.,* 2004). The utilization of barley for malting and brewing industry has picked up recently with an increase of consumption of beer and other malt based products in many countries including India. With the changing lifestyles and increasing urbanization, the diseases like coronary heart disease, diabetes etc are on the rise all over the world. One of the ways suggested to control these diseases is changes in the dietary habits. Besides this in past few years it has been shown that inclusion of nutraceuticals such as soluble dietary fibres can help in controlling the blood cholesterol and glucose levels besides providing benefits to gut health. Barley grains possess higher amounts (3-7%) of one such dietary fibre called beta glucan. The mixed linkage (1-3; 1-4) beta glucans have been shown to lower postprandial blood glucose and lower the LDL cholesterol and is approved in many countries as health benefitting soluble fibre (Behall *etal.*, 2004; Fadel *et al.*, 1987; Braaten *et al.*, 1991; Pins and Kaur, 2006). Barley is also a rich source of tocols, including to copherols and to cotrienols, which are known to reduce serum LDL cholesterol through their antioxidant action

Crop scenario: During 2012-13, globally barley was grown on nearly 49 million hectares area with a production of around 132 mt. The area was decreasing around the world until mid

nineties but after that there has been stabilization, though the productivity is improving. In India presently the productivity is below the world average, but there has been a continuous gain in productivity through research efforts on varietal development and production technology. In India also, the trend of reduction in area under barley has been similar to world trend over the years. However, during past 15-20 years the area under barley has almost stabilized with minor annual fluctuations depending upon the market prices and industrial demand.

Barley improvement in India:

The barley research in Indiahas been progressed with development of varieties for different purposes such as feed, malt, fodder and hulless barley for varied agroclimatic conditions. However, major emphasis of barley breeding programme has been madeon development of feed, malt and dual purpose varieties with high and stable yield, resistance to biotic stresses(yellow rust, leaf blight, aphids and cereal cyst nematode)and abiotic stresses (drought, salinity, alkalinity, rainfed, brackish water and diara lands). In addition, breeding forearly maturity, bold and plump seeds and adaptation to specific environments has also assumed importance. A substantial progress in enhancing yield with reducing the losses from biotic stresses, increasing the seed size, lodging resistance and tolerance to salinity stress has been made by adopting the appropriate breeding approaches suchas pure line selection, pedigree method, bulk method, backcross method, single seed descent method, mutation and biotechnological tools for molecular profiling.

The research programme for improvement of this cropwas initiated in India, sometimes during 1916 with research activities such as;

i. Introduction of exotic barley germplasm and improvement through selection

ii. Collection of land races of barley and improvement through selection

iii. Development and popularizing package of practices to encourage its cultivation

iv. To recommend well tested varieties both hulled and hulless for cultivation.

Prior to inception of the AICBIP, a numerous varieties were selected from land races and developed the improved barley varieties with high yield along with other desirable traits. As a result of selection from land races a variety C 251 was developed during 1928 (Gupta, 2013).It combined high yield potential along with excellent malting quality and tolerance to saline/ alkaline conditions of soil. Other varieties developed and released were Type 4, Type 5, C 84, C 50, NP 100, barley local, BR 21,BR 22, BR 32, CN 292, CN 294, K 12 Balia barley, K14, RS 17, KB 71, Ratna and PR 502. All these varieties were recommended on the basis of performance in the irregional tests. Four hulless varieties namely CN 292, CN294, Sindhu and Nurboo were directly selected from local materials. Varieties CN 292 and CN 294 were suitable forplain zone, whereas Sindhu and Nurboo were adopted for summer cultivation in Leh and Laddakh.

Barley improvement for feed and food purposes*:*

Barley is a good source of feed and fodder. It is a key animals feed and fodder in dry areas of India (Kumar *et al.* 2013).Majority of barley produced in India is utilized as feed for cattle and poultry and in few areas as food purposes. The Barley Network centers under

AICW&BIP has gota major research component on the barley improvement for grain/ feed purposes. A large number of varieties have been developed/released either by CVRC for different zones orby respective SVRCs for specific states addressing different production conditions and agro-climatic situations by different centers under AICW&BIP. Incorporation of resistance to major diseases and pests along with improvement for grain yield has been the major objective of the programme after the reorganization of the network in 1990-91. Prior to this there was no organized system being followed for screening of resistance under artificially inoculated conditions at hot spot locations and only the natural incidence in yield evaluation trials was being recorded. Subsequently a large number of improved varieties with resistance to diseases were developed for feed and food purposes for different production conditions/ zones (Table 1).Hulless barley or naked barley (*Hordeum vulgare* L. nudumHook F.) is a form of domesticated barley with an easier to remove hull. It is consumed as both food and feed purposes. It is also used for making alcoholic beverages particularly in the high hills.

Hulless barley is preferred over hulled types because it allows easier removal of the hull and a fairy new industry has developed of selected hulless baley in orderto increase the digestible energy of the grain, especially for swine and poultry. Hulless barley has been investigated for several potential applications as whole grain and for its value added products. These include bran and flour for multiple food applications (Bhatty, 1999b). Several research paper shave revealed that soluble dietary fibre and β-glucanare of particular interest to the consumers due to their effect on blood cholesterol and blood glucose. Keeping in mind the importance of hulless barley, some varieties have been released in India (Table 2)and breeding work is being in pace way.

Malting quality improvement:

Barley is used for a wide range of end uses. The major portion of the produce is utilized for feed and food purposes and nearly 20-25% of the produce is consumed by the malting industry (Verma*et al.*, 2008). With the growing urbanization, more open economy and changing lifestyles demand for quality malt and malt products has increased in last two decades. Malt is being utilized for brewing, distillation, baby foods, confectionaries, cocoa-malt drinks and medicinal syrups with the major share going to brewing. The annual requirement of barley for malting purposes is on rise in recent years. Though no authentic data are available in this regard, however the rough estimates depending uponthe capacity of the major malting units indicate that total quantity of barley needed annually for malting purposesis nearly 240,000 MT. An expected growth @ 10% perseveral new malting and brewing units are entering inthe field. The malt utilization for different uses has alsochanged in recent years, with an increase in proportion ofmalt being used for brewing and decrease in distillation. The current estimates indicate that now approximately30% malt is used for energy drinks/pharmaceuticals &confectioneries, 8% for whiskies and the balance (around60-62 %) is used by breweries. Research on malt barley improvement in the country was initiated with the several two-row malt varietiesintroductions like Peat land and Pedigree (USA),Manchuria (Germany) and Odessa (Russia) which were evaluated at IARI, New Delhi along with indigenous varieties like Type 4, C 251 and NP 113. These exotic collections were found to be inferior for traits like 1000gw and protein content. Also the differential

requirements for brewer's and distiller's malt were not clear. With rise in industrial demand for malting, malt barley improvement programme was again taken up in early nineties. Two more introductions ALFA 93 and BCU73, both two row, good malt type varieties were released by CVRC in 1994and 1997, respectively, for commercial cultivation in North Western Plains Zone (NWPZ) under timely sown conditions. However, late maturity, weak straw, poor grain filling under heat stress and low yield levels still remained major concern for their popularization among farmers ,in absence of any premium by industry for quality.Some six-row type cultivars were released subsequently (RD 2503 for NWPZ, K 551 for NEPZ and DL 88 for Peninsular Zone) for cultivation under irrigated timely sown conditions having good malting qualities amongst six-row barley. In the mean time minimum standards were also fixed for various malting quality traits of barley grain and malt in India as a guideline to breeders in mid nineties. There are number of grain and malt traits, which are considered essential/important by malting and brewing industries Therefore, it was considered essential to start concerted efforts on development of indigenous malting quality varieties to suit Indian climatic conditions. A 'National Core Group on Malt Barley Development' was constituted in 1995 comprising of barley research workers and industry representatives. The group finalized the minimum standards of barley grain and malt qualities, as a guideline to barley breeder sand all concerned agencies, taking into consideration the European Brewery Convention (EBC),American Malt Barley Association (AMBA) and ISI guidelines during its first meeting in December 1995at Karnal. These standards are being adhered by the programme while selecting / approving any barley variety as malt barley in the network evaluation and release. These efforts resulted in the development of first indigenously bred two-row malt barley variety(DWR28) in the country, which was released by CVRC for commercial cultivation in North Western Plains Zone.

Origin

According to Vavilov (1951) there are two main centres of diversity *i.e.* One group of investigators considered North- East Africa and Mountainous regions of Abyssinia as the principal centre of origin because many diverse forms are available there. This region is particularly rich in two rowed, hulled, awned types which are classified as *occidental type* Another group of investigators considers that possible centre of origin is south eastern Asia, particularly China, Japan, Tibet and Nepal which is characterized by hull-less six rowed varieties with short awn or no awn which grouped as oriental type barley. All the cultivated forms of barley are thought to have originated from a wild species *Hordium spontaneum* a species very similar to the present two-rowed barley.

Adaptation

Barley is a ***rabi*** (winter season) cereal crop having short growing season. The ideal condition for growing barley is moderately dry period for sowing, occasional showers during the growing season and good weather for harvesting. The growing period in the plains lasts for about 5 months. It is grown mainly in the northern plains for malting purpose. It is a hardy crop and is quite suitable for rain fed drought prone areas and sodic condition. In areas of good irrigation and medium fertility soils, malt barley of good quality can be produced.

Area, Production and Productivity

The leading barley producing countries are USSR, China, France, Canada, USA andSpain. The area under barley cultivation in India has been gradually going down as farmersare shifting to more remunerative crops like wheat and gram or cash crops like rapeseed and mustard or safflower. Barley is grown mainly in the northern plains of the country but its cultivation extends up to an altitude of about 4,575 metres in the Himalayas. In India, barley occupied 0.62 m ha area and produced nearly 1.63 m tons grain, with a per hectare productivity of 24.2q/ha during 2014-15. Its greatest concentration is in the states of Uttar Pradesh, Rajasthan, M.P., Punjab, Haryana and Bihar in plains and Himachal Pardesh, Uttrakhand and Jammu & Kashmir in hills. In Haryana barley is grown on an area of 42thousand hectare with a production of 137 thousand tones and average productivity of 3262kg/ha (2009-10). The major barley growing districts are Hisar, Sirsa, Bhiwani, Mohindergarh, Rewari and western part of Jind, Rohtak and Gurgaon.

Classification

Barley can be classified in different groups which are given below:

a) Classification based on arrangement of spikelets on rachis

Aberg and Wiebe (1946) classified all the cultivated barley varieties into three distinct species based on the number of rows of grain and their arrangement:

(i) *Hordium vulgare* L.– six-row barley

(ii) *Hordium distichon* L.– two-row barley

(iii) *Hordium irreglare* L.– two-row barley

Six-rowed hulled and some hull-less barley are generally cultivated in the country. Invery high altitudes in Leh and Kargil with cool arid climate, 6-rowed hull-less type is grownin summer for food. With the demand from malting industry, the introduction and release ofsome 2-rowedimproved barley has also created considerable interest towards their cultivation. The 2-rowed varieties are preferred for malting because of their bold, plump grains, uniform germination, higher malt extract and other desirable traits.

b) Classification based on Awns

Depending on the presence or absence of awns in grains it has been grouped into:

(i) Awned type (ii) Awn less type: Awn less types are also called hooded because of the hood shaped structure that develops in place of awn.

On the basis of nature of awn presence they are sub-grouped into:

(a) Smooth awned (ii) Rough awned.

c) Classification Based on Adherence of Chaff to grains

Barley are grouped into 2 types as i) Hulled (*syn.* husked) type: (ii) hull-less (*syn.* naked) type. In case of hulled barley the husk, *i.e.* floral glumes also called chaff remains attached to grains resulting in poor flour making. In the hull-less type the husk readily falls after threshing and naked grains free of chaff can be collected.

Growth stages

Barley has well defined stages of growth and development similar to wheat as follows:

1) **Germination and seedling stage**: After germination below the soil surface the coleoptiles emerges on the soil surface. This stage is marked by the exhaustion of endosperm and initiation of crown roots. This stage lasts up to 20-25 days after sowing.

2) **Tillering**: The seedling after initial establishment of crown root system starts tillering. In general, two barley produces more tillers than six row barley. This stage of growth continues up to 30-35 days after sowing.

3) **Jointing and booting**: At this stage plant develops its vegetative parts like stem, nodes start multiplying and internodes distance become longer. This stage lasts up to 55-65 days after sowing

4) **Heading**: The flag leaf give rise to emergence of ear head and anthesis begins in the central florets ultimately resulted into milk stage. This stage lasts up to 75-85 days after sowing.

5) **Ripening**: At this stage grain filling and grain development starts resulted into hard dough stage. This phase lasts up to 90-100 days after sowing.

6) **Maturity and drying**: This stage is the final stage in the crop life, plant turn yellowish, loose stiffness and become droopy and becomes ready for harvest.

Climatic requirement

Barley requires cool weather during early growth and warm and dry weather at maturity. It grows reasonably well in temperate as in sub-tropical regions of the world. The optimum temperature at the sowing should be around 22- 24oC. The crop requires around 12-15oC during growing period and around 30oC at maturity. Being drought resistant, barley suits to areas with scanty rainfall. The crop can withstand cool humid and warm dry climates, hot humid climate disfavour its growth, mainly due to prevalence of diseases. It cannot tolerate frost at any stage of growth and incidence of frost at flowering is highly detrimental for yield. Intermitted drought during the growth period results in premature ripening with high nitrogen content and shrivelled grains unfit for malting. Uniform moisture supply and bright sunshine at the ripening are important for the production of clean bright kernels required by the malting industry.

Soil requirement

Sandy to moderately heavy loam soils of Indo-Gangetic plains having neutral to mild saline reaction and medium fertility are the most suitable for barley cultivation. However, thrives well on well-drained fertile deep loam soils. Severe lodging occurs when grown on extremely fertile soils. Its cultivation also extends, although to a limited extent, to medium black soils of Maharashtra and Karnataka. It is more tolerant to alkali and saline conditions than other *rabi* cereals and is grown extensively under such conditions in Rajasthan, Punjab Haryana, Uttar Pradesh and Bihar.

Crop rotation

It is generally rotated with crops, such as pearlmillet, maize, paddy, sorghum, cotton, groundnut, smaller millets, greengram and balckgram in different parts of the

country.Double-cropping with barley is practiced under assured soil moisture or irrigation facilities.Barley is grown pure or mixed with other *rabi* crops, such as gram, peas and lentil.Sometimes, rape and mustard, *taramira* and linseed are also intercropped with barley. Thefollowing are common crop rotations where barley is included: Paddy – barley, Maize – barley, Sorghum – barley, Cotton – barley, Pearlmillet - barley, Groundnut - barley,Blackgram – barley, Greengram – barley, Cowpea – barley, Guar – barley.

Field preparation

Barley requires a well-pulverized but compact seedbed for good and uniformgermination. Two to three ploughings, repeated harrowing, cultivation and planking beforesowing are required to prepare seedbed. Cultivation is essential after effective rainfall toconserve moisture in the soil under rain fed condition.

Sowing time

Sowing time plays a pivotal role in barley production. Under rainfed condition theoptimum time for barley sowing is second fortnight of October, whereas, under irrigatedsituation is better to plant the crop between 15-30th November for harvesting a good crop. High malt content varieties such as BH 393 sowing must be completed between 15-30tNovember otherwise it will affect malt content in grain.. Under late planting the quantity anquality of malt is reduced.

Seed rate

Under irrigated conditions 100 kg/ha seed is required for sowing. However, under late sown condition increase the seed rate by 25%.,

Method of sowing

Sowing method depends upon the moisture content in the top soil. If the moisture is sufficient in the top soil than seed can be sown by kera method, otherwise, it must be planted by pora method. Row to row spacing must be maintained at 22 cm under normal planting, however, under late sown condition it should be reduced to 18-20 cm for obtaining optimum plant population.

Time of Sowing, Spacing & Seed Rate

Production Condition	Seed rate (kg./Ha.)	Time of Sowing	Spacing (cm)
Irrigated Timely sown	100	10-25 November	23
Irrigated Late sown	125	26 Nov.-31 Dec.	18
Rainfed Plains	100	25 Oct.-10 Nov.	23
Rainfed Hilly Region	100	20 Oct.-7 Nov.	23

Varieties

Husk less barley varieties: Karan 3, Karan 16, Karan 18, Karan 19, Karan 750, Karan 757, DL 487 and K 1155.

Hulled barley varieties: Karan 15, Karan 280, NH 87, K 392, DL 472.

Malting and brewing purpose: Alfa 93, BCU 73, DWR 28, DWRUB 52, RD 2668 and DWRB, RD 2552, PL 751, BH 902, BH 393 and RD 2592 (Irrigated), K 560, K 603, RD 2624, RD 2660 (Rainfed), DL 88, RD 2552, NDB 1173, NDB 1020 and NDB 209 (Saline soils)

Nematode resistant variety: Raj Kiran.

Dual purpose Barley variety:

In last couple of years, it was observed that dual purpose barley can be utilized as an alternative source of green forage in the arid and semi arid regions as parts of states like Rajasthan, Haryana, Punjab, M.P. and U.P due to increasing scarcity of green forage availability.

The marginal farmers would prefer to grow barley varieties giving high forage yield for their live stock and food-grain for human consumption, as it is an outstanding source of proteins, vitamins and minerals.

Also in case of hills, most of the farmers are growing barley in apple orchards mainly for utilization as green forage. During the late seventies a few varieties like Azad, K141 and Ratna were recommended for single cut for green forage. The Barley Network took a new initiative during last few years to look at the possibility of utilizing barley as a dual purpose crop to meet the requirements in association with AICRP-FC, Jhansi. It was found that barley crop can be given one cut (at 50-55 days after sowing in plains and 70-75 days after sowing in hills) for green forage and the regenerated crop can be utilized for grain purposes. Already released feed type varieties RD 2035 and RD 2552 have been found equally good to be used as dual purpose. Two more new varieties (RD 2715 for central zone and BHS 380 for NH zone) have been released by CVRC as dual purpose barley as forage cum grain crop.

Dual purpose barley varieties released in India

Variety	Year	Production Condition	Area of Adaptation	Developed at
RD 2715	2008	Irrigated	Central zone	ARS, Durgapura
BHS 380	2010	Rainfed	Northern Hills	IARI, RS, Shimla
RD 2035	1994*	Irrigated	NWPZ	ARS, Durgapura
RD 2552	1999*	Irrigated	NWPZ	ARS, Durgapura

***These varieties were released as grain type earlier but also observed best for dual purpose in northern plains**

There is immense need to continue working on this area to develop better varieties to be used as dual purpose barley. There is also a need for evaluation of the forage quality traits to improve the overall suitability as green forage. Thus barley can serve as supplementary crop for augmenting the green forage demand in the arid/ semi arid areas of northern plains under limited irrigations and in hills under rain fed conditions. It also gives satisfactory levels of grain yield from the regenerated crop, which can also be utilized as feed for cattle or human food. The economics goes in favour of dual purpose crop instead of only grain type in

forage scarcity areas of northern plains. Cultivation of dual purpose barley varieties would prove boon for meeting the forage and food requirements of the farmers for sustaining their livelihood and stabilizing productivity of barley.

Fertilizer management

Barley needs 60 kg N, 30 kg P2O5 and 15 kg K2O/ha under irrigated condition. Applyfull dose of P2O5, K2O and half nitrogen at the time of planting and remaining half dose ofnitrogen should be applied at first irrigation. However, under rain fed situations barley needs30 kg N and 15 kg P2O5 /ha and all the fertilizers should be applied at the time of sowing. Avoid excessive nitrogen application as it leads to lodging which will reduce the grain quality. Application of FYM helps in conservation of moisture.

Fertiliser Application

Zone/State	Production conditions	N: P: K Recommendations9kg/ha)		
		N	P	K
Northern Hill Zone	Rainfed	40	20	20
NWP Zone and NEPZ Zone	Irrigated timely sown	60 90	30 40	20 (feed) 20 (malt)
	Irrigated late sown	60	30	20
	Rainfed	40	20	20 (full basal)
Dual purpose in Plains and Hills	Irrigated/Rainfed	75 60	30 30	20 (plains) 20 (Hills)

Mode of Application

In case of irrigated condition, half of the nitrogen and full dose of Phosphorous should be applied as Basal and remaining half of the Nitrogen should be Top Dressed after first irrigation or 30 days after sowing, while in case of light soils, one third of nitrogen and full dose of Phosphorous should be applied as basal, one third of Nitrogen after first irrigation and rest one third of Nitrogen after second irrigation.

Irrigation management

Due to low water requirement, barley can be grown as a rainfed crop. To harvest good yields, barley requires two irrigations at the active tillering stage (40 - 45 DAS) and the other at the anthesis stage (80 - 85 DAS). One extra irrigation is required only on sandy soils. If the supply of water is inadequate, its efficiency can be increased by a proper timing of its application at the critical stages of growth of the crop. If only one irrigation is available, its application near the tillering stage has proved very profitable. On highly alkali-saline soils, frequent light irrigation gives better results than a fewer heavy irrigation.

Generally Barley crop require 2 to 3 irrigations for better yield. Depending upon the water availability, suitable stages for irrigation should be identified.

Availability of Irrigation	Crop Stage
Two	1st at Crown Root Initiation (25-30 Days After Sowing) 2nd at Panicle Emergence (65-70 Days After Sowing)

One	Tillering Stage (35-40 Days After Sowing)

Barley Based Cropping System

- Barley is mainly grown in Uttar Pradesh, Rajasthan, Punjab, Madhya Pradesh, Haryana, Bihar, Himachal Pradesh, West Bengal and Jammu Kashmir.
- Barley is being grown in three distinct type of soil groups mainly Sandy Loam, Loam and Medium & Heavy Black Soils.
- In sandy soils the crop is mainly grown as irrigated crops after Bajra, Guar, Til, Cotton and Groundnut crops.
- In Loam soils barley is planted after Kharif pulses like Moong, Urd, Maize & Bajra.
- In medium to heavy soils Barley is planted after Soybean , Urd, Groundnut, Maize, Jowar and Small Millets.
- In sonic area Barley is also planted after rice.
- If barley is grown in cereal -cereals rotation i.e. Maize—Barley, Jowar—Barley, Bajra —Barley, Rice—Barley. The nutrient removal is only from upper layer of soil i.e. 6'' depth soil. If such cropping system is followed for longer period, it creates nutrient deficiency & nutrition imbalance. Due to nutrient removal from a particular zone with the soil depth 6'', which ultimately results in poor yield of the cropping system.
- Legume based cropping system helps in proper and efficient utilization of applied fertilizers. In some of the cropping rotation, it has been observed that if Phosphorus is applied during the[Kharif, legume, there is no need to apply Phosphorus to the Barley crop. The same is true for potash.

Some of the crop rotations followed in respect of barley are given as under:-

State	Crop Rotation
Bihar	Sugarcane-Barley, Sesame-Barley, Pigeonpea-Barley
Jharkhand	Sugarcane-Barley, Sesame-Barley, Pigeonpea-Barley
Haryana	Sugarcane-Barley
Himachal	Pradesh Maize-Barley, Rice-Barley
Jammu & Kashmir	Rice-Barley
Punjab	Rice-Barley, Maize-Barley, Cotton-Barley
Rajasthan	Cluster bean-Barley
Uttar Pradesh	Maize-Barley, Rice-Barley, Sorghum-Barley, Pigeonpea-Barley, ugarcane-Barley, Bajra-Barley

Weed management

Weeds generally pose greater problem in irrigated areas, though barley is known to bea good competitor of weeds due to its fast growing habit and high initial vigour.

Bothbroadleaf (*Chenopodium album*) and narrow leaf weeds (*Phalaris minor* and *Avenaludoviciana*) are common in barley. The weed population also depends upon the extent of tillage practices followed prior sowing of barley crop. To prevent losses from weeds, one hand weeding after first irrigation is quite useful. Application of 2, 4-D sodium salt @ 1 kg/ha in 500 litres of water after 1st irrigation (40 DAS) can take care of broadleaf weeds. Broadleaved weeds can also be controlled with the application of Algrip 20 WP (Metsulfuron Methyl) @ 20 g + 500 ml surfactant or Affinity 40DF (Carfentrazone ethyl) @ 50g per hectare in 500 litre of water at 40-45 DAS. Whereas, application of Axial 5 EC (Penoxadene)@1 litre per hactare in 500 litre of water at 40-45 days after sowing can control narrow leaf weeds. For control of mixed weed flora apply Axial 5 EC (Penoxadene) @1 litre mixed with Algrip 20 WP (Metsulfuron Methyl) @ 20 g + 500 ml surfactant or Affinity 40DF (Carfentrazone ethyl) @ 50g per hectare in 500 litre of water at 40-45 DAS.

Type of weeds	Weedicides	Dose/ha	Method of application
Broad leaf	2,4-D	500 g	Spray at 30-35 days after seeding using 400-500 litres of water
	Metsulfuron	4 g	Spray at 30-35 days after seeding using 400-500 litres of water
Narrow leaf	Pinaxaden (Axil)	30-35 g	Spray at 30-35 days after seeding using 400-500 litres of water
	Pendimethilin	1000-1500 g	Spray pre-emergence using 400-500 litres of water
Both Narrow and Broad leaf	Isoproturon	750-1000 g	Spray at 30-35 days after seeding using 400-500 litres of water
	Isoproturon +2,4-D	750+500 g	Spray at 30-35 days after seeding using 400-500 litres of water

Diseases management

Rusts (Puccinia spp.): Black, brown and yellow rusts occur in barley. Rust resistant varieties of barley are: -

Black rust:- Azad, BCU 73, BH 505, BH 508 and HBL113.

Brown rust: - Alfa 93, BCU 73, HBL 113, BH 514, RD 2503, RD 2508 and PL 419.

Yellow rust:- BH 902,C 164, BH 75, Alfa 93, R 2503, RD 2508, PL 419, BH 393.

Seed treatment with Vitavax or Carbendazim (Bavistin) @ 2g or Tebuconazol (Raxil-2 DS) @ 1g per kg seed is quite effective.

Covered Smut (*Ustilago hordei*) is observed at the time of heading. All the ears of diseased plant become infected and all the grains in the ear turn into smut sori. Each smut sorus remains covered by a white, shining, silvery membrane. The membrane may ruptures by mechanical pressure during threshing and release smut spores black powders. For control this diseses infected plants should be rouged out and burnt. Shallow sowing should be followed. Seed treatment with carbendazim (Bavistin) or carboxin (Vitavax) @ 0.2g/Kg seed is quite effective. Resistant varieties K 12, K 18, K 24 and BG 105 should be cultivated.

Stripe Disease (*Dreschlera graminea)* usually occurs at late tillering stage. Narrow yellow stripes initially appear on lower leaves and later appear on the upper leaves also. As the disease progresses, yellow stripes increase in length parallel to the veins and soon turn

reddish to dark brown. Heavily infected leaves mature early which later on dry and give shredded look. The spots also appear on glumes and spike- lets. Seed treatment with Bavistin (2g/kgseed) is quite effective in managing the external seed infection. Foliar spray of Dithane M 45 @ 0.2% at the initiation of disease. Resistant varieties K 12, K 24, K 125, Vijaya, C 164, BG105 and BH 87 should be cultivated

Insect management

There is no major insect in case of barley, however, termite attack is observed in this cropand for its control treat the seed with Chlorpyriphos 20 EC or Formathion 25 EC @ 6 ml /kg ofseed andprepare the solution in 25-30 litres of water for one hectare area, mix the insecticide welln water and spray the solution on the seed and air dry it overnight before sowing

Harvesting

Barley crop gats ready for harvest by the end of March to first fortnight of April. Since barley has shattering character, it should be harvested before over ripening to avoid breaking of spikes due to dryness. Barley grain absorbs moisture from the atmosphere and should be stored at an appropriate dry place to avoid storage pest losses

Barley ears bend downwards when they mature and are prone to be blown off by strong winds and this can cause huge yield losses. It is therefore crucial that the barley must be harvested as soon as it reaches a moisture content of 12.5% in order to minimize the risk of ripe barley being exposed to possible damage by wind and other stress. In malting barley, skinning of the grain is avoided during harvesting. Skinning impairs germination and introduces problems during malting. Thus the combine harvester operation should not be as aggressive as for wheat. The recently released two row malt barley varieties can produce as much as six row feed barley varieties in optimum production conditions.

Chickpea
Cicer arietinum L.

Chickpea probably originated in south-eastern Turkey and spread west and south via the Silk Route. Four centers of diversity have been identified in the Mediterranean, Central Asia, the Near East and India, as well as a secondary center of origin in Ethiopia. It ranks second in area and third in production among pulses worldwide. Globally it is the third most important pulse crop after dry beans (*Phaseolus vulgaris*) and dry peas (*Pisum sativum* L.).

Chickpea, also known as Bengal gram is an important pulse crop of the world. About 70 % of world production of chickpea comes from Asia. It is predominantly grown in cool, dry periods on receding soil moisture after the kharif season. India is the largest producer of chickpea in the world, sharing 65 and 70 % of the total global area and production respectively. The area under chickpea has increased from 6.5 million ha in 1992-93 to 8.6 million ha in 2009-10. Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh and Karnataka are the major chickpea producing states sharing over 95% area. Madhya Pradesh with area of 2.8 M ha and producing 2.6 Mt with productivity of 981 kg/ha, ranks first in area, and production. The national average productivity is 895 kg/ha, which is much lower than the highest average productivity (1800 kg/ha) in Egypt. It is basically a self-fertilized crop in which the flowers fertilize before they open and in rare cases are cross pollinated. The pods are rectangular swollen structure containing 1 or 2 seeds. Its leaves contain Malic and Citric acid which are very useful for stomach ailments and also acts as blood purifier. Nutritionally it is very rich as it contains 17 – 21% protein, 62% carbohydrate and also good source of Ca, Fe and vitamin C and B_1.

The Indian gram has been classified in two broad groups:

i) Desi or Brown gram (*Cicer arietinum)*: In this group the colour of the seed ranges from yellow to dark brown. Seed size is small with good branching habits.

ii) Kabuli or white gram (*Cicer kabulium*): In this group the colour of the seed is white. The yield potential of this group is less than desi gram.

Desi chickpea	**Kabuli chickpea**
The seed coloured ranges from yellow to dark brown	The seed colour is usually white
Seed size is usually small	Seeds are bold and attractive
Yield potential is high	Yield potentially is low
Plants are small and have good branching ability	Plans are generally taller and stand erect
Canopy colour is dark green	Canopy colour is light green
Leaflets are smaller in size	Leaflets are larger than desi gram
2n = 14, 16	2n = 16

Madhya Pradesh has the largest area and production under chickpea followed by Rajasthan and U.P. Nagaland has the highest productivity (1500 kg/ha). In Bihar Gram is cultivated over an area of 57 thousand hectares with a production of about 60 thousand metric tons. The average productivity of gram in Bihar is about 1044 kg/ha. The highest area under gram is in the district of Bhabhua (6.7 thousand ha) followed by Aurangabad, Patna, Bhojpur, Lakhisarai, Nalanda, Rohtas and Gaya. However the maximum production is received from

Bhojpur (7.5 thousand metric tons) followed by Patna, Bhabhua, Aurangabad, Nalanda, Rohtas, Lakhisarai and Gaya.

Climate and soil requirement

Chickpea is usually grown after rainy season on stored soil moisture during winter. It is mainly a winter season crop but severe cold and frost harm the crop. It requires less rainfall and having a deep root system it performs well under dry tracts which receive rainfall within 60 – 100 cm. The crop cannot tolerate water logging, saline and alkaline conditions. It is highly sensitive to saline and sodic soils. A pH range of 6-9 is favourable. Well drained sandy/silty clay loam to deep loam soils of medium fertility is ideal for chickpea cultivation. During its growth the average air temperature varies from 25^0 – 30 ^{0}C. The nights must be warmer with 20 – 25 ^{0}C temperature. The optimum temperature regime for chickpea is 24^0 – 30 ^{0}C. The growing degree days range from 1400 – 1600 at 10 ^{0}C base temperature.

In India two distinct agro climatic regions are identified. During Rabi season of North India, the crop duration is 160 – 170 days. In Peninsular India, where the winters are warm, the crop duration is short (90 – 110). Hence the productivity of chickpea is higher under North Indian conditions.

Growth and development

The germination of chickpea is Hypogeal and it has pubescent leaves (presence of hairs on leaves). Gram is a small herbaceous plant with maximum height of 45 to 60 cm. The leaves are bi-pinnately compound having 9 to 15 pairs of leaflets. The flowers are single axillary recemose having white or pink colour. It is a long day plant and requires 12 – 16 hours of bright sunshine per day. There is no qualitative photoperiodic requirement for flowering in chickpea but flowering is progressively earlier in long photoperiods. Flowers appear 3 – 5 days earlier in unirrigated crop and close spacing. Flowering may continue for 20 – 30 days in crop on stored soil moisture but with irrigation the period may extend by 10 – 15 days. Temperature is more important than photoperiod in determining the length of reproductive period. Higher temperatures usually shorten the crop duration.

Yields are higher where the growing period is long. Crop duration can be extended by a month by applying irrigation leading to large increase in yield. Yield per plant is determined more by the number of pods than by either the number of seeds per pod or the seed size. Pod per plant depends on total number of nodes and on how many of these become reproductive. The Harvest Index of chickpea is usually greater (0.35 – 0.50) than other pulses.

Seasons

In India chickpea is mainly grown during Rabi as rainfed crop on receding soil moisture. Second fortnight of October is the optimum time for sowing chick pea in most of the chick pea growing areas. However under irrigated condition middle of November is the optimum time. If the temperature is more than 30°C then chickpea should not be sown as it will lead to high vegetative growth and increase the incidence of wilt. Early sowing of chick pea results in excessive vegetative growth and poor setting of pods. The optimum time for sowing of Kabuli chickpea is the end of October to first week of November.

Tillage

Very fine and compact seedbed is not good for chick pea. If requires a loose and well aerated seedbed. Where chickpea is sown after Kharif rice, land preparation is a problem. Under such situations, tillage is only restricted to harrowing in order to break open the surface soil followed by planking to break the clods. Since the time gap between the harvest of the kharif rice and sowing of the gram crop is very less, minimum tillage is the only option.

Seeds and Sowing

Chickpea has wide variation in seed size from 12 to 40 g per 100 seeds. Small seeded varieties require less seed in comparison to large seeded varieties. Drilling or sowing behind the furrow is preferred. A row spacing of 30 cm in Desi types and 40 – 45 cm in Kabuli types should be used with plant to plant spacing of 10 cm. Under late planting conditions (December) in irrigated areas spacing should be 25 cm. Seeding depth under rainfed conditions is 8 – 12 cm while under irrigation it is 5 – 8 cm. Generally 10 cm depth of sowing is optimum. For timely planting of desi type, 40-45 kg seed per ha is adequate, however for bold seeded varieties a seed rate of 75-80 kg seed per ha is optimal. In case of kabuli types the optimal seed rate is 80 - 100 kg per ha. Under late planting conditions, the seed rate should be increased by 20-30% (50-55 kg/ha) so as to compensate the per plant yield loss. The optimum plant population is around 33 plants/m^2 under rainfed condition and 55 plants/m^2 under irrigated condition. When sowing time is delayed and the time to flower is shorter, an increase in plant population will generally increase the yield under no stress condition.

Nutrient management

Chick pea being a leguminous crop fulfills the major part of its nitrogen requirement (about 75%) through the process of symbotic nitrogen fixation which works effectively from three to four weeks after sowing. However, soils with low organic matter and poor nitrogen supply may require 20-25 kg per hectare of nitrogen as starter does which can meet plant requirement before the formation of nodules. Besides nitrogen, pulses respond very favourably to phosphorous application if the soils are deficient in phosphorous supply. If both nitrogen and phosphorous are required to be supplied then diammonium phosphate (18-46-0) at the rate of 100 to 150 kg per hectare should be applied uniformly before the last disk ploughing. Responses to potassium application have been inconsistent. It is better if all the fertilizers are drilled in furrows at a depth of 7-10 cm.

Water management

Chick pea is mostly sown as a rainfed crop. However, where irrigation facilities are available, a pre-sowing irrigation is beneficial. It will ensure proper germination and good crop growth. If winter rains fail, one irrigation at pre-flowering (45 to 60 DAS) stage and one at pod development stage is very much effective. Under adequate irrigation facility and light soil condition four irrigation (sowing, branching, pre-flowering and pod filling) can be applied. Chickpea should not be irrigated at flowering stage otherwise flower drop may take place. A light irrigation should be given because heavy irrigation is always harmful to gram crop. Excess of irrigation enhances vegetative growth and depresses chick pea yield. The water requirement varies from 300 to 400 mm. Scheduling irrigation at IW/CPE ratio of 0.4

or at 50 percent DASM is adequate for optimum yield. Chickpea is usually irrigated by check basin method of irrigation. Kabuli chickpea needs a little more irrigation.

Weed control

Chickpea suffers severely by infestation of weeds. The dominant weed flora associated with chickpea crop are *Chenopodium album, Melilotus indica, Lathyrus aphaca, Medicago denticulata*, *Trigonella polycerata, Polygonum, Euphorbia* and *Anagallis arvensis*. One hand weeding or inter culture with hand hoe or wheel hoe after 25-30 days and second if needed after 60 days of sowing may take care of weeds. Fluchloralin (Basalin) 1 kg per hectare in 800-1000 liters of water as pre-planting spray may be used as an effective herbicide. It should be well incorporated in the soil before sowing. Other pre emergence herbicides include Pendimethalin, Isoproturon and Pendimethalin + Imazethapyr. Hand weeding at 45 DAS or inter culture with the help of hoe facilitates aeration in the soil.

Seed treatment

For nodulation and nitrogen fixation, the seed must be treated with specific Rhizobium culture before sowing. The seeds are treated with *Bradyrhizobium sp*. cicer for better nodulation. The inoculation should be done 10 to 12 hours before sowing. To inoculate 10 KG seed, 100 g Gur is to be added in 1 L of water followed by heating up to prepare homogeneous mixture. After cooling the mixture at room temperature, one packet of Rhizobium culture is added in it and mixed up thoroughly. Rubbing this mixture of the culture solution on seeds provide a uniform thin coating all over. After drying in shade for about 6 to 8 hours seeds can be used for sowing.

Nipping

It is the process of plucking the apical buds of the crop at about 30 – 40 days after sowing. Nipping stops the apical growth and promotes lateral branching, thus the plants become more vigorous and produce more flowers and pods and increases yield per plant. However Kabuli types are self branched and do not need nipping.

Cropping system

Chick pea is sown after the harvest of kharif crops. Chick pea in rotation with cereal crops help in controlling soil borne diseases. The most common cropping systems are as below:

1. Rice-Chick pea
2. Pearl millet-Chick pea
3. Sorghum-Chick pea
4. Maize-Chick pea

Expansion of short duration varieties of chickpea in the non-traditional areas/rice fallows to ensure double cropping systems.

Intercropping:

1. chickpea + mustard
2. chickpea + linseed
3. chickpea + sunflower or chickpea + Coriander

Varieties

Samrat, JG 14, PG – 186, Aparna, JCP 105, Radhey, Avrodhi, L550, Pusa 240, Pusa 256, BR 168, GCP - 105, DCP-92-3

Kabuli types: JGK 3, Pusa shubhra, KAK 2, Phule G 0517, Pusa 1003, Subhra.

Harvesting and Storage

Chickpea takes about 150 days for maturity. The plants are pulled out or cut with a sickle and carried to threshing floor. After sun drying for about a week, it is threshed under the feet of cattle or by beating with sticks. Clean dry seeds are stored similar to other pulses.

Diseases management

1. **Ascochyta Blight** (*Ascochyta rabiei*): This disease appears on leaf blade, petioles, flowers, pods, branches and stem in the form of brown spots. Disease spreads rapidly in the field and field gives the burnt appearance.The disease is both externally and internally seed borne. For control of blight, seed treatment with Bavistin or Captan @ 2.5 g/kg seed and spray of Dithane M-45 @ 0.2% at the initiation of the disease.
2. **Wilt** (*Fusarium oxysporum f. Sp. Ciceri*): The disease appears on 3-6 weeks old seedlings in susceptible varieties. Petioles, rachis and leaves turn yellow and become straw coloured. For the control of wilt deep ploughing during the summer months and destruction of diseased debris. Crop rotation with non leguminous crop and do not sow the crop before 10th of October. Seed treatment with Bavistin @ 2.5 g/kg seed. Seed treatment with *Trichoderma viride* (Bioderma) @4g + Vitavax @1g by making a paste in 5 ml of water per kg seed is also effective.
3. **Root Rot or Collar Rot** (*Rhizoctonia solani*, *Fusarium solani*, *Sclerotium rolfsii*): The symptoms are sudden and complete wilting of the plants. The disease appears at any crop stage. The initial symptom appears as dark brown spots around the stem at the soil level by *R. solani*, whereas in case of *F. solani*, spots are yellowish in color and ultimately plant wilts. Seed treatment with Bavistin @ 2.5 g/kg seed is advised for its control.

Insect management

1. **Termites** (*Microtermos obesus*): Termites damage the crop from sowing to maturity. The damaged plants dry up completely and are easily pooled out. The damage is generally more in low irrigated light soil areas. For control treat the 100 kg seed with 850 ml Monocrotophos 36SL or 1500 ml Clorpyriphos 20 EC make the total solution of 2 litre by adding water and then after spreading the seed on polythene sheet or floor, mix solution with seed.
2. **Cut worms** (*Agrotis sp.*): The caterpillar of this pest are polyphagus in nature and causes the damage by cutting the stem or branches of growing shoot. For control spray 200 ml Fenvalrate 20 EC or 125 ml Cypermethrin 25 EC or 225 ml Decametharin 2.8 EC by mixing in 500 litre of water per hectare.
3. **Pod borers** (*Helicoverpa armigera*): The borers of this pest are greenish or yellowish in appearance, which generally feed on the leaves, buds and pods. These completely destroy the crop by eating the grains developing in size of the pods. For control spray 1 liter Quinalphos 25 EC or 1 kg Carbaryl 50 WP or 500 ml Monocrotophos 36 SL or 200 ml Fenvalerate 20 EC or 300 ml Cypermetharin 10EC or 375 ml Decametharin in

250 litre of water per hectare as and when average one caterpillar per metre row length of plants at 50 % pod formation stage is noticed. Repeat second spray after 15 days.

Lentil

Lens culinaris

Lentil or masur is one of the oldest crops that originated in near East and Mediterranean region. The cultivated lentil is supposed to be originated in Central Asia. It is the fourth most important pulse crop of the world after beans, pea and chickpea. It is used as a cover crop to check the soil erosion in problem areas. The plants are ploughed back into the soil as green manure. It derives the name Lens from the lens shaped seeds. It is a rich source of protein (26%). Lentils are relatively tolerant to drought and are grown throughout the world. It is mixed with wheat flour in bread and cake production. It is also ground into flour to make variety of preparations. It is also used in preparation of several snacks and sweets. The dry leaves and stems, empty pods and broken bits all are used as cattle feed. Lentil residues form important livestock feed. Lentil has high Saponin content (3.7 – 4.6 g/kg seed) which reduces the cholesterol level in blood.

Globally lentil shares only 5% of the total area under pulses. Lentils are relatively tolerant to drought and are grown throughout the world. Asia accounts for 65% of the world production. India accounts for about 40% of the global production. Globally Canada is the leading lentil producing country. It is grown throughout northern and central India. Major lentil producing states are U.P, M.P, Bihar and W.B. these states account for about 95 % area and production in the country.

Two types of lentil are known: Macrosperma (Masur) with large flat pods and large seeds (6-9 mm diameter) found in the Mediterranean, Africa and Central Asia and Microsperma (Masuri) with small convex pods and small seeds (2-6 mm diameter) mainly found in India, Pakistan and South West Asia.

In Bihar the total area under lentil crop is 1.77 lakh ha with a production of 1.50 lakh ton. The average productivity of lentil in Bihar is about 898 kg/ha. The highest area under lentil is in the district of Patna (29 thousand ha) followed by Nalanda and Bhojpur. The maximum production is received from Patna (30 thousand metric tons) followed by Nalanda and Bhojpur. The productivity of lentil in these districts ranges from 1120 – 1300 kg/ha.

Botanical description

It is a herbaceous annual plant mostly erect and bushy type with four to six primary branches. It grows not more than 50 – 60 cm in height. Leaves are small, compound and pinnate. Small sessile leaflets occur in pairs of five to seven. The end of leaflets sometimes form tendrils. The inflorescence is a raceme of two to four flowers. The pods contain mostly two seeds. The crop is generally self-pollinated. The number of pods per plant may vary from 17 to 500 depending on the type of genotype. The 100 seed weight varies from 1.07 to 8.05 g.

Soil requirement

Lentil can be grown on a wide range of soils ranging from light loamy sand to heavy clay soil in northern parts and in moderately deep, light Black soils in Madhya Pradesh and Maharashtra. Well-drained loam soils with neutral reaction are best for lentil cultivation. Lentil cannot be grown on acidic soils.

Season

It is a cool season crop and a long day plant. It requires cold temperature during its vegetative growth and warm temperature at the time of maturity. It is very hard and can tolerate frost and unlike chickpea remains unaffected by rains at any stage of its growth. Optimum temperature regime for growth and development is 15 – 30 ^{0}C. It can tolerate cold however temperature less than 10 ^{0}C delays germination with reduced vegetative growth. As lentil can establish well with minimum tillage it is mainly confined to marginal lands. One ploughing followed by one or two harrowing is adequate for optimum seed germination. Optimum seeding time is from October first fortnight to November first fortnight. It is also grown as relay crop. The seed is broadcasted in standing rice crop a week before its harvest. Late sowing require a seed rate of 50 – 60 kg/ha with a closer spacing of 20 × 5 cm. optimum seeding depth is 3 to 4cm.

Crop rotation

Lentil is generally grown as rain fed crop during Rabi after rice, maize, Pearl millet, sorghum and cotton. It is grown as an inter-crop in autumn planted sugarcane. Two lines of lentil may be sown 30 cm apart in the centre of two sugarcane rows. In north-eastern plains it is also grown as utera crop after rice. Intercropping of linseed + lentil (2:1), lentil + mustard (4-6:1) in regions of UP is also promising. Lentil is relatively more shade tolerant than chickpea. Hence it performs better in mixed and intercropping system.

Field preparation

Soil should be made fraible and weed free so that seeds could be placed at a uniform depth. In case of light soils, less tillage is required to prepare an ideal seedbed. In heavy soils after harvest of kharif crop 1 deep ploughing followed by 2 to 3 Cross harrowing should be given. After harrowing the field should be levelled for better irrigation. There should be proper moisture in the soil at the time of sowing for proper germination of seeds. In utera/paira cropping system of rice - lentil, seeds are sown in standing rice crop and therefore no tillage is required.

Seeds and Sowing

The seed is sown in second fortnight of October under rain fed condition. However it can be sown in the month of November in irrigated areas. Under late sown condition the seeds can be sown up to first week of December but under late sowing condition 20% grain yield reduction takes place compared to normal sowing. Optimum seed rate is 50 kg/ha for macrosperma when sown at optimum time with a spacing of 30 ×10 cm. Late seeding requires higher seed rate of 80 kg/ha and closer spacing of 20 × 10 cm. Microsperma for timely sown requires a seed rate of 30-40 kg/ha with a spacing of 30 × 5 cm. Late sowing require higher seed rate of 50 – 60 kg/ha with a close spacing of 20 × 5 cm. Treat the seed with Benomyl or Aagrosan GN @ 2 g/kg of seed before sowing. The lentil seed should be treated with rhizobium culture before sowing.

Nutrient management

A starter dose of 20-25 kg Nitrogen /ha is adequate to meet the needs of crop till nitrogen fixation is initiated. For most of the situations 50-60 kg P_2O_5 /ha is optimum. Lentil is highly susceptible to zinc deficiency especially after rice crop. An application of 25 kg

$ZnSO_4$ /ha in rice can meet the zinc need in lentil crop, otherwise foliar application of 0.5 % $ZnSO_4$ is advised in the standing crop.

Weed management

Weeds do much harm to the lentil crop. It is slow growing in early stages and, therefore, suffers adversely from competition with weeds. The first weeding is done 25 -30 days after sowing and the second when the crop is 40 -45 days old. The important weeds which infest lentil crop are bathua (*Chenopodium, alhum),* gajri *(Fumaria parviflora),* Chatrimatri *(Lathyrus sp.),* ankari *(Vicia sativa),* kateli *(Cirsium arvense*), and senji (*Melilotus alba*). Lentil crop is poor weed competitor due to slow initial growth. The first 45 to 60 DAS is the critical period of weed competition. The major weeds found in lentil fields are

Hand weeding at 30 and 60 DAS is the traditional practice. Pre emergence herbicides such as Pendimethalin (1.0 – 1.5) can effectively control the weed in lentil crop.

Water management

Lentil crop is usually grown during Rabi on stored soil moisture. If seeded early (November) there is no need for irrigation. Flower initiation and pod development stages are critical stages for water deficits. In general 1st irrigation should be applied at 45 DAP and second if needed at pod filling stage. The crop may be given one to two light irrigations at flower initiation and pod development stage. The crop needs about 90 – 100 days to mature from October/December to February/March and produces about 8 to 9 q/ha under rain fed and 12 to 18 q/ha under well fertilised irrigated condition.

Varieties

HUL – 57 (1092 kg/ha), Moitree (1083 kg/ha), KLS – 218 (1051 kg/ha), IPL – 81 (1040 kg/ha), PL – 06 (1369 kg/ha), NDL – 1, DPL – 62, Jawahar Lentil 3, VL Masoor 125.

Harvesting and Yield

The crop matures in 100-160 days depending upon the variety, climatic condition, soil fertilizers, etc. The leaves turn reddish-brown and the plant becomes dry. The pods also turn reddish brown. When pressed with thumb or finger, the pods open and seeds come out. The plants and pods should not be allowed to become too ripe, otherwise a large quantity of produce may be lost due to shattering. The crop should be harvested in the morning hours when dew is there and the shattering of seeds may not take place. The plants are usually cut with a sickle from 7-10 cm above the ground. The harvested plants should be left in the sun for drying before threshing. For safe storage the moisture content of seeds should be brought down to 12%.

Peas

Pisum sativum

The field pea is believed to be native of the Mediterranean region of southern Europe and South western Asia and India. In India it is cultivated mainly in Uttar Pradesh, Madhya Pradesh, Bihar, Punjab, Haryana and Delhi. It is grown for both vegetable and pulse purpose and is a highly remunerative crop.

Pea is an annual herbaceous plant of leguminoceae family. The plants are succulent and erect in case of garden pea with height of 30 to 45 cm while it is 50 to 75 cm in case of field pea. Plants of garden pea remain erect while in case of field pea they have a tendency to climb. Plants bear taproot system with nodules on the surface. The leaves are compound with three pairs of leaflets and terminal one is modified into a branched tendril. The flowers are arranged in the form of axillary receme. The flowers may be reddish, purple or white. They are self pollinated and develop into 5 to 9 cm long cylindrical pods containing 5 to 11 seeds.

Two types of peas are commonly grown in India. The garden pea (*Pisum sativum*var var hortense) is green coloured wrinkled seeded sweet in taste and used for table and canning purpose. Young green pods are plucked and sold in the market.

Another type of pea is grain type used for pulse and popularly known as field pea (*Pisum sativum* var arvense). The seeds are round, hard and whitish in colour. The plants are very hardy and resistant to drought and frost.

The inflorescence of pea is known as axillary receme. The maximum area under pea cultivation is in U.P.

Climate and soil

The crop prefers about 22 to 25°C at the germination stage and moderately lower temperature of 15 to 18°C during flowering and fruiting period. High humidity associated with cloudy weather results in spread of fungal disease like damping off and powdery mildew.

Pea needs medium soil type ranging from Sandy to clay loam and free from soluble salts. The soil must be well-drained as water logging is extremely harmful for growth and development and even survival of the crop. The crop grows well under neutral soil pH of 6.5 to 7.5.

Land preparation

The soil must be free from weeds and stubble's of kharif crop grown earlier. The bed should be thoroughly levelled specially in case of irrigated condition of proper distribution of irrigation water.

Fertilizer management

For an ideal crop it is recommended to apply about 15 to 20 tons of well decomposed organic manure like compost or FYM in case of very light soils supplemented with 15 to 20 kg N/ha, 60 to 80 kg P, 20 to 30 kg K and 15 to 20 kg zinc sulphate (once after three years)

per hectare. The entire quantity of manures and fertilisers should be basal placed about 10 to 15 cm deep in furrows.

The garden pea respond to higher doses of nitrogen and therefore the crop should be supplied with 60 to 80 kg N per hectare along with other nutrients. Besides application of fertilisers and manure it is essential to treat the seeds with a suitable Rhizobium culture for better nodulation, plans vigour and higher grain yield. Besides major elements application of about 30 kg sulphur per hectare has been found beneficial in getting higher yields.

Water management

The soil should have sufficient moisture at the time of sowing for proper germination. The crop after germination needs two light irrigations at 45 to 50 days and 75 days after sowing or first at flowering and second at pod filling stage of the crop. The water requirement of peas is about 154 mm water. The crop may be given additional light irrigations when frost is expected so that it may not be damaged with frost. Whenever one irrigation is available the crop should be irrigated at preflowering stage.

Weed control

The pea field should be free from weeds for the period up to 40-50 days after sowing. The major weeds found in pea crop are Chenopodium album (bathua), Fumaria parviflora (gajri), Lathyrus spp. (chatri-matri), Melilotus alba (senji), Vicia sativa (ankari). The field should be kept free from weeds by giving two weedings and hoeings after three and six weeks of germination. This competition may be minimised or avoided by giving two hand weeding at 20 and 45 days after sowing. Application of Basalin at 0.75 kga.i./ha as pre-plant soil incorporation or Tribunil at 2.5 kg per hectare as pre-emergence spray may be used to control weeds. Fluchloralin (Basalin) at the rate of 0.75 kg a.i. per hectare in 800-1000 litres of water as pre-planting spray may be used as an effective herbicide. It should be well incorporated in the soil before sowing.

Crop rotation

Field pea is sown as rabi crop. The most common rotations are: Maize-field pea, Rice – field pea,Cotton-fieldpea,Sorghum-fieldpeaandPearlmillet-fieldpea.It is generally grown mixed with chickpea, barley, wheat, oats, rape and mustard crops. It is also grown as an intercrop in autumn sugarcane. Two rows of field pea may be sown 30 cm apart in the centre of two sugarcane rows sown at 90 cm spacing.

Sowing time

The pea is generally sown in India in rabi season from the beginning of October to mid of November in the plains and from middle of March to end of May in the hills. In case of early sowing, special care should be taken against stem borer. It should be sown when daily maximum temperature is below 30°C and the daily minimum temperature comes down to 20°C.

Seed rate and Method of sowing

The early maturing varieties are given closer spacing and higher seed rate and the late varieties are given wider spacing and lower seed rate. In case of early maturing dwarf varieties crop should be sown in rows 20 cm apart and about 100-125 kg seed per hectare should be sown. In late maturing and taller varieties a row spacing of 30 cm is optimum. The seed rate should be reduced to 75-80 kg per hectare. It may be sown by dibbling or behind the plough. The recommended seed rate for pea is 60 - 80 kg/ha. The pea crop needs cool and dry climate for its growth. The seeds should be treated with Rhizobium inoculation of Rhizobium leguminosarum.

Varieties

Ambika (IM – 9102), Aparna, Arkel, Azad (P – 1), HFP – 9907 B, Malviyamatar – 15 (HUDP – 15), Rachna. Arkel and Asauji are varieties of *Pisum sativum var. hortens* while Rachna and Harbhajan are varieties of *Pisum sativum var. arvense*.

Field pea		**Garden pea**	
Name	**characteristics**	**Name**	**characteristics**
T – 163	Duration 130 - 150 days. Yield 20 – 25 q/ha.	Arkel	Pod picking starts 55 – 60 DAS. Yield 70 – 100 q/ha in 3 pickings.
BR – 12	Duration 150 - 160 days. Yield 20 – 25 q/ha.	Bonneville	Pod picking starts 80 – 85 DAS. Yield 130 – 140 q/ha green pods.
Aparna	Resistant to powdery mildew. Yield 25 – 30 q/ha.	Asauji	Pod picking starts 55 – 60 DAS. Yield 90 – 110 q/ha green pods.
Harbhajan	Matures in 90 – 100 days. Yield 15 q/ha.	T – 19	Pods may be plucked 75 DAS and takes 120 days to mature. Yield 80 – 100 q/ha.
Rachana	Resistant to powdery mildew. Duration 122 – 130 days. Yield 22 – 30 q/ha.	Early December	Pod picking starts 55 – 60 DAS. Yield 80 – 100 q/ha green pods.

French bean

Phaseolus vulgaris L.

French bean (Phaseolus vulgaris L.) also known as rajmash, rajma, haricot bean,kidney bean, common bean, snap bean and navy bean is a legume plant. It is valued for itsprotein rich (23%) seeds. Seeds are also rich in calcium, phosphorus and iron. The fresh podsand green leaves are used as vegetable. The anti metabolites of dry beans need removal bycooking and soaking in water.

Origin

Vavilov (1951) reported Mexico and Central America as the primary and Peruvian Ecquadrion-Bolvian region of South America as the secondary center of French bean.Brazil is the leading producer of french beans. Columbia, USA, Canada, Ethiopia, China and Turkey are other leading countries producing french bean. In India, it is grown onan area of about 1 lakh ha mainly in the states of Maharashtra (60,000 ha), Jammu andKashmir (10,000 ha), Himachal Pradesh and Uttar Pradesh Hills, Nilgiri (Tamil Nadu) andPalni (Kerala) hills, Chickmagalur (Karnataka) and Darjeeling hills (West Bengal).

Biological description

It is an annual herbaceous plant with determinate or indeterminate growth habit. The plant produces tap root system. The leaves are trifoliate slightly hairy with long petioles. The flowers are complete and self pollinated. The pods are flat and narrow gaining size up to 20 cm × 1.5 cm which may bear up to 10 seeds. The seeds are oblong globular or kidney shaped.

Climatic requirement

Major french bean producing areas are located in tropical and temperate regions witha temperature around 21°C. The optimum temperature for better growth is 16-24°C. Growthof plant ceases if temperature falls below 10°C. Temperatures above 35°C cause dropping ofbuds and flowers resulting in poor yield. It is highly susceptible to frost. The crop is generallyraised in areas receiving 50-150 cm annual rainfall. Water logging at any stage adversely affects its yield. Rains cause flower drop and spread of leaf spot diseases.

Soil requirement

French bean grows on a variety of soils ranging from light sand to heavy clay, butwell drained loams are the best. Soil pH around 6 – 8.5 is optimum. The crop is sensitive tosalinity. Soil havinghigh amount of organic matter promote more vegetative growth.

Field Preparation

Crop requires fine seedbed and adequate soil moisture for good germination. A deepploughing followed by 2-3 harrowings and planking is adequate to obtain required tilth.

Sowing time

French bean is grown in kharif and rabi seasons in different parts of the country. Theoptimum time of sowing in rabi season varies from state to state. For Haryana 10-20September is the optimum sowing time for higher yield. In early sowing the plant die due

tohigh temperature and in delayed sowing after 20thSeptember, there is yield reduction due tolow temperature and frost at the time of pod formation and grain filling stage. It is first andsecond fortnight of November for central Uttar Pradesh and north Bihar. For early varieties, October end isthe optimum, while late varieties can be sown up to mid November. In kharif, mid May– midJune is ideal.

Seed rate and spacing

Seed rate varies with seed size. Bold seeded varieties with a test weight of 350-450 g need 120-140 kg seed/ha, while in small seeded varieties, it varies from 80-100 kg/ha. The seed rate in intercropping may vary with row proportions. French bean is generally sown in rows 30 cm apart. The Plant to plant spacing is 15 – 20 cm. For obtaining good yield, its plant population should be 2.5-3.0 lakh plants/ha. The optimum depth of sowing is 5 – 7.5 cm.

Fertilizer requirement

French bean lacks biological N fixation because of poor or no nodulation. Hence, it needs liberal N fertilization 100-120 kg/ha. The crop requires 60 kg P_2O_5, 20 KG K_2Oand20 KG S per ha. The field should be supplied with 15 to 25 t of organic manure for better yield. There is no nodulation response for Rajma crop as no suitable strains of Rhizobium is available. Seed inoculation with P. S. B (Bacillus polymixa and B. megaterium) gives better response.

Irrigation management

French bean has shallow root system and hence moisture stress at any stage is detrimental to its performance. As a rainy season crop, it does not require irrigation, when rainfall distribution is even throughout crop cycle. However, rabi crop requires irrigation. The irrigation should be avoided at flowering stage to avoid flower shedding. Irrigation at 25 days after sowing (DAS) is critical. In north-east plains zone, 3 irrigations at 25, 75 and 100 DAS and in central zone, 4 irrigations at 25, 50, 75 and 100 DAS are necessary for optimum crop performance.

Weed mamagement

French bean suffers severe competition from weeds in initial stages. First 30-40 days after planting is the critical period for crop weed competition. One hoeing at 20-25 DAS and second at 40 -45 DAS are found beneficial. Pre-emergence application of pendimethalin @1.0 kg/ha or pre-plant incorporation 1.0 kg/ha of fluchloralin have been found effective in controlling weeds.

Crop rotation

In rabi, intercropping of potato + french bean (3:2 ratio) is being practiced in central and eastern Uttar Pradesh and northern Bihar. Intercropping of French bean with Rabi maize (2:2 ratios) is productive. French bean +linseed (2:1) are also found to be an efficient cropping system.

Varieties

Udai 14, Malviya, Rajmash 15 (HUR – 15), Malviya Rajmash 137 (HUR – 137), VL – 63. Duration : 110 – 130 days. Yield: 1.8 – 2.5 t/ha.

Lathyrus

Lathyrus sativus L.

Lathyrus is also known as Chickling pea or Grasspea. It is an important crop of India, Bangladesh, Pakistan, Nepal and Ethiopia. It belongs to the family leguminosae. It can tolerate drought and can be grown in areas with average annual reciprocation of 380 to 650 mm. This crop can also tolerate water logging to some extent. It is basically grown on poor soils as well as heavy clay soils. It is often broadcast standing rice crop 1 to 2 weeks before the rice crop is ready for harvest.

Excessive consumption of grasspea can lead to neurological disorder called Lathyrism in man and domestic animals when at least 30% of the calorie intake for a period of 3 to 4 months include grasspea.

Economics

Lathyrus is the third important cool season pulse crop in India occupying an area of 0.52 mha with annual production of 0.35 mt. It's cultivation is mainly concentrated in the states of Madhya Pradesh, Chhattisgarh, Maharashtra, Bihar and West Bengal. About 70% of the acreage is concentrated in Chhattisgarh and Vidarbha region of Maharashtra. This is a mainly rice growing area having canal irrigation for rice and no water is available for winter crops. Under this situation it resists extreme harsh condition of excessive moisture at sowing and moisture stress at later stages of crop growth making lathyrus as the only alternative.

Lathyrus production scenario in different states of India during 2009 – 10.

State	Area (000 ha)	Production (000 t)	Yield (kg/ha)
Bihar	87.1	82.2	944
Madhya Pradesh	43.4	31.7	730
Maharashtra	9.9	4.3	434
West Bengal	28.1	19.7	701
Chhattisgarh	280.9	175.6	625

The area under lathyrus has declined over the years of cultivation.

Research program on identifying the neurotoxin in lathyrus and eliminating or reducing it was initiated two approaches:

i) the development of varieties of lathyrus which are either low or completely free of ODAP through breeding.

ii) The detoxification of dal through leaching as ODAP is a water-soluble compound. About 90% of neurotoxin is known to seep out into boiling water bath the process has limited practical scope because marketing of detoxified seeds is not possible as well as keeping quality is also hampered.

Recently three varieties have been identified with low ODAP (ß-ODAP (ß-N-oxalyl-L-∞,ß-di aminopropionic acid) content which are Ratna (Bio L 212), Prateek (LS 157 – 14) and Mahateora (RLS 4595). These varieties have been developed with yield level of 1.2 - 1.5 t/ha and low neurotoxin level of (0.1%).

RAPESEED AND MUSTARD

Botanical Name: *Brassica* spp.

Family: Brassicaceae (Cruciferae)

Rapeseed and mustard are the third most important edible oilseed crops of the world after soybean and oil palm. The seeds of rapeseed-mustard are used as spices, preparation of raita, pricles etc. Rapeseed-Mustard oil used mostly as edible vegetative fat. Poor quality oil is used for lubrication, lightning and preparation of soap, resin and paints. Rapeseed-Mustard cake is used for cattle feed, poultry feed and raw quality cake is used as organic manure. Rapeseed and mustard comprise of 6 species as given below.

1. Indian mustard (*Brassica juncea* L.)
2. *Toria* (*B.rapa* L. ssp. *toria*); Yellow *sarson* (*B.rapa* L. ssp. Yellow *sarson*); Brown *sarson* (*B.rapa* L. ssp. *Brown sarson*). *B.rapa* is synonym to *B. campestris*
3. *Gobhi sarson* (*B. napus* L.)
4. *Karan rai* (*B. carinata* Brown)
5. Black mustard (*B. nigra* (L.) Koch)
6. *Taramira* (*Eruca sativa* Mill.).

Differences between Yellow sarson and Brown sarson

Character	Yellow sarson	Brown sarson
1.lowermost 1–2 leaves	Lamina prominent upto very base of leaf	Lamina practically absent in the basal half
2.Colour, texture of leaf	Dark and fleshy	Pale and thin
3.Corolla	Petals narrow spaces between each other	Petals broad generally overlap each other
4.Anthers	In bud and open flower all 6 anthers introrse	In bud all 6 authers- introrse but in open flower 4 median stamens – extrorse
5.Siliqua	Thick and broad	Thin and narrow
6.Grain	White or yellow, non-mucilaginous	Dark- reddish brown ,brown; mucilaginous
7.Maturity	One week later in flowering and maturity	One week earlier in flowering and maturity.

Differences between Brown sarson and Toria

Character	Brown sarson	Toria
1.Leaves and stem	Al least the flower leaves hairy and so also the lower part of the stem, leaves are thin.	Leaves and stems – glabrous, leaves are somewhat fleshy.
2. Grain	Mucilaginous more dark coloured seeds	Non-mucilanious, lighter coloured seeds
3. Maturity	15 days late in flowering and maturity	15 days earlier in flowering and maturity

These crops are grown under a wide range of agro-climatic conditions. Indian mustard is the most important member of the group, accounting for more than 70% of the area under

rapeseed-mustard, followed by *toria*, yellow *sarson* and brown *sarson*. *Taramira* is raised on very poor sandy soils with low rainfall. Mustard and *sarson* group of plants, however, are grown both on sandy and heavy soils under irrigated as well as rainfed conditions. These crops are commonly cultivated in areas of marginal and submarginal productivity, either mixed or intercropped with wheat, barley, gram, pea, sugarcane, lentil etc. In areas of advanced agronomy, they are chiefly grown as pure crop.

The oil content varies from 37 to 49%. The seed and oil are used as condiment in the preparation of pickles and for flavouring curries and vegetables. The oil is utilized for human consumption throughout the northern India, in cooking and frying purposes. It is also used in the preparation of hair oils and medicines. It is used in the manufacture of greases. The oil cake is used as feed and manure. Green stem and leaves are a good source of green fodder for cattle. The oil cakes contain 'sinigrin', that causes palatability problem due to its bitter taste, and glucosinolate that limits use of oil cake as protein supplement. The leaves of young plants are used as green vegetables as they supply sulphur and minerals in the diet. In the tanning industry, mustard oil is used for softening leather.

Origin

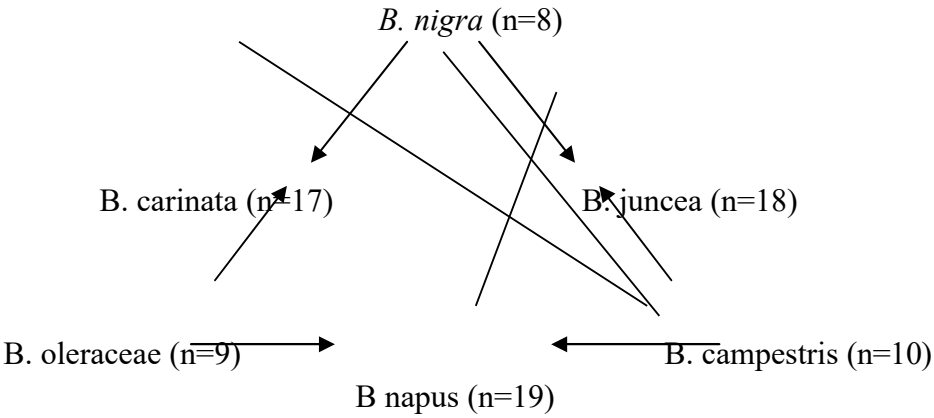
Brassica juncea is the oldest cultivated amphidiploid, and is believed to have originated from *B. rapa* and *B. nigra* in Asia minor and southern Iran. Song *et al*. (1988) based on RFLP (Restriction Fragment Length Polymorphism) studies suggested two centres of origin viz. Middle-East and China.

B. rapa (rapeseed) is grown as leafy vegetable (China and Japan), oilseed (India) and as turnip-rape (Europe). Want *et al*. (1995) suggested Anhui Province (South China) as the center of origin of *B. rapa.* based on erucic acid content. However, Reiner *et al*. (1995), based on taxonomic studies, advocated Europe as its center of origin. Brown *sarson* is the oldest form of *B. rapa* from which yellow *sarson* (mutant for seed colour) and *toria* (selections for early materials) have been evolved.

B. napus has recently evolved in the South-West Europe and Mediterranean region by repeated hybridization between *B. rapa* and *B. oleracea*. It contains both oilseed and swede types. *B. carinata* has originated in East African plateau by hybridization between *B. nigra* and *B. oleracea*. It is widely cultivated in North-East Africa particularly in Ethiopia. *B. nigra* called "Sarshap" (in Sanskrit) is cultivated as spice since 3000 BC. It is closely related to *Sinapis arvensis*. It is widely distributed in Europe, Africa, Asia minor, Afghanistan, India, Palestine and Syria. *Eruca sativa* is native to South Europe and North Africa and is a recent introduction into India.

The relationship of the rapeseed yielding species

Howard (1940) suggested that *B. campestris* should be reserved for forms with 2n = 20 and *B. napus* with 2n = 38. The relationships of the rapeseed yielding species belonging to the genus Brassica are illustrated by the Japanese scientists 'U' (Nagaharu U). He expressed the relationship with the help of a triangle and according to his name the triangle is known as triangle of 'U'.



Triangle of U

There are 3 basic species, *B. nigra* (n=8), *B. oleracea* (n=9) and *B. campestris* (n=10). By hybridization 3 new species *B. carinata*, *B. juncea*, and *B. napus*, are obtained. This hybridization had been made by nature very long ago. This opens new vistas for the breeders in developing new varieties suited for specific situation through hybridization.

The following Scientific names of mustard, sarson and toria are used to avoid further confusion.

Mustard: *Brassica juncea*;
Yellow sarson: *Brassica rapa* var *glauca*;
Brown sarson: *Brassica rapa* var *napus*;
Toria: *Brassica campestris*.

.Area Production and Distribution

The important rapeseed and mustard growing countries of the world are India, China, Canada, Pakistan, Poland, Bangladesh and Sweden. India ranks first in the world in respect of acreage and second in production next to Canada. It accounts for about 18% of total oilseed production in the country producing 4.1 mt (2000-2001). In India, its cultivation is mainly confined to Uttar Pradesh, Rajasthan, Madhya Pradesh, Haryana, Punjab, Assam, Bihar, Gujarat and West Bengal. UP produces about 20% of total rapeseed and mustard production in our country.

Climatic Requirement

Rapes and mustards are grown in India as a *rabi* (Winter season) crop. This crop prefers moderate temperature during its entire growth period (below 25^0C day temperature). It requires low temperature up to flowering in comparison to other oilseed crops. But it can withstand a temperature of 40^0C for limited period during vegetative stage. In generating phase this crop is more tolerant to high temperature, but high temperature in connection with drought reduces grain filling, seed size and seed oil content (Canvin, 1965). Drought along with high temperature during seed filling also produces wrinkled grain and low yield with low oil content. This crop can tolerate frost to some extent during its vegetative phase. But frost during seed filling stage damages seeds due to chlorophyll contamination which colours the oil green make it unsuitable for edible purpose. Toria having very short vegetative period, can make best use of long days and high light intensity. Rapeseed and mustard appeared to be generally tolerant of soil moisture deficit. This drought resistant quality is a considerable

asset in tropical high country. Rainfall of about 400 – 500 mm during vegetative to flowering period is desirable, with a total rainfall of 700 mm for high seed yield. This crop can be grown in regions having 300-1000 mm rainfall. This crop can not stand water logging or damp condition in the field.

Soil

Rapeseed and mustard will grow on a wide range of soils types – fairly heavy clay to light sandy on volcanic ash soils. But this grows well in medium or heavy loam soils. Heavy soils and land subjected to water logging should be avoided. It requires a neutral soil but can be grown on soils having pH range of 5.5 – 8.0.

Cultivation

Rape and mustard are mostly cultivated as a mixed crop with wheat, barley, gram etc. It is broad cast or sown in rows. Generally the cultivators do not grow pure crop due to failure of the crop for the attack of aphids.

Crop varieties

Rai (mustard): Varuna (T-59), Seeta (B-85), Bhagirathi (RW-351), T 11, RL 19, Sarama (RW-85-59), Pusa bahar, Pusa bold, Prakash.

Yellow sarson: Binoy (B-9), Subinoy, NC-1, Patna 66, T 151, Rajendra 1, YS 932, NDYS 921.

Brown sarson: Pusa kalyani, BID 2, BID 3, B-65, BS-70, KOS 1, KSB 3.

Toria: Agrani (B-54), Panchali (TWC-3), Bhavani, Jowahar, Sangam, Karmah, ITSA, T-9.

Recommended variety for Bihar

Improved variety for Rai:

Improved variety	Sowing time	Maturity period (Days)	Average yield (q/ha)	Remarks
Varuna	15th-25th Oct	135-140	20-22	Oil % 42
Pusa Bold	15th-25th Oct	120-140	18-20	Oil % 42
Kranti	15th-25th Oct	125-130	20-22	Oil % 40
Rajendra rai pichheti	15th Nov-10th Dec	105-115	12-14	Oil % 41
Rajendra anukul	15th Nov-10th Dec	105-115	10-13	Oil % 40
Rajendra suphalam	15th Nov-25th Dec	105-115	12-15	Oil % 40

Improved variety for Yellow Sarson:

Improved variety	Sowing time	Maturity period (Days)	Average yield (q/ha)	Remarks
66-197-3	10th-20th Oct	120-125	14-16	Oil % 43
Rajendra Sarson-1	10th-20th Oct	95-100	15-16	Oil % 46
Swarna	10th-20th Oct	110-120	14-16	Oil % 47

Improved variety for Toria:

Improved variety	Sowing time	Maturity period (Days)	Average yield (q/ha)	Remarks
RAU TS-17	25th Sept-10th Oct	90-95	12-15	Oil % 43

Panchali	25th Sept-10th Oct	95-105	10-12	Oil % 40
PT 303	25th Sept-10th Oct	95-100	12-14	Oil % 43
Bhavani	25th Sept-10th Oct	90-95	10-12	Oil % 41

Season and time of sowing

It is a winter season crop. This crop is usually sown early in the season as compare to other winter oilseed crops. Time of sowing depends on the place of crop occupies in rotation. In mixed cropping, the time of sowing of the crop will be governed by the sowing of the main corp.

Sowing time of rapeseed and mustard in different regions in India

Crop	Northern India	Central India	Eastern India
Toria	2nd half of Sept	1st half of Oct	October
Brown and yellow sarson	1st half of Oct	2nd half of Oct	2nd half of Oct
Mustard	2nd half of Oct	1st half of Nov	2nd half of Nov

Land Preparation

Soil should be well pulverized well. About 3-4 ploughing are needed to make fine tilth of the 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.

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. 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/ha; In Pure crop- 4-5 kg/ha

Seed treatment: It is very much required to treat the seeds with fungicides and insecticides for protecting the crop from seed borne diseases and insect pests. The seeds should be treated with Bavistim @ 2.5g/kg seed before sowing.

Spacing: Mustard- 35-40cm X 10-15cm, Brown and yellow sarson- 30cm X 10cm and Toria- 25cm X 8-10cm. Optimum plant density for mustard-20-25 plants/m^2, for yellow and brown sarson-30-35 plants/m^2 and for toria-40-45 plants/m^2.

Depth of sowing: 2.0-2.5cm depth was the best for rapeseed and mustard. Both shallow (1.5cm) and deep sowing (over 3.0cm) resulted in low emergence and poor crop stand (Sandhu, 1963).

Manure and fertilizer management

For Rai & Sarson: Compost 8-10 ton/ha

For irrigated condition: 80:40:40 N:P_2O_5:K_2O/ha
For unirrigated condition: 40:20:20 N:P_2O_5:K_2O/ha

For Toria: Compost 4-6 ton/ha + 60:40:40 N:P_2O_5:K_2O/ha

Compost should be applied 20-30 days before sowing. Full dose of phosphorous and potash and half dose of nitrogen should be applied uniformly before sowing during last

ploughing. Remaining amount of nitrogen should be applied at the time of flower initiation. In zinc deficient soil 25 kg zinc sulphate should be added to the soil at the time of land preparation.

Irrigation

Toria is generally grown under rainfed conditions in India. In terai areas of UP, brown sarson is grown in rainfed condition. Yellow sarson and Rai are definitely benefited by irrigation. Toria is short duration crop (75-80 days). If dry spell occurs, one irrigation at peak flowering may increase 10-15% seed yield. Both yellow and brown sarson require 2-3 irrigation at branching (25-30 DAS), peak flowering (40-45 DAS) and siliqua development (60-65 DAS) stages for better growth and high seed and oil yield. Mustard requires 4-5 irrigation at branching (25-30 DAS), peak flowering (45-50 DAS), siliqua formation (60-65 DAS) and siliqua development (75-80 and 90-95 DAS) stages for obtaining high seed and oil yield. If water available for only one irrigation it must be given at peak flowering stage. Irrigation in rapeseed-mustard field is given by boarder and strip method and 5-7 cm ha water is applied per irrigation.

Weed control

To get good harvest; the crop should be kept free of weeds at early stages of growth. Very little work is so far been reported in weed control of mustard field with the use of herbicide. Mulching with polythene sheet in between rows will give good results in controlling weeds in mustard field, here the dominant weeds are *Cyperus* spp. and *Chenopodium album* were effectively controlled by pre-sowing application of Eptam @ 2.0 kg ai/ha (67.9% control of weeds) and pre-emergence application of Lasso @ 3.0 kg ai/ha (62.9% control of weeds). These herbicides significantly improved the seed yield giving 32.9% and 27.7% increase over weedy check. Herbicides cause some abnormalities, but these disappeared soon and plants grow normally thereafter. Post-emergence application (30 DAS) of TOK E.25 @ 1.5 kg ai/ha also gave 19.2% increase in seed yield.

Plant protection measure

Insects:

Aphids (*Brevicorye brassicae*) are the most serious insect pest attacking rapeseed and mustard. It appears in the field sometime in Nov. – Dec depending on the weather conditions and growth of the crop (blooming and onwards). Even the tender plants are sometimes literally covered with hundreds of thousands of the insects. Cloudy and moist weather is conducive to the rapid multiplication of this pest. Spraying of Thiodan (35 EC) or Deimecron (100 EC) can control this pest effectively.

Mustard sawfly (*Athalia colibri*) also attacks the crop in seedling stage and can be controlled with the spraying of the above insecticides.

Flea beetle (*Psylliodes chrysocephala*) also causes fairly serious damage to the mustard plants in the seedling stage in the plains as well hills. It can be checked by dusting of 5% BHC.

Diseases:

Alternaria Blight, White rusts, dowry mildew and powdery mildew are very common disease in rapeseed and mustard.

Control: Blight – (i) Solar heat treatment or hot water treatment of seed

(ii) 4:4:50 Bordeaux mixture spray

Mildew – Spraying of 0.25% perenox 2-3 times

Harvesting

Maturity of the crop varies with crop types- Toria matures in 90 – 100 days, sarson matures in 115 – 120 days, rai matures in 125-135 days.

The crop is ready for harvest when the plants have turned yellowish or brownish, most of the leaves either shaded or turn yellow, but most of the siliqua except the basal few siliqua remain green with considerable moisture. When 75% of siliqua become dry and yellow then the crop should be harvested and dried in sun. In case of late harvesting there is a chance of seed shattering. Storage should be done 3-4 days after sun drying. At harvest the moisture content of siliqua is about 25% with 25 ppm chlorophyll content, during threshing the moisture content reduces to 10-11% and it should be reduced to 7% for storing.

Use of Rapeseed-Mustard

85% of Rapeseed-Mustard seeds used for oil extraction, 10% used for domestic purpose and 5% used for seed purpose.

Fatty Acid Composition:

Fatty Acids Saturated	***Brassica juncea***	***Brassica campestries***
Palmitic	2-4	3-4
Stearic	1-2	1-2
Uusaturated		
Oleic	15-25	35-50
Linoleic	12-20	18-30
Linolenic	10-15	8-10
Eicosenoic	10-14	8-10
Erucic	18-40	0-20

Yield: 14-16 q/ha for rapeseed and 20-25 q/ha for mustard.

Pungency of mustard oil

Mustard seeds contain a glucoside called Sinigrin and an enzyme called Myrosine (Potassium myronate). Sinigrin and Myrosine present in mustard seed in different cell. During crushing the seeds are ruptured and both sinigrin and myrosine come in close with each other. Sinigrin under high temperature and pressure hydrolyzed under the influence of enzyme myrosine and produces dextrose, Allyl-iso-thiocyanate (an essential oil) and potassium hydrogen sulphate.

$C_{10}H_{16}O_9 + NS_2K + H_2O = C_6H_{12}O_6 + CH_2{=}CH\text{-}CH_2\text{-}N{=}C{=}S + H_2S$

(Sinigrin) (Myronate) (Dextrose) (Allyl-iso-thiocyanate)

The pungency of mustard oil is due to this essential oil. Mustard oil contains about 0.247% Allyl-iso-thiocyanate. Mustard seed do not poses and pungency.

Quality of mustard oil: The quality of vegetative oil depends on the percentage of unsaturated fatty acid present in it. Generally the oil containing >90% of unsaturated fatty acid is regarded as good for human consumption. Mustard oil contain nearly 8-12% saturated fatty acid.

High Erucic acid content mustard oil consumption may cause arthritis problem to the human body. Double zero mustard oil is suitable for arthritis patient.

Sunflower

(Helianthus annuus L.)

Sunflower *(Helianthus annuus* L.) is an important oilseed crop of the country since its oil is considered as premium compared to other vegetable oils because of its light colour, bland flavour, high smoke point and high level of linoleic acid and absence of linolenic acid. Its oil is having great consumer acceptance because of its high content of unsaturated fatty acid along with vitamin E.

Origin & Distribution

The center of origin is North America. It is a crop of recent introduction to India. In 1969, the varieties like VNIMK, PEREDOVIK and Armavirskij were introduced to India from Russia

Area, Production and Yield

In world the highest Area & Production is in Russia. In India, Karnataka, Maharashtra and Andhra Pradesh are the major sunflower growing states. Karnataka is having highest area and production in India.

Plant:

Root: Central main tap root with extensive lateral roots

- Tap root is short (20-30cm), lateral roots extensive
- Shallow tap root limits anchorage to plant, resulting in lodging
- More lateral roots requires frequent irrigation
- Hence tolerant to moisture stress, but highly sensitive to waterlogging

Stem: typically unbranched

- Agronomically, 1-2 basal branches with the main stem is desired

Flower: determinate

- Disc shaped head is called capitulum/ racemose head borne terminally
- Outer Floret: Ray floret (showy and yellow)
- Sterile (No anther)
- Main function: to attract honeybees and pollinators
- Disc flower: Perfect
- Pollination: Cross (By bees)

Seed: Each disc floret develops to a seed, called Achene

- Seeds has dormancy period of 10 - 45 days
- For immediate use, ethereal (25 ppm) treatment can be done.

Climate

It is a day neutral plant. The optimum temperature for sunflower is 20-25 ^{0}C. High temperature above 38 ^{0}C and temp. below 16 ^{0}C reduces seed yield and oil content. The planting time should be selected to avoid flowering period coinciding with temp. above 38-40 ^{0}C. High temp. at flowering causes dessication of pollens and drying of stigma. Sunflower is well suited to the present day situation of increased CO_2 levels in the environment. Sunflower is a drought resistant crop. The rainfall requirement for a good crop of sunflower is about 500

mm, although crop can be grown with a rainfall of 300 mm. But it is susceptible to excess water. Rainfall and cloudy weather at flowering causes pollen indehiscent. It is also susceptible to wind damage. The crop requires a cool climate during germination and seedling growth, warm weather from seedling stage upto flowering and non cloudy sunny days during flowering to maturity.

Soils

Sunflower performs well on a wide range of soils such as sandy loams, black soils and alluvials. But, it does best on fertile, well-drained neutral soils. The ideal pH is around 6.5- It can tolerate slight alkaline conditions but not acidity. **Tillage and seed bed preparation**

Sunflower requires well prepared seed bed for better germination, establishment and growth. Plough once or twice followed by planking and harrowing for obtaining desired and weed free seed bed. Avoid low lying areas and make necessary provision for safe drainage particularly in soils which are ill drained. For growing sunflower after puddled rice, ploughing with tractor drawn mould board plough followed by rotavator twice helps in better germination and seed yield on sandy loam soils.

Sowing time

Sowing time should be decided in such a way that the flowering and seed filling stages of the crop do not coincide with continuous rainy period or high temperatures above 38°C. As it is a day neutral plant, it can be grown in winter, rainy and summer seasons. But its performance is better in *rabi* and early summer season compared to *kharif* because of favourable factors like irrigation, clear sunny weather and less disease and pests.

- ***Rabi***
  - Rainfed: September to first fortnight of October
  - Irrigated: November
- ***Kharif***
  - Second fortnight of June to mid July
- **Summer** (**Irrigated**): Second fortnight of January to first week of February
- **Spring**: 15th January to end of February

Ultimate seed yields in rainfed *rabi* crop depends on the extent of residual moisture available at planting time and the subsequent rains in the later part of September and early October. Therefore, prefer early planting and avoid moisture stress at critical stages of crop growth.

Seed rate

Normally, a seed rate of 5 kg/ha should be adequate to achieve the required plant stand. Due to uncertainty of adequate soil moisture in the seed zone and germinability of seed lower than the prescribed standard, it is safer to go in for higher seed rates of 5 to 7.5 kg/ha and then thin out the excess seedlings to achieve optimum plant population.

Pre-soaking and seed treatment

For quick germination and better stand establishment in dryland conditions, soak the seed in freshwater (1:1 W/V) for about 12 hours and shade dry. Seed should be treated with

thiram or captan @ 2-3 g/kg of seed to protect from seed borne diseases. Seed treatment with metalaxyl @ 6 g/kg can protect the crop against downy mildew disease. Treat the seed with imidaclorprid @ 5 or 6 g/kg seed before sowing against insect vectors.

Spacing and plant population

In general, prefer wider spacing of 60 cm between rows and 30 cm within the row for hybrids and long duration populations. For short duration and dwarf varieties (Morden), follow 45 x 30 cm spacing.

Thinning

Maintenance of optimum population by judicious thinning at 10-15 days after germination to maintain single healthy plant per hill is essential for obtaining higher yields, besides easy inter-culture and crop management. The head diameter of sunflower gives an indication of the plant population. If head diameter is higher (> 20 cm), it indicates lesser plant population than optimum, while a diameter of < 10 cm indicates higher plant population. The optimum plant population is generally 15 cm.

Manures and Fertilisers

Incorporate 7-8 tonnes of well decomposed FYM/compost/ha 2-3 weeks prior to sowing.

Dose: Rainfed- 50:40:40 kg NPK/ha

Irrigated- 80:60:60 kg NPK/ha

Apply 50% of the nitrogen and entire dose of P2O5 and K2O while planting preferably in the form of band placement. In case of dry lands, top dress rest of the nitrogen at around 30 days of crop growth depending on rainfall and soil moisture preferably at the time of interculture. For the irrigated crop, apply the remaining nitrogen in two equal splits first at 30 days after sowing (DAS) and the second at 15 days thereafter.

Nitrogen is the most important nutritional limitation to sunflower production. Prefer single superphosphate as source of P as it also supplies sulphur which plays an important role in increasing oil yield.

Sulphur fertilization: Application of sulphur @ 20 kg/ha through ammonium sulphate or single super phosphate significantly enhances the yield and returns from sunflower and benefits the seed yield and oil yield besides maintaining soil fertility especially sulphur.

Boron application: Providing directed spray of borax (0.2% i.e. 2 g/l of water) to capitulum at ray floret opening stage increases seed filling, yield and oil content. A spray mixture of 500 l/ha is required.

Weeding and interculture

The most critical period of weed competition is 4 weeks after emergence. Important parasitic weed is Orobanche. Timely weeding and interculture is a must for checking weed growth and obtaining full benefits from applied nutrients and soil moisture. Provide two hoeings at 15 and 30 DAS. Alternatively, use of alachlor or pendimethalin (as pre-emergence) or fluchloralin (PPI) @ 1.5 kg a.i./ha in 600 litres of water spray followed by one hand weeding and interculture at 35 DAS provide effective control of weeds. Earthing up may be done when the crop is 60-70 cm tall when sown in flat bed to prevent lodging.

Irrigation management

Deep and extensive root system, hence can extract moisture effectively from a greater soil volume. Hence, it can withstand prolonged periods of moisture stress.

Critical crop growth stages: Bud Initiation (35-40), Flower opening (50-55) and Seed filling (70-80)

Avoid moisture stress at these sensitive crop growth stages, as it adversely affects seed set, filling and consequently the yield. Avoid excessive and too frequent irrigations as such practice pre-disposes the crop to attack of wilt and root rots.

Supplemental pollination

Bees play a very important role in increasing seed set in sunflower more particularly in open pollinated populations. Do not resort to insecticidal spray during the blooming periods, as it affects the visit of pollinators (bees). If absolutely essential, spray or dust in the evenings after 3 P.M. preferably with relatively safer insecticides like endosulfan or phosalone.

Realisable yield potentials with improved technology

By adopting the recommended package of practices, on an average, the following yields can be realised under various situations.

- Rainfed: 800-1000 kg/ha
- Assured rainfall areas: 1000-1500 kg/ha
- Irrigated: 2000-2500 kg/ha

The average results of performance of improved production technologies under real farm situations under varied soil and farming conditions indicate, improvement in yield to the extent of 20 to 65% over the prevailing farmers' practices.

Varieties/hybrids

- **First variety:** Morden
- **First ever sunflower hybrid variety:** BSH 1
- **Hybrids:** BSH-1, APSH-11, MSFH-8, MSFH-17, L5H-1, LSH-3, KBSH-1, PSFH-67, PKVSH-27, Jwalamukhi, PAC-36, PAC-1091, DSH-1, Sungene-85, TCSH-1
- **Others:** MLSFH-47, KBSH-41, KBSH-42, KBSH-44, HSFH-848, NDSH-1, SH-416, Pro.Sun 09, PSFH-118, RSFH-1

Harvesting and Threshing

Sunflower can be harvested at any time after physiological maturity when the back of the head turns to lemon yellow colour and the bottom leaves start drying and withering. Crop matures in about 90 – 120 days. Further delay in harvesting causes reduction in yield due to lodging, breakage and termite attack. After separation of the heads, dry them for 2-3 days to facilitate easy separation of seed. Thresh the harvested heads either by beating with sticks or rubbing or through manual or power operated threshers. Dry the seed before storage so as to bring the moisture content to around 9-10%.

Crop Protection

The important diseases and insect pests and their control methods are

Bird damage: Birds, particularly parrots, pose serious problem to sunflower. Safeguard the crop from bird damage during the period from seed filling to harvest through effective bird scaring particularly in the morning and evening hours. Tying bright reflector ribbons above the crop will support to scare away the birds. In addition to birds, rats and squirrels also cause considerable damage to plant establishment by picking the seeds after sowing. Manual watch to scare these rodents and birds ensures good crop stand establishment.

Important diseases of sunflower and their management

Soil borne:

a) Downy mildew *{Plasmopara halstedii)*

a. In endemic areas avoid continuous sunflower growing, follow Crop rotation for 3-4 years to be adopted.
b. Early sowing, shallow planting escapes from the disease.
c. Clear cultivation, roguing of infected plants reduces the disease incidence.
d. Treat the seed with Metalaxyl 35 SD @ 6 g/kg of seed an
e. In disease prone areas use resistant hybrids such as LDM

b) Root and Collar Rot *{Sclerotium rolfsii)*

a. Seed dressing with captaf/carboxin 3-6 g/kg of seed.
b. Adding of soil amendments and antagonistic fungi such a
c. Avoid moisture stress/water logging conditions in the field

Foliar diseases

c) Alternaria blight and leaf spot *{Alternaria helianthi)*

a. Treat the seed with captan/thiram @ 2.5 g or carbendazim
b. Early planting *(kharif)* escapes the disease.
c. Spray the crop with mancozeb (0.3%), 3-4 times at 15 days interval.

d) Rust *{Puccinia helianthl)*

a. Foliar spray with mancozeb/zineb 0.2% or calixin 0.1% at

e) Head rot *{Rhizopus arrhizus)*

a. Spray Blitox @ 0.4%

f) Charcoal rot *{Macrophomina phaseolina)*

a. Seed treatment with thiram 3 to 4 g/seed.
b. Avoid moisture stress during high summer.
c. Follow deep ploughing in summer and crop rotation.

g) Sunflower Necrosis Disease (new viral disease).

Important insect pests of sunflower

1. **Seedling Pests**

- Cut worm
- Grasshoppers

2. **Sucking pests**

- Leaf hopper
- White fly

- Thrips

3. **Foliage pests**

- Tobacco caterpiliar
- Bihar hairy caterplllar
- green semilooper

4. **Capitulum borer:** *(Helicoverpa armigera)*

Oil Quality and By-products

Seed Composition:

- Oil content of kernel = 48 – 53 %
- Oil content of seed = 28 – 53 %
- Protein = 14 – 19 %
- oil is considered as premium compared to other vegetable oils because of its light colour, bland flavour, high smoke point and good nutritional quality.
- Oil is having high oleic (42 – 57%) and linoleic acid (33 – 48%).

Anti-nutritional constituents: Chlorogenic acid and Phenolic compounds

SAFFLOWER

Botanical Name: *Carthamus tinctorius* L.

Family: Asteraceae / Compositae

Chromosome Number: 2n=24

Safflower (*kusum, kusumbha, kardi*) has been under cultivation in India for its brilliantly coloured florets and the orange red dye (carthamin) extracted from them and seed. The seed contains 24-36% oil. The cold pressed oil is golden yellow and is largely used for cooking purposes. The oil is as good as sunflower oil having enough amount of linolic acid (78%), which is very useful for reducing blood cholesterol content. The unsaturated fatty acids of safflower lower the serum cholesterol.

The oilcake particularly from decorticated seeds is used as cattle feed. Safflower cake contains about 40-45% protein. The green safflower crop can be used as a green fodder for cattle as it is relished by cattle. The oilcake from undecorticated seeds is used as organic manure as it contains about 5% N, 1.44% P_2O_5 and 2.23% K_2O.

Safflower oil has good drying properties and is used in the manufacture of paints, varnishes and linoleum. The oil obtained by hot dry distillation is black and sticky and is used only for greasing purposes. It is also used in the preparation of 'Roghan' which is used in preservation of leather and production of water-proof cloth.

Origin: The cultivated forms of safflower are supposed to have originated either from *Carthamus lanatus* (saffron thistle) or *Carthamus oxyacantha* (wild safflower). According to De Candolle, safflower is probably a native of Arabia. Vavilov expressed the opinion that cultivated forms of safflower perhaps originated from India, Afghanistan and Ethiopia.

Area and distribution:

Growing countries are India, Mexico, U.S.A, Australia and Spain. It is grown over an area of 1.2 Mha with a total production of 1.0 Mt in world. India ranks first in the world in respect of acreage accounting for about 60% of the world total. The genus *Carthamus* contains about 25 species (mainly indigenous to Mediterranean) of which only *C. tinctorius* is commercially grown. In India, Maharashtra and Karnataka states are major producers of safflower.

Botanical description:

It is herbaceous annual plant attains a height upto 30-150 cm depending on the type of cultivar. Cultivars grown for seed are usually shorter than those grown for fibre production. Plat has thick tap root with numerous thin laterals, leaves are sessile, dark green with pronounced midrib. Inflorescence is called head and the flowers contain 20-100 individual florets.

Climate:

Safflower is cool season crop. The optimum temperature for germination is about 15.5oC. The day temperature in the range 24-32oC at flowering are congenial for higher yields. Seedlings are tolerant to low temperatures. . At seedling stage, however, the crop can tolerate much lower temperatures (-12 to –10oC). When flower buds are being formed or flowering has just commenced, temperature below 0oC may cause considerable damage in the form of sterile heads. High temperatures at the time of flowering are harmful to the crop. Waterlogging due to poor drainage or prolonged rains can cause drastic reduction in yield.

The crop is not fit for the tracts of heavy rainfall. It is cultivated from sea level to an elevation

of 1000 m above sea level. The seed yield and oil content reduces with increasing elevation. At all the stages of growth, excessive rainfall or humidity increases the infestation of fungal diseases. It is a day neutral plant. However, temperatures are more important than photoperiod in safflower. Short day lengths prolong rosette stage.

Soil:

Being drought resistant, it is cultivated on all types of soils, including sandy soil, but the crop is best suited to deep, well drained fertile soil with a high water holding capacity with a neutral Ph. Though it is fairly tolerant to salinity bur under such soils oil content of seed is reduced.

Varieties:

- Type-65: Matures in 180-190 days with a yield potential of 14-15 q/ha.
- Malvia 305: Matures in 160-165 days with a yield potential of 16-18 q/ha.
- N-62-8: Matures in 140 days with a yield potential of 10-12 q/ha.
- Tara: Matures in 120-125 days with a yield potential of 12-14 q/ha. It has non shuttering character.
- A-1: Matures in 125 days with a yield potential of 8-9 q/ha.
- A-300: Matures in 125 days with a yield potential of 7-9 q/ha.
- Manjira: Matures in 105-110 days with a yield potential of 12-14 q/ha. Moderately resistant to powdery mildew and tolerant to alternaria blight.
- K-1: Short duration variety, matures in 120 days with a yield potential of 6-8 q/ha.

Field preparation:

Safflower needs cold-free and weed free seed-bed with a firm sub soil and adequate moisture for germination and stand establishment. In black cotton soils (single cropped *rabi* areas), harrowing 3-4 times during the monsoon is as effective as deep ploughing during summer as soon as the *rabi* crops are harvested only when the field are infected with pernicious weeds. One deep Ploughing followed by 2-3 crosswise harrowing and planking respectively make the field ready for cultivation.

Time of sowing: First week of October to first week of November is the normal planting time of the crop. Delayed sowings may cause flowering to coincide with period of high temperature, resulting in reduced yield.

Spacing:

Pure crop : 40-50 cm x 20-25 cm

Rainfed crop : 60 cm x 30-35 cm

Mixed cropping : 20-25 cm x 20-25 cm

Seed rate

Healthy seeds of improved varieties should be selected for sowing. Safflower has branching ability, and the optimum population ranges between 1.0 to 1.1 lakh/ha. The seed rate varies from 7 to 20 kg/ha depending on situation.

Manures and fertilizers

15-20t FYM/ha should be applied at the time of last harrowing. 40 kg N, 40 kg P_2O_5 and 20 kg K_2O per hectare is sufficient for safflower cultivation. The mixture of fertilizers

should be placed in furrows 8-10 cm deep and 4-5 cm away from the seed row at the time of sowing.

Method of application

Apply the entire quantity of fertilizers as basal dose using bullock drawn ferti-seed-drill wherever available; otherwise drill the fertilizer preferably 1-2 weeks prior to recommended planting time with the help of local seed-drills and then seed adjacent to fertilized rows. For maximum efficiency, fertilizer should be placed deep in the seed furrows (10 cm below the soil in Deccan *rabi*; 10-15 cm in Uttar Pradesh, Bihar, north-western India).

Water management

Although the crop is grown without irrigation, but higher yields are obtained with irrigation. The seasonal consumptive use varies from 250-300 mm. No response to irrigation is observed when soil contains 200-250 mm/m moisture at the time of sowing. The flowering and grain-filling stages are more sensitive to water stress conditions. One irrigation 30 days after planting helps in better growth of the crop.

Weed control

Safflower is very susceptible to weed competition during its rosette stage which lasts about 25-30 days in Deccan region and 60 days or more in other parts with prolonged winter. The field should be kept weed-free during this critical phase through timely weeding and interculture once or twice 25-30 or 45-50 days after planting depending on the length of rosette period and the severity of weed infestation. Pre-plant application of trifluralin @ 0.5 kg/ha or EPTC @ 0.5 kg/ha or pre-emergence application of atrazine @ 0.75 kg/ha or Alachlor @ 1.5 kg/ha can be used for effective weed control in safflower.

Diseases: The important diseases are rust, Cercospora leaf spot, Alterneria leaf spot and wilt.

- Rust is caused by a fungus ***Puccinia carthami*** which caused considerable yield loss in safflower. All green parts of the plant are attacked, but the infection is more on the leaves. Small round rust pistules with ruptured epidermis are formed scattered on both the surface of the leaves.
  Control: Grow resistant variety like, treat the seed with Thiram or Bavistin @ 3g/kg of seed.
- Cercospora leaf spot is caused by a fungus ***Cercospora carthami*** which may appears at any stage of the crop. The colour of the severely affected leaves turn brownish and the leaves get distorted.
  Control: Grow resistant varieties and spraying of Zineb or mancozeb 75 WP @ 2 kg in 1000 litres of water per hectare.
- Alternaria leaf spot is caused by fungus ***Alternaria carthami.***
  Control: Spraying the crop with 0.2% Ziram or Zineb can be effective.
- Wilt is caused by a fungus, ***Sclerotinia sclerotiorum***
  Control: Seed treatment with carbendazin (Bavistin) @ 3 g/kg of seed keep the weed under check.

Insect pests: The following pests are important in safflower crop

- Safflower flies are ash colored with light brown legs. They damage the buds and flowers and pupate in them. Infested bud begins to rot and the offensive smelling fluid oozes out from its apical portion.

Control: Spraying the crop with Dimethoate (Rogor) 30 EC @ 1 litre in 1000 litres of water per hectare can control the insects.

- Safflower aphids are small black, soft bodies insects. They suck the sap from the leaves, twigs, flowers and capsules.
  Control: Spraying of oxydemeton methyl 25 EC or Dimethoate (Rogor) 30 EC @ 1 litre in 1000 litres of water per hectare can control the insects.

Harvesting and Threshing

The high yielding varieties of safflower mature in 115-140 days. Harvest the crop preferably in the early hours when shattering would be minimum and spines are relatively soft. Cut the plants with the help of sickles at the base or wherever possible uproot (black soils) and stalk them in the field in the form of small and well-pressed heaps till they are fully dried. For easy handling and transport to the threshing yard, use improvised socks and gloves made from gunny bags to protect legs and hands against spines. Thresh either by beating with sticks or with the help of bullock drawn stone-rollers or if available, power-operated thresher.

Yield

With improved agronomic practices, safflower can yield, on an average 1.0-1.2 t/ha under scanty moisture conditions and 1.5-2.0 t/ha under favourable moisture situations. Hybrids can yield 2.0-2.5 t/ha.

LINSEED

Botanical name: *Linum usitatissimum* Linn.
Family: Linaceae
Chromosome Numaber: 2n=30

Among the oilseed crops raised during *rabi*, linseed is next in importance to rapeseed-mustard in area as well as in production. In technical oil production, it ranks first in the country. Every part of the linseed plant is utilized commercially, either directly or after processing. Seed contains 33 to 47% of oil. On a very small scale, the seed is directly used for edible purposes. About 20% of the total oil produced is used at farmer's level, and the rest 80% oil goes to industries in various forms, such as boiled oil, borated oil, eposidized oil, aluminated oil, urethane oil, isomerized oil etc. The oil is rich (> 66%) in linolenic acid, and is a perfect drying oil. Hence it is utilized in the manufacture of paints, oil cloth, varnish, pad-ink, printed ink, linoleum etc.

The oil cake is a good feed for milch cattle and poultries and hence priced 50% higher than rapeseed-mustard cake. It is good in taste and contains 36% protein, 85% of which is digestible. It is also used as organic manure. It contains about 5% N, 1.4% P_2O_5 and 1.8% K_2O.

Linseed is globally cultivated for its fibres and is called flax. Fibres are used for the manufacture of linen. The stem yields fibre of good quality having high strength and durability. The weather resistant fibre is lustrous and blends very well with wool, silk, cotton etc. Strong twines, canvas, suitings, shirtings and various indispensable products for defence purposes are manufactured from it. Woody matter and short fibres may be used as raw pulp for making paper of quality comparable with that of currency notes. The rough and strong linseed fibre can effectively be used for low-cost roofing tiles based on convertible polymers and for fibre-reinforced plastic (FRP).

Origin and History

The genus *Linum* has 20 species spread in warm temperate Europe and Asia and 50 species spread in America. Most of the investigators are of the opinion that the wild flax (*Linum angustifolium*) which is a native of Mediterranean region may be the ancestor of the cultivated species *Linum usitatissimum.* According to Vavilov linseed or flax had two centres of origin. *The small seeded type*: These are grown mainly for oil purpose, and appear to have originated in south-western Asia comprising, India, Afghanistan and Turkey. *The bold seeded type*: These are grown for fibre purpose, and seem to have originated in the Mediterranean region including Asia Minor, Egypt, Algeria, Spain, Italy and Greece.

Geographic Distribution

Linseed is one of the most important crops of the world cultivated in over 2.6 million ha. The important linseed growing countries are India, Canada, China, USA and Ethiopia. India ranks first in the world in respect of acreage accounting for 23.8% of the world total and third in production contributing of 10.2% of the world total. Canada and China are other main linseed producers in the world. The productivity is the highest in Romania (1751.4 kg/ha).

In India, it is cultivated on 0.53 m.ha with a production of 0.21 mtonnes. Its cultivation is mostly confined to Madhya Pradesh, Maharashtra, Chattisgarh, Uttar Pradesh and Bihar. Madhya Pradesh occupies 1st position in India in respect of both area and production.

Classification

Howard and Rahman (1924) classified the Indian linseeds into three main groups based on colour of seed as Yellow or white coloured; Fawn coloured, and Brown coloured. The above 3 groups are again sub-divided according to the colour of corolla, mainly white, light blue or purple. In India, 6 species of *Linum* namely, *L. usitatissimum*, L.*mysorense, L. angustifolium, L. grandiflour, L. perenne* and *L. strictum*. Of these 6 species, *angustifolium* and *grandiflour* have been introduced into the country as ornamental types.

Botanical Description

It is herbaceous annual plant growing to a height of 30-120 cm. Cultivars grown for seed (oil) are usually shorter than those grown for fibre production. The root system is usually shallow. The main tap root is slender and having numerous small lateral roots, that develop in the top 30 cm soil. Stems are narrow and may branch from the base. Seed varieties possess more branches than flax. The leaves are narrow and short, alternate on the stem and sessile. The leaves are linear to lanceolate and blunt at the apex. The inflorescence consists of a terminal panicle that bears numerous flowers. Flowers are usually white or blue, complete and perfect with 5 petals, 5 sepals and fine stamens. Linseed is normally a self-pollinated crop. The fruit is capsule, which is globular in shape. These are divided into 5 locules where seeds are borne. The seeds are flat, shiny and relatively small. The seed colour ranges from white to shining yellow or light brown.

Climatic requirements

Linseed is a cool season crop. The temperature during the vegetative development of the crop should be moderate or cool. Temperature above 32oC accompanied with drought during the flowering stage reduces the seed yield, oil content in seed and also the quality of the oil. Moderate temperatures (21o-26oC) are ideal. At the time of flowering, frost is very harmful to the crop. The crop is well suited to tracts of low rainfall and is generally raised where the average annual rainfall ranges from 45 to 75 cm.

Soils and its preparation

Linseed can be profitably raised in places where the other crops may fail. Hence, it is often grown on marginal and sub-marginal rainfed soils as pure crop, mixed crop, intercrop and *paira* or *utera* crop. Linseed can be raised in almost all types of soils, where sufficient moisture is available, but it also does better on heavier soils having greater water-retention capacity. It is also tolerant to wide range of soil pH (5.0-7.0). However, it grows best on well drained loam to clay loam soils rich in humus. In Madhya Pradesh and Maharashtra, linseed is largely raised on black cotton soils having high clay and lime content. It is also raised on light alluvial soils of Uttar Pradesh, Bihar and West Bengal.

Land should be ploughed 2-3 times followed by 2-3 harrowings to bring a fine tilth. To conserve moisture, it is advisable to create a soil mulch with the help of a hoe after each good

shower. *Utera* cropped linseed needs no land preparation, as it is broadcast in standing rice crop.

Seed and Sowing

Linseed is usually sown by broadcast or by drilling in rows. The seed requirement is more in bold seeded varieties and in *utera* cropping system. Treat the seeds with capatan or agrosan GN @ 2.5 g/kg seed before sowing. This ensures a good stand by protecting seedlings against seed borne diseases.An inter-row spacing of 20-30 cm and intra-row spacing of 7-10 cm are ideal. The time of sowing varies from early October to mid November in different states. Rainfed crop requires early sowing. Early sowing also helps the crop to escape from powdery mildew, rust and podfly menaces.

Depth of seeding

Depending upon the soil moisture, the seed should be placed 2-3 cm below the soil. However, shallow sowing is always advantageous if there is adequate moisture in the soil.

Varieties

The linseed varieties recommended for different states are given in Table.

State	Variety
Madhya Pradesh	Jawahar-1, Jawahar-17, Jawahar-18, Jawahar-552, Jawahar-7, Jawahar linseed-9, Jawahar-23, T-397, Sheetal, Pusa-2, Padmini (LMH-62), Kiran (RLC-6), Parvati (LMH-16-5)
Uttar Pradesh	BAU-204-1, Garima (LHCK-39), Gaurav, Hira, Jawahar-23, Jeevan (DLP-21), T-397, Swetha (LHCK-131), Subhara (LHCK-21), Shekhar (LCK-9313), Mukta, Sheetal, RL-993, Padmini, Neelum, Meera (RL-933), Shikha (LCK-8528), Laxmi-27, Rashmi (LCK-9216), Parvati
Bihar	Sabour Tisi-1, BAU-204-1, Gaurav, Jeevan, T-397, Swetha, Subhara, Sekhar, RL-993, Shikha, Rashmi, RL-914
Orissa	Jawahar-23, Sheetal, Pusa-2, Padmini, Kiran
West Bengal	BAU-204-1, Gaurav, Jeevan, Swetha, Subhara, Sekhar, Neela, RL-993, Meera, Shikha, Rashmi
Assam	Gaurav, Jeevan, T-397, Swetha, Subhara, Sekhar, RL-993, Meera, Shikha, Rashmi
Maharashtra	C-429, Jawahar-23, S-36, Jagadamba (RLC-4), NL-97, Sheetal, Pusa-2, Kiran
Rajasthan	Jawahar-23, Triveni, T-397, Surabhi, Sheetal, RL-993, Pusas-3, Pusa-2, Padmini, Meera, Kiran, LC-54, Rashmi
Punjab	Jeevan, Surabhi (KL-1), Pusa-3, LC-185, LC-54, Sheela (LCK-9211), K2
Haryana	Jeevan, Surabhi, Pusa-3, Pusa-2, LC-54, Sheela, K2
Himachal Pradesh	Janaki, Himalini, Jeevan, Surabhi, Pusa-3, Pusa-2, LC-185, LC-54, Sheela, K2

Manures and Fertilizers

Linseed crop is generally grown without manuring. Application of 8-10 tonnes of FYM or compost/ha at the time of final field preparation is beneficial. In vertisols of Madhya Pradesh and alluvial soils of Bihar, best crop is raised with use of FYM and castor cake. Improved varieties of linseed respond to fertilizers. Seed purpose crop require 60-90 (irrigated) and 40 (rainfed) kg N/ha, whereas, dual purpose crop needs still higher N dose (120 kg/ha). Similarly higher P fertilization (50 kg P_2O_5/ha) of dual purpose crop is necessary in comparison to rainfed (20 kg/ha) and irrigated (40 kg/ha) seed crop. Response to 20 kg/ha each of S and Zn is increasingly observed in irrigated crop under intensive cropping systems. Under irrigated conditions, half the dose of N with full amount of P, S and Zn should be applied as basal at sowing. The remaining N is applied with the first irrigation 35 days after sowing.

Water management

Linseed is a crop of rainfed areas (> 90%). However, it responds well to irrigation. Branching, flowering and capsule formation stages are critical for irrigation. Two irrigations are sufficient to obtain good yields. First irrigation should be applied 30-40 days after sowing and the second just before flowering. However, 3 irrigations (35, 55 and 75 days after sowing) have proved very effective.

Weed control

This crop is usually dwarf statured, and therefore suffers severe competition by weeds. Initial 3-6 weeks after sowing is critical period of crop-weed competition. The uncontrolled weeds can reduce yields by 25-40%. The losses are more in rainfed and *utera* cropping systems primarily due to competition for moisture followed by nutrients.

The important weeds of linseed include *Anagallis arvensis, Vicia hirsuta, Fumaria parviflora, Melilotus* spp., *Chenopodium album*, *Phalaris minor* etc. The crop is parasitized by *Cuscuta* sp. leading to heavy losses of yield. Post emergence (2-3 weeks after sowing) application or Pronomide @ 1.5 kg/ha and crop rotation with cereals have been recommended for its effective management. Weeds can also be controlled by 2 weedings after 3 and 6 weeks of sowing. When crop is 8-15 cm tall or just before branching, post-emergence application of MCPB @ 0.5 kg/ha can effectively control annual broad leaved weeds.

Cropping systems

Linseed is a component of various sequential and intercropping systems. Higher monetary returns can be realized if linseed is grown as a pure crop instead of a mixed or intercrop. It is usually grown in rotation with hybrid maize, sorghum, pearlmillet, soybean, groundnut, cowpea etc.

Piara or utera cropping

This system has been in practice for efficient use of residual moisture in rice fields, where tillage is a problem. About 25% of the linseed area (0.5 million ha) is under *utera* cropping. The area under linseed is increasing with the decline in *khesari* (*Lathyurus*) cultivation. In this practice, linseed is broadcast in the standing rice fields, when the rice crop is between flowering and dough stages. Linseed is allowed to complete its life-cycle under

moisture stress, with inadequate nutrients and plant protection measures, resulting in poor yields. To raise the yield levels, the following package of practices should be adopted.

Improved varieties should be raised for the purpose of more productivity and good quality oil. Heavy textured soils with good water-retention capacity are ideal for this system. Adequate FYM or green manure should be applied along with phosphate fertilizers to rice. A dose of 20 kg N/ha should be applied 2 or 3 days before linseed is sown using a seed rate of 35-40 kg/ha. In *cuscuta* infested areas *cuscuta* seeds should be removed from the seed lot before sowing. Sowing linseed when rice is at the dough stage proves to be the best. Manual weeding should be given once or twice.Crack system of sowing is a new method, which can be followed in areas where sufficient water is available. In this method 5 cm deep cracks are allowed to develop in the field, when the rice crop is at the boot-leaf or panicle formation stage and the field is irrigated. After keeping the water standing for 5-7 days, the normal practice of *utera* is followed. This method has been found to give 50-100% more yields and has no adverse effect on rice yields.

Harvesting and Threshing

The crop takes about 130-150 days to mature. At maturity, the leaves become dry, capsule turns brown and the seed becomes shiny. After harvesting, bundle the plants and leave them on threshing floor for 4-5 days for drying. Threshing is done by beating the plant with sticks or trampling by bullocks.

Yields

The crop yield varies from place to place depending on the climate, soil, technology and variety. A well managed crop may yield 1.5-2.0 tonnes of seeds/ha.In linseed; oil to seeds crushed is 33% while cake to seeds crushed is 67%.

Berseem

Trifolium alexandrinum

Berseem is the prominent legume fodder crop of rabi in entire North West, Zone, Hill Zone and part of Central and Eastern Zone of the country. Berseem makes most digestible and palatable green fodder to the cattle and especially milch animals are very much benefited with berseem. It provides fodder with high tonnage over a long period from November to May in 5 - 6 cuts. It has 20-24% crude protein and 70% dry matter digestibility. It is very good soil builder and adds about 0.38-0.46% organic carbon, 15 -26 kg available phosphorus and 45 kg available nitrogen to the soil.

Climatic requirements:

Berseem prefers dry and cool climate for its proper growth. Its productive crop can be obtained between 15-25° C temperatures. Its regenerative growth is retarded during severe cold or frosty period or at temperature above 40°C. It can be grown successfully in areas which receive annual rainfall of 150-250 cm or even lower but the irrigation must be assured.

Soil

Berseem can be grown on all types of soils except very light sandy soils. Well-drained clay loam soils rich in calcium and phosphorus are ideally suited for it cultivation. The crop can be grown successfully on alkaline soils having good water retention capacity. The crop can tolerate mild acidity also.

Field preparation

The seeds being very small, berseem requires a fine seedbed. One deep ploughing with soil turning plough and 2 harrowing are essential. The field may be laid out in to smaller beds of convenient size according to topography and source of irrigation water.

Sowing time

After the arrest of rains, sowing of berseem can be done from last week of September to first week of December in North West to Eastern and Central India. The time of sowing berseem is ideal when mean day temperature is 25° C, which is recorded mostly in the first to third week of October in north India.

Seed rate

The optimum seed rate is 25 kg/ha, which may be increased up to 35 kg in early or late sown conditions. For yield compensation in first cutting, 1.5 kg mustard should be sown along with berseem. For elimination of chicory weed (*kasani*), the seed should be poured in 1% common salt. Floating chicory seed should be taken out and remaining seed of berseem should be sown.

Seed treatment

Seed treatment with *Rhizobium* culture is essential, when the berseem crop is to be grown first time in the field. Before treating the seed, it should be first soaked into fresh water for about 8-12 hours. For better sticking of culture with seed, the culture is prepared with jiggery. About 1.5 litres of water is mixed with 150 g of jiggery and boiled. After cooling, 2.5 packets of berseem culture are mixed with it and then seed is well mixed and dried in a cool shady place.

Sowing method

There are two methods for sowing of berseem i.e. dry and wet bed. For satisfactory germination and good plant stand, wet method is better. Seed should be sown in beds of convenient size by broadcast method after flooding the beds with 5-6 cm deep water. Before sowing seeds, the water in the beds should be stirred thoroughly with the help of peddler or rake so as to break the clods and capillary to avoid leaching during successive irrigations. The crop should be re-irrigated after 5-6 days of sowing when germination is complete.

Manures and fertilizers

Berseem, being a legume crop, requires less nutrient replenishment in the soil. For obtaining good yield, 20 kg N and 80 kg P2O5/ha should be applied as basal dose. In saline or light textured soil, addition of 20 tonnes of well decomposed FYM is beneficial. FYM may be excluded if the previous crop of the rotation was liberally manures and fertilized

Varieties -

S.No.	Name of Variety	Area of recommendations
1	Mescavi	All barseem growing regon
2	Wardan	-do-
3	BL-1 and BL-10	Panjab, H.P. and J & K
4	UPB-110	Central and South zone
5	BL-2, BL- 22	Hill and sub temperate
6	JB-2 and JB-3	Central India
7	BB-3	Bihar & North- Eastern zone

Irrigation

The depth and frequency of irrigation is decided by soil type, number of cuttings and nature of berseem crop, i.e. sole or mixed. First two very light irrigations (4-6 cm depth) should be given at 5-6 days interval. Subsequent irrigations may be given at an interval of 10 days in October, 12-15 days in November to January, 10-12 days in February-March and 8-10 days in April-May. Thus, about 12-15 irrigations will be needed during the entire crop season. Normally the crop should be irrigated after each cutting.

Weed control

Chicory, the associated weed of berseem should be eliminated for higher herbage and good quality fodder. Application of **Fluchloralin @ 1.2 kg a.i./ha** at pre planting stage controls the chicory and other weeds effectively. However, floating of berseem in 10% common salt is effective against chicory only.

Harvesting

The first cutting should be taken at 50-55 days after sowing of crop. The subsequent cuttings should be taken at 25-30 days interval. The number of cuts depends upon rate of growth and temperature during the life cycle of the crop.

Yield

A good berseem crop can give 80-100 tonnes/ ha green fodder and 15-20 tonnes/ha dry fodder.

Lucerne

Medicago sativa

Lucerne is a valuable leguminous forage and hay crop which is generally grown in areas where water supply is inadequate for berseem. Its deeper root system makes it very well adaptable to dry areas with irrigation facility. It grows well as rain fed or un irrigated crop in high water table areas. It is an important winter fodder crop in Rajasthan, Gujarat, and parts of Tamil Nadu, Kerala and in Leh area of Laddakh. It is perennial (3-4 years), persistent, productive and drought tolerant forage legume which contains 15% crude protein with 72% dry matter digestibility. It supplies green fodder for a longer period (November - June) in comparison to berseem (December - April).

Climatic requirements

Lucerne is adapted to relatively dry conditions and it may tolerate heat as well as cold. It cannot be grown under humid conditions with high temperature. It has wide ecological amplitude and can grow at 2,500 m asl to hot summer with 49°C with adequate moisture available in the soil.

Soil

Lucerne needs sandy loam to clayey soil but heavy soils need an efficient drainage system as the crop does not tolerate waterlogging. It cannot thrive on alkaline soils but can be grown on acid soils with liberal application of lime. Lucerne prefers a fertile soil which is rich in organic matter, calcium, phosphorus and potash.

Field preparation

Like berseem, Lucerne also needs very fine seedbed, as the seeds are very small. One deep ploughing with 2-3 harrowing follies sufficient. Sowing time: The best sowing time of the crop is mid-October to early November However, sowing date may spread from early October in the North to late December in the East and South Zone. In the temperate zone, spring sowing is done in March.

Variety	**Area of cultivation**
Anand-2,	Gujrat , rajasthan &MP
Anand-3	Hills (Cold dry zone)
Panjab type-8, 9, Chetek	UP, Bihar, Haryana, and Punjab
Kandhar, Sirsa-8, RL-88	Northern zone

Seed rate and seed treatment

The seed rate depends upon method of sowing and type of the crop, i.e. pure or mixed stands. In case of broadcast method, a **seed rate of 20-25 kg/ha** should be used while line sowing needs only 12-15 kg/ha but in case of intercropping, it requires only 6-12 kg/ha. Like berseem, **seed treatment with Rhizobium culture** is beneficial.

Method of sowing

Line sowing is preferred over broadcasting. Like berseem, 10–20 m long beds should be made along with slope with irrigation channels 4-5 m apart. Water-soaked seed is sown in shallow furrows at row distance of 30 cm by seed drill or pora at sufficient soil moisture.

Manures and fertilizers

Lucerne being a leguminous crop requires less nitrogen. However, due to perennial nature of the crop, it is beneficial to add well-decomposed **FYM @ 20-25 tonnes/ha** before

sowing in the first year. Normally, **20 kg N and 100 kg P2O5/ha** should be applied as basal dose for good harvest. Application of molybdenum and boron may be done based on soil test. In subsequent years, annual supplementation of 80 kg P2O5 and 40 kg K2O/ha should be done.

Irrigation

To attain good germination, pre-sowing irrigation is essential. The crop needs very frequent irrigation during its early growth period at an interval of about one week but once the plants are established, subsequent irrigations are provided at an interval of 15-20 days during winter and 10-12 days during spring and summer seasons. Proper drainage should be ensured to avoid waterlogging in rainy season.

Weed management

Lucerne takes a long time to establish itself and gives ample scope for weed infestation up to the first cutting. It is very difficult to control weeds in broadcast crop. If crop is sown in lines, weeding and hoeing become easier. First weeding should be done 20-25 days after sowing .Pre-emergence application of **Pendimethalin@1-2kg a.i./ha**. Or post emergence application of Diquat @ 6- 10 kg./ha.(5-10 days after sowing) effectively controls Cucuta.

Disease and insect-pest management

Lucerne weevil and aphid are two important insects of this crop. These insects can be managed through the application of neem oil @ 30 ml. per litter of water. The most important diseases of Lucerne are rust leaf spot, downey mildew and phytopthora rot. Application of Dithan M-45 (0.25%) as spray is effective for rut and leaf spot control. Spraying with Mancozeb is recommended for control of downy mildew. Phytopthora root rot occurs in wet soils.

Harvesting

The first cut should be taken at 55-65 days after sowing and the subsequent cuts may be taken at 30-35 days interval. In general, annual Lucerne gives 4-5 cuts while in the perennial crop, 7-8 cuts can be taken.

Yield

Annual Lucerne yields green fodder to the tune of 65-80 tonnes/ha while perennial crop may provide 80-100 tonnes/h

Oat

Avena sativa

Oat is one of the most important cereal fodder crops of *rabi* season in North, Central and West Zone of the country. It provides soft and palatable fodder rich in crude protein (10-12%). Oat is also used as straw, hay or silage. Its grain makes a good feed particularly for horses, sheep and poultry.

Climatic requirement

Oats are well adapted to cooler environment. Its optimum growth is attained in sites with 15-25° C temperature in winter with moist conditions. Although, it can tolerate frost up to some extent but its fodder yield and quality is reduced due to hot and dry conditions.

Soil

Oat grows the best in loam to clay loam soil with adequate drainage. They produce satisfactory yields on heavy or light soils with proper moisture. It can be grown under moderate acidic or saline conditions also.

Varieties:

(Variety)	**Area of cultivation**
JHO-822, JHO-851, JHO-99-2	
Kent, OS-6, OS-7	All oat growing area of the country
Palampur-1, &IGFRI-S-54,	Himachal Pradesh
Bundel jai-822,(single cut)	Central zone
Harita (RU-19)	Maharastra
Bundel jai-99-1	Hilly zone

Seed rate and sowing time:

A seed rate of 80-100 kg/ha is recommended for uniform stand in oats. Low tillering varieties should be sown with 20-25 cm row spacing while higher tillering type should be sown 30 cm apart. Sowing of seed should preferably be done in line with seed drill or *pore/kera* behind the plough. Sowing time varies from one location to other. Normally, oat sowing should be started in early October to end of November in North-West to East Zone of the country. For regular supply of fodder from December to March, scattered sowing is also advocated.

Manures and fertilizers

The requirement of oats for manures and fertilizers is less as compared to other *rabi* cereals. It depends upon number of cuts taken. In general, addition of 20-25 tonnes of farmyard manure (FYM) before 10-15 days of sowing with the application of 80 kg N, 40 kg P2O5/ha to single cut and a dose of 120 kg N, 40 kg K2O/ha to multicut varieties attains good crop growth. In double and multicut varieties, top-dressing of 40 kg N/ha after first cut and two equal split doses of 40 kg N/ha after first and second cut should be done respectively.

Irrigation

Oats require 4-5 irrigations including the pre-sowing irrigation. If soil is dry, first irrigation is given before preparing the seedbed. Subsequent irrigations are given at intervals of about contributes to higher forage yield.

Weed control

Oat is infested with winter season grassy and broad-leaved weeds mostly found as in wheat. Effective control of weeds in oats can be obtained with weeder cum mulcher at 4 week crop stage followed by application of 2, 4-D @ 0.37 kg a.i./ha at 6 weeks crop stage.

Harvesting

Proper stage of harvesting determines the herbage yield and quality of Oat. The harvesting of single cut oat varieties is done at 50% flowering (about 50-55 days of sowing). In double cut varieties, first cut should be taken at 60 days followed by second cut at 50% flowering stage. However, in multicut varieties, first cut is recommended at 60 days, second cut at 105 days and third cut at 50% flowering. For seed production, the crop should be left for seed after the first cutting, which should be taken 50-55 days after sowing. For good re-growth, first cut should be taken 8-10 cm above the soil surface.

Yield

The average green fodder yield from single, double and multi-cut varieties of oat ranges from 30-45, 40-55 tonnes/ha green fodder. And 2.0-2.5 tonnes/ha seed and 2.5-3.0 tonnes/ha straw is obtained.

Potato

Potato (*Solanum tuberosum* L.) is one of the most potential crops for meeting the food requirements of the people of subtropical and temperate region. Even in tropical regions it is grown at high altitudes during winter season. It occupies the largest area under any single vegetable crop in the world and produces more food per unit area than cereals and that too within a short period. The ratio of protein to carbohydrate is higher in potato than in many cereals and other root and tuber crops. It ranks first in protein production per hectare per day. Besides this, potato has many agro-economic advantages such as it is a short duration crop and one to three crops can be raised under different situation in a year. It fits well in crop rotations and intercropping system.

Origin and history

The **Peru-Bolivia** region seems to be the main centre of origin of cultivated sp. of potato. where, great diversity of forms of potatoes are found. The secondary centre of origin may be **Chile.** The varieties extensively cultivated in south and central America are of *Solanum andigenum* types and the varieties derived and developed from the island of Chiloe spread throughout the world for their extensive cultivation as a food crop are of *Solanum tuberosnm* types.

Distribution

Globally, potato is sharing about 1.35 percent of the total cultivated land area resulting in a production of 265.44 million tones. The USSR, China, Poland, India and USA are the leading potato growing countries in the world. India ranks fourth in area and fifth in production. The major potato growing states in India.

State	Area 100 ha	Production (mt)	Productivity (t/ha)
U.P.	348	6.6	18.99
W.B.	256	6.26	24.46
Bihar	160	1.48	9.23

Potato as a major food crop in Agriculture

Potato is a whole sum food with high nutritive value. It contents practically all the essential dietary nutrient constituents except fat and fat soluble nutrients. Apart from carbohydrates which is the major constituents, potato is also provides essential nutrients such as proteins, minerals and vitamins like B, B_2, B_8 and C.

Outstanding feature of potato production

Apart from being a source of nutritive food, potato has certain other outstanding virtues which make it a valuable article of our diet in daily life. This virtues are discussed below.

1. Easy to cook, break or boil, whole or mashed dried or fried and is equally palatable to different people of the world.
2. In its fresh state it has a good storage life which can be extended over a long period by its conservation into dry product.
3. It blends very well in almost all food staff of vegetable and animal origin.
4. Combined with cereals in flour or in mash state, potato not only improves taste but also increases the quality, flavour and acceptability of the product.

Potato as a crop in Indian agriculture

Wide acceptability of potato throughout the country gives it a significant position in Indian agriculture. It has several qualities for which its importance in Indian agriculture is tremendous as a major food crop. The following qualities of potato generally put to its high position.

1. It yields the highest amount of food per unit area with shortest possible time. In subtropical plain it brings substantive income of farmers within 2 – 3 months.
2. It fits nicely in relay or rotational cropping with other crops.
3. Under best cultural condition main crop of potato can produce an average of 40 t/ha within 110-120 days.
4. As a relay crop it yields up to 15 – 20 t/ha (both during autumn and spring) within 60 – 80 days.
5. The surplus produce can be converted easily to dried and other processed product.
6. Depending on the agro-ecological condition 2 – 3 crops can be taken in the same field in some specific region (Chotanagpur plateau, Nilgiri etc.)
7. It is an easily digestible, nutritive and transportable food for different personnel specially those are posted in difficult terrains.

Comparative statement of food value with rice and what

Crop	Average Yield (kg/ha)	Calories in (kg cal/ha)	$C_6H_{12}O_6$ (kg/ha)	Protein (kg/ha)	Fat (kg/ha)
Rice	2100	7850	1729.3	138.6	15.2
Wheat	2000	6838	1509.4	250.1	47.1
Potato	20000	17010	3762.3	400.2	20.0

This table clearly shows that potato as a food crop has the highest capacity to supply not only energy but also carbohydrate and protein as compare to rice and wheat (principal food crops).

Some physiological aspects of potato

Suberisation

When we cut a potato tuber a whitish fluid like substance comes on the surface on the cut wound. This fluid is nothing but suberin (a carbohydrate compound) dissolved in water. If we keep the cut potato as such for couple of days we find a hard blackish coating over the cut surface which can protect the tuber from infestation of different diseases and pest through this wound. The white substance ´**suberin**´ along with some vitamins and protective hormones are responsible for protecting the cut tubers. The formation of hard coating over the cut surface is known as "suberisation".

Solanization

When the tubers come out of the soil due to various reasons (damaging ridges due to faulty irrigation, weeding etc.) they expose to sunlight and develop chlorophyll under skin. The chlorophyll reacts with carbohydrate and produces ´**solanin**´ on the tubers below the skin. This process is known as solanization and solanized tubers become green in colour. Solanin is highly toxic to human consumption. If a stock contains more than 2.0% solanized tubers, it should be screened out before consumption or the green portion of each tuber must be discarded by peeling at the time of food preparation. Otherwise, the stock having solanized tubers may be used for seed purpose.

Stolonization (stolon formation)

Stolon is a shoot of potato plant developed under the soil. Generally stolons are formed from the buds of the leaf axils that remain under the soil. If stolon comes out of the soil, it behaves as a shoot. The formation of stolon (a stalk like structure under the soil) is known as "Stolonization". The basal portion of the potato plant is covered with soil by earthing up for better stolonization.

Tuberaization (tuber formation)

The stolon growth takes place as a result of apical growth of the stolon by the action of gibberellin. After a horizontal growth of the stolon in the soil under darkness, its tip swells all on a sudden and forms tuber. This is known as "tuberization". The rapid multiplication of surrounding cells at the stolon tips due to the action of cytokinin results swelling of stolon tips and formation of tubers in the absence of epical growth.

Dormancy of potato tubers

Dormancy is the absence of consistent growth owing to certain physical and chemical condition in the tubers influenced by number of factors including the environment which is operating on growing tubers. When all the conditions which prevent the various reactions and processes of growth have disappear then dormancy is at its end. If all but one of the inhibiting factors have disappear, the bud till may remain dormant.

Climatic requirement

The original area of cultivation and growth of potato is found in south and central America. There exists short day length and moderate temperature. Light intensity is rather high with occasional rain. It is a cool season cop. Frost free days and clear sky is essential for its proper growth and development.

The ideal condition for potato cultivation is low night temperature (15 to 20^0C). Optimum temperature for emergence and stem elongation is 18^0C. Stem elongation ceased at 6^0C and it is very slow at 9^0C. Under high light intensity leaf development was rapid and it dried earlier at lower than at higher temperature. But under low light intensity the reverse had been observed. Maximum leaf growth has been found at 12-14^0C where as maximum stem growth occurred at 18^0C. Optimum temperature for flowering is also at 18^0C. Flowering inhibited by low night temperature (12^0C).

Optimum soil temperature for tuber formation is 15 – 18^0C. Optimum air temperature for tuber formation is 20^0C. But under low light intensity maximum tuber weight obtained 12^0C – 14^0C; while under high light intensity it was at 18 – 20^0C. High temperature is favourable for stem growth and unfavorable for leaf expansion and tuber formation. High crop yield may be obtained at short day, high light intensity and relatively high day temperature (30^0C) along with low night (17^0C) temperature.

Soil

Loose friable soil is essential for developing stolon and tubers. Cracking black cotton soils are not suitable. Alluvial soils, red and lateritic soil with friable porous texture are ideally suited for potato cultivation. Potato is well suited in acidic soils. The optimum pH ranges from 5.2 to 6.5. Sandy well drained loamy soils with high organic matter content are best for potato growing.

Cultivation aspects

Growth of potato in the field

In the field the growth of potato plants takes place in 3 distinct phases.

Emergence: It involves establishment of stem, root and leaf surface from material store in the mother tuber and it occurs at a rate determined in soil temperature and size of the sprout at planting.

Haulm growth: Haulm growth takes place immediately after emergence. It includes the growth of aerial stem, expansion of leaf surface already form and production of new leaf and branches.

Tuber growth: The growth of tuber takes place after initial haulm growth. It starts immediately after formation of stolon by sudden swelling of stolon tips to forms tubers. Once haulm growth, stolonization and tuberization takes place, all these processes continues simultaneously till the break of the tuber bulking rate achieved under field situation.

Cropping system: (i) Generally it is cultivated as pure crop at optimum management level.

(ii) In some cases safflower, sunflower, mustard are planted around the border of the potato filed or around the different strips of potato crop as **border cropping/bund cropping.**

Land preparation

The potato needs well pulversed field for tuber production. The soil is brought to a fine tilth by 4-6 crosswise ploughing followed by planking and levelling. Land preparation and organic manuring is usually started at 10-15 days before the planning of potato tubers.

Potato varieties

The common potato varieties that are cultivated in the plains are listed below.

(i) **Early varieties** (75-100 days)**:** Kufri Chandramukhi, Kufri alankar.

(ii) **Medium varieties** (100-120 days)**:** Kufri Sheetman, Kufri Bahar, Kufri Red, Kufri Lalima, Kufri Jyoti, Kufri Pokhraj.

(iii) **Late varieties** (130-135 days)**:** Kufri Safed, Kufri Dewa, Kufri Sindhuri, Kufri Kumar, Kufri Giriraj, Kufri Kanchan.

(iv) Low sugar content varieties: Kufri Chipsona-1 and Kufri Chipsona-2

Planting of tubers:

Planting time: 2nd half of October to 2nd half of November is the normal planting time of potato in the plains of Eastern India.

Seed rate: 2.5-3.0 t/ha **seed tubers** are required. It should be healthy, disease free, good quality and medium to large in size. The quality of potato seed tuber is the most important as about 50% cost of potato cultivation goes for seed purpose. Nowadays **true potato seed (TPS)** derived from matured berry is gradually using for potato production. The TPS seed requirement is also very low. Only 100 g seeds are required for planting one hectare land. Thus it is most cost effective.

Preparation of planting material: Before planting, the seed tubers receiving from the cold storage should be kept in airy shade for one week or so for sprouting. Sprouting of seed tubers before planting is practiced to secure quick emergence and uniform establishment which is turn results in increasing the number of shoots per tuber, better growth, higher productivity and uniform maturity of the crop. Seed piece of 20-25g weight is good for good stand and high yield. When good quality large tubers are used for planting, each tuber is cut into small pieces of about 20g weight. Each piece should have two or preferably three eyes. During seed material preparation any tuber showing any spot or ring must be discarded and the cutting knife must be disinfected.

Seed treatment: Seed potatoes taking from the cold storage or from the market may be infected with some diseases. So, seed treatement is essential to protect the crop from seed and surface borne diseases. Mancozeb 75% WP and Carbendazin 50% WP are generally used for seed treatment. Seed materials should be treated with Dithane M-45 or Indofil-4-45 @ 2.5

g/lit or Lerbanedazin (Bavistin) @ 1 g/lit of water before planting to protect them from infection by seed borne and soil borne diseases.

Method of planting: (i) **Flat bed** and (ii) **Ridge and furrow** methods.

In **Flat bed** method, tubers are planted in shallow furrows and covered with soil by spade. After emergence when the plants attain a height of 10-12 cm a light earthing up is done at about 20-25 DAP. The second earthing up is done at 10 days later.

But in **Ridge and furrow** method, small furrows are made by spade or small plough and seed tubers are planted in the furrows at suitable distance. Immediately after planting, the tubers are covered with soil with the help of spade forming small ridges on the seed rows. Here, one earthing up is done at about 25-30 DAP.

Flat bed is avoided due to damping of sprouted tubers particularly in early planted crop. Ridge and furrow method is better for planting potato tubers in different regions for better establishment and crop management.

Spacing (Crop geometry): 50-60 cm row to row and 20-25 cm plant to plant is generally followed in normal planting. But 50 X 20 cm spacing is recommended for early and medium duration varieties and 60 X 20 cm spacing is recommended for late/long duration varieties.

Depth of planting: The tubers should be planted at 5-7 cm below the soil surface for easy sprouting of the tubers and better crop establishment.

Fertilization: Potato is a heavy feeder crop. It should be planted under optimum nutrient level to exploit its full yield potentiality. Any deficiency of nutrients for a short period may result in heavy reduction in productivity. So, the land should be well fertilized before potato planting. On the basis of soil fertility status the fertilizer schedule should be prepared.

Generally on fertile alluvial loamy soils potato is fertilized with 150 kg N, 100 kg P_2O_5 and 100 kg K_2O/ha. But red and lateritic sandy loam soils and sandy soils being poor in fertility status require more amount of fertilizer application. Here 200 kg N, 150 kg P_2O_5 and 150 kg K_2O/ha is generally recommended to get a good harvest of the crop. Apart from inorganic fertilizers, organic manures in the form of Vermicompost (5.0 t/ha), FYM (10 t/ha) or mustard oil cake (500 kg/ha) may also be applied during land preparation and mixed thoroughly with soil at 7-10 days before planting the potato tubers to get good results.

Method and time of fertilizer application: Application of high dose of fertilizer at planting some time causes high salt concentration of the surface soil in the furrows resulting in delay in sprouting and some time hampers the plant growth which ultimately records 10-15% less in pant density and also in productivity. To avoid it half dose of N and full dose of P and K fertilizers should be applied at final land preparation and mixed thoroughly with soil during land preparation. Remaining half N should be applied at 25-30 DAP during earthing up.

Intercultural operation: Earthing up and weeding are the main intercultural operations required in potato cultivation. Potato sprouts emerge out of the soil in about 3 weeks and stolons are formed within a week after emergence then tuberization starts.

The objectives of **earthing up** and **weeding** are to destroy the weeds, cover the basal part of the potato plants with soil and keep the soil loose for better stolonization, tuber formation and tuber growth.

The first earthing up should be done when the plants are about 10-15 cm high and touch each other within a row. Second earthing up may be done to cover the exposed tubers properly. Earthing up should be completed within 25-30 DAP. If delayed beyond 30 days, it may damage the young stolons and newly formed tubers resulting in reduction in tuber yield. In the hills initial earthing up at planting helps in conserving soil moisture and ensure quick and uniform germination. Sometime **hoeing** is done for breaking the hard soil crust that formed due to rain or irrigation after planting but before complete emergence.

Intercultural operations like hoeing, weeding or earthing up help in checking the weed infestation. Potato is heavily infested with weeds because of liberal application of fertilizer and wider spacing which encourages the luxuriant growth of weeds. The weeds in potato field can be controlled in the following way. **Hand weeding** is practiced universally. Weeds may also be removed by hand tools. Generally weeding is done along with earthing up to have satisfactory control of weeds. Different **herbicides** are applied at different times depending on their mode of action and accordingly they can be used. Preplanting application of Fluchoralin (Basalin) @ 0.7-1.0 kg ai/ha effectively controls the weeds and increases the tuber yield of potato. Lasso/Alachlor (Nitrofen) @ 1.0 kg ai/ha may be very effective herbicide in controlling the weeds in potato crop. Stam F-34 (Propanil 35% EC) @ 2.5 lit/ha and Sencor (Metribuzin 70% WP) @ 3 kg/ha are most effective as post emergence herbicides.

Irrigation:

Any stress during emergence to cessation of tuber bulking period causes drastic reduction in tuber yield. The crop should be provided with adequate water supply throughout the growing period. When available soil moisture depletes to 67% (at 33% available soil moisture) irrigation should be given. The time interval between irrigations depends upon the type of soil, climatic condition, variety and growth stage of the crop. Normally in light soils irrigation is given at 15-20 days interval, but in medium type of fertile soils, it should be given at 20-25 days interval. 5-6 cm-ha water per irrigation is generally applied in furrows between the crop ridges.

Plant protection:

The potato is attacked by a large number of insect pests both in the field as well as in the storage. The potato pests can be classified into four categories in accordance with their mode of feeding and habit: soil pests, sap feeders of sucking insects, defoliating pests and storage pests. Among the insect-pests, **Cut worms** (*Agrotis epsilon*), **White grub** (*Anomala* sp.) and **Aphids** (*Myzus persicae*) are most important.

The **cut worm** took shelter in the soils just bellow the damaged plant. So, it is necessary to kill the cut worm by digging the soil just below the damaged plant. The plants that are soft and succulent are subjected to such damage. So, excessive nitrogen dose should not be used in a single application. **Chloropyriphos 20 EC** @ 1.5ml per liter of water should

be sprayed on foliage and ridges soon after noticing the incidence of cut worms. **Monocrotophos** @ 1ml/liter may be used for controlling **Aphids**.

Among the diseases, **Early blight** (*Alternaria solani*) and **Late blight** (*Phytophthora infestans*) are important.Both the diseases can be prevented by applying **Mancozeb 75% WP** 5 g/lit of water, **Carbandazin 50% WP** 1 g/lit. **Bavistin** 1 g/lit of water or **Blitox** 205 g/lit of water. Besides the following preventive measures should be taken.

i) Use healthy disease free seed tubers,

ii) Collect pure type good quality seed tubers from genune source,

iii) Use freshly harvested tubers from the hills treating with dormancy breaking chemicals,

iv) Follow 3-4 year crop rotation,

v) Treat seed tubers in fungicide solution and

vi) Use seedling tubers from TPS crop.

Harvesting:

The crop should be harvested at full maturity stage for prolong storage. When the leaves turn yellow and dry, haulms dry up and tuber skin becomes rough and hold firmly with flesh indicates the maturity of the crop. Potato crop depending upon the varieties takes about 3-4 months to mature in the plains of eastern India. Sometime the haulms are cut 10-15 days before lifting to enforce maturity, particularly in late varieties. During harvesting, the soil must be moist and easily workable condition. It is never advisable to harvest tubers in wet land as this condition leads to dirty look of the produce and reduces its market value besides making it difficult to collect the tubers. Potato may be left as such in the field even after maturity period under such situation. The method of harvesting potato varies from region to region. In the river bed sandy soils, the tubers are taken out simply by stirring the sand by hand. Besides, khurpi and hand hoe are used in Jharkhand, Bihar and Easter UP. Spade and country plough are most common and popular implements throughout the country for harvesting potato tubers.

Curing and grading:

Curing and grading are essential for storing or marketing of potato tubers. After harvesting, the tubers should be kept in a airy dry and cool shade for 10-15 days to reduce moisture content in the tubers. During grading, care should be taken to remove the cut and disease tubers. The tubers should be separated into small, medium and large size before baging and leveling. The seed tubers may be treated with 3% boric acid for 30 minutes after grading for preventing disease infestation, leveled properly and kept separately in the storage.

Production of disease free potato seed tubers in the plains

Growing of the disease free seed tubers in the plains: One should give much more attention to grow disease free quality seed tubers in the plains than other potato fields used for

consumption purpose. The technique by which the seed potatoes are grown in the plains is known as **"Seed Plot Technique".** The following steps are taken to grow disease free quality seed tubers in the plains:

(i) Collect virus free seed tubers from a reliable source with high health standard and true to the type. Here one can use TPS seedling tubers obtained from breeding station.

(ii) Use healthy large size whole tubers with multiple sprout and earth them immediately after planting.

(iii) Plant the crop preferably in the 3rd week of Oct. to 1st Week of Nov. in the plains of West Bengal (Eastern India).

(iv) Apply systemic granular insecticide at the rate of 15 kg/ha (Thimate 10g) in the furrows before planting of tubers to make the plants free from the attack of insect pests from the beginning.

(v) Used freshly harvested hill tubers for planting and treat them with dormancy breaking chemicals before planting (Dipping of seed in 1% thiourea + 1 ppm G. A. 1 : 1 ratio for 1 hour then momentarily dipping of seed in 3% ethylene chlorohydrine and then keeping them in an air tight drum for 24 hours).

(vi) Use herbicide to control weeds in seed potato field.

(vii) Remove off types or infested plants when showing symptoms of any disease or pest incidence by rouging twice in the field. First inspection should be done soon after full emergence when adjacent plants of a row touch each other (generally 1 month after planting). The 2nd rouging should be done when the plants between the rows touch each other. It is generally done at 40 DAP.

(viii) Withhold irrigation by the 3rd week of Jan. (10-15 days before haulm killing).

(ix) Haulm killing should be done when the tuber bulking ceases and aphid build up reaches its critical number (20 aphids/100 leaves). Haulm should be removed by sickle or herbicide like 2,4-D (1.0 kg/ha) with 600 liter water.

(x) Check re-growth of the stumps which begins soon after removal of haulms.

(xi) Lift the crop about 10-15 days after haulm killing when the skin of the tubers is harden and firmly held with flesh, cure the produce by keeping it in a cool dry place (cool and airy place) for about 10 days. Grade them after curing.

(xii) Treat the seed tuber with 3% boric acid solution for 30 minutes to protect against the surface burn diseases in the storage.

(xiii) Dry the treated tubers in shade and level them after bagging.

(xiv) Store the produce in cold storage at 1-2^{0}C within 4-6 weeks after removing of haulm.

(xv) Fallow 2-3 years of crop rotation to grow potato seed tubers. Maintain at least 30 m isolation distance around the seed potato field to protect the seed potato from infestation of different diseases from the surrounding fields.

True Potato seed technology (TPS)

Besides the regular seed production systems, potato production from true potato seed (TPS) has been possible in most of the potato growing areas. TPS can be used as a low input alternative for raising commercial crop especially in areas where availability of quality tuber seed at reasonable price is a major constraint. An advantage of this method is that the planting of one hectare potatoes require only 100-150 g TPS instead of 20-25 t of tubers, which could result in a tremendous saving in cost of production. Added advantages are that the problems and high cost of transport and storage of potato tubers can be avoided by the use of TPS.

TPS is produced in the berries that are formed after the potatoes have flowered. Due to genetic recombination, each seed develops into a different plant with different characteristics, resulting in potato crops that are heterogeneous with regard to agronomical characters and tuber quality. Through selection, several open pollinated and hybrid populations have been developed. TPS populations, TPS C-3, HPS 1/13 and PT- 92-27 are the few being grown at farmers' field.

Following two methods have been found successful for raising commercial potato crop using TPS derived planting materials.

1. Transplanting seedlings.
2. Planting seedling tubers.

Transplanting TPS seedlings is successful in areas where the winters are mild, irrigation is available, and seedlings get established in shorter time and produce acceptable yields. Second method using seedling tubers as planting material is successful in all areas wherever potato is grown through seed tubers.

Production of potato crop from seedling tubers in the field: The recommended cultural and manorial practices of the region may be followed for potato production from seedling tubers.

i) The different grades of seedling tubers produced in the previous crop season may be used as seed for raising the ware crop by adjusting inter and intra row spacing according to their size.

ii) For mechanical cultivation, keep the inter-row distance at 60 cm and for manual cultivation at 45 to 50 cm. The plant to plant distance in a row may be kept according to the size of seedling tuber as below :

Size of seedling tuber(g)	Manual cultivation		Mechanized cultivation	
	Spacing (cm)	Seed rate (q/ha)	Spacing (cm)	Seed rate (q/ha)
20-40	45-50 x 20	30-33	60 x 20	25
10-20	45-50 x 15	20-22	60 x 15	17
5-10	45-50 x 10	15-17	60 x 10	13

Follow the seed plot technique viz. timely planting, timely spray of pesticides and haulm cutting before the critical level of 20 aphids per 100 compound leaves is reached in the crop, if the produce is to be used for seed purpose. In traditional areas of seed production, the produce can be retained as seed for another 3-4 years if seed plot technique is followed strictly.

Sugarcane

Sugarcane

Uses and Importance

Sugarcane is rightly called as 'wonder cane' owing to its versatile utility and the vast capability to meet the demands of the burgeoning population. It is utilized in manufacturing of sugar, bio-fuels, spirit besides generation of electricity. This particular sector has attained the most privileged status as one of the pivotal agriculture based industries. In addition, these agro based industries provide raw materials for papers, fertilizers, amendments, chemicals, distilleries and other associated sectors. Thus, sugarcane provides livelihood not only for the recently inducted foreman in the industry but also for the vulnerable peasant legacy engaged in the cane cultivation from the time immemorial.

Sugarcane is the main source of sugar in India and holds a prominent position as a cash crop. It is mainly an industrial crop as the cane is supplied to sugar industries, where various products, from its juice are prepared by using a series of industry. The by-products from sugarcane further require some form of industry. Only a fraction of its production is used in small scale industry for making local Khandsari' and 'gur'. Sugarcane's products like sugar and fermented products are very important in making and preserving various kind of medicines like syrups, liquids; capsules etc. Sugarcane provides a juice, which is used for making white sugar, and jaggery (gur) and many by-products 1ike bagasse and molasses. Bagasse is used as a fuel, for production of fibre board, papers, plastics and furfural. Molasses is used in distilleries for the manufacture of ethyl alcohol, butyl alcohol, citric acid etc. Rum is the best potable spirit made from molasses. Molasses, also, is used as an additive to feeds for livestock. Green tops of cane are a good source of fodder for cattle. Its remains are good manure in alkaline and saline soils.

Sugarcane is an important commercial crop of the country occupying around 3.8 million hectares of land with an annual cane production of around 270 million tonnes. That is, it occupies about 2.8% of the cultivated land area and contributes about 7.5 % to the agricultural production in the country. About 35 million farmers grow and depend on sugarcane for their livelihood. And an equal number of agricultural labourers earn their living by working in sugarcane farms.

The sugar industry is the second largest agro-based industry, next only to textiles, in the country. There are 435 sugar mills installed which utilize around 40-50 % of the cane produced manufacturing around 15 million tonnes of sugar. About 5 lakh workmen are directly employed by the industry besides a host of others gaining employment in industries that utilize by-products of sugar industry as raw material.

Sugar factories, being located in the rural areas, support huge economic activities in the rural India. In addition to improving the economic condition of the farmers and agricultural labourers engaged in sugarcane farming, they also support several others like transport operators, agro-service agencies, input dealers, petty businessmen and financial institutions.

Most of the factory workers are drawn from the surrounding areas. Thus sugar factories generate rural employment. Many sugar factories also promote education and co-operative movement in their areas of operation.

By-products of sugar industry

By-products of sugar industry are also playing an important role in the national economy. Molasses, the chief by-product, is the main raw material for alcohol and thus for alcohol-based industries in the country. Sugarcane bagasse (the fibrous material left over after crushing) is the chief source of power in the sugar mills. Excess bagasse is now being used as raw material in the paper industry. Besides, co-generation of power using bagasse as fuel is considered feasible in most sugar mills. It has been estimated that about 3500 MW power can be generated annually without extra fuel and investments much less than that required for generating the same through thermal power plants. Another by-product, pressmud, contains considerable amount of plant nutrients and could be an important source of organic matter, major and micronutrients. Sugarcane green tops are used as cattle feed. In urban areas sugarcane juice has great demand as a thirst quencher. In many of our festivals, sugarcane is an important item of worship.

Crop products

The main product of Sugarcane is sugar, however, there are many by products of sugarcane industry are bagasse, molasses, press mud and green top, which are used by various industries like Bagasse based industries mainly produce pulp, paper, particle boards using bagasse as a fuel, cattle feed, medium for cultivation of edible mushroom, production of furfural etc., Molasses based industries mainly produce potable alcohol for Distillery, Acetic Acid, Fuel Alcohal, Cattle feed and many Pharmaceutical products etc. Press mud based industries mainly produce fertilizer and the wax and compost industries, as animal feed.

Average sugar recovery in sugarcane:

The sugar recovery in sugarcane varies from state to state average sugar recovery in the country is 10.25% (P).

Origin

Cultivation of sugarcane in India dates back to the Vedic period. The earliest mention of sugarcane cultivation is found in Indian writings of the period 1400 to 1000 B.C. It is now widely accepted that India is the original home of *Saccharum species. Saccharum barberi* and *Polynesian* group of island especially New Guinea is the centre of origin of *S. officinarum.* It belongs to family Gramineae (Poaceae), class monocotyledons and order glumaceae sub family panicoidae, tribe Andripogoneae and sub tribe saccharininea. The cultivated canes belong to two main groups: (a) thin, hardy north Indian types *S.barberi* and *S.Sinense* and (b) thick, juicy noble canes *Saccharum officinarum*. Highly priced cane is *S. officinarum*.

Area, production and yield of sugarcane in major growing countries:

Brazil is major sugarcane producing country with an area about 90.77 lakh ha and production of about 717.46 Million ton followed by India. Sugarcane productivity is highest in Colombia (101.32 t/ha) followed by Philippines (93.71 t/ha). Amongst 10 major producing country Colombia has the highest yield of sugarcane due to the richest biodiversities in the world and has access to multiple climates. The yield gap of sugarcane in India with respect to 10 major sugarcane producing countries during the last 5 years is ranges 1.33 – 31.22 t/ha.

Area, production and yield of sugarcane in major growing states:

In Tropical zone Maharashtra is the major sugarcane growing state covering about 9.4 lakh ha area with production of 61.32 Million ton, whereas the productivity of Tamil Nadu is highest in tropical zones. Uttar Pradesh is the highest sugarcane producing State in sub tropical zone having area about 22.77 Lakh ha with the production of 135.64 Million Ton cane whereas Haryana has highest productivity of sugarcane in Sub tropical zone.

Classification

Sugarcane belongs to the genus *Saccharum.* The word *saccharum* owes its origin to the Sanskrit word *'sarkara'* or *'sakkara'* meaning sugar. This became *'sukkar'* in Arabic and *'Sakharon'* in Greek. It is placed in the family Poaceae, sub-family Panicoidae and tribe Andropogoneae. Traditionally six species have been recognised in the genus *Saccharum* viz., *S. officinarum, S. barberi, S. sinense, S. robustum, S. edule* and *S. spontaneum*. Today, for all commercial purpose of sugar industry, only interspecific hybrids involving chromosomal complements from allied species and allied genera are grown. Sugarcane today is not a member of *Saccharum officinarum* but a *Saccharum*inter-specific hybrid.

- *Saccharum officinarum:* This is best represented by thick-stemmed, colourful, soft and juicy sweet canes. It has never been found in the wild. Available clones of this species were part of the kitchen gardens of primitive tribes in the Melanesian islands who used these canes for chewing. Owing to the majestic appearance and quality, the Dutch settlers in Java named the cane of their chaoice as **'Noble cane'**. It is an octoploid (2n=80), with a basic chromosome numberof x=10. Before the advent of hybrid varieties in the 20th Century, varieties of this species were used by the sugar industry. This species is in general susceptible to most of the pests and diseases of sugarcane
- *Saccharum sinense:* The *sinense* or the China cane was brought to India from China by the East India Company around 1796 and was received by Roxburg, who treated it as a new species and named *S. sinense*. This species is characterized by long and thin stalks, broad leaves, low to medium sucrose content and early maturity. This species includes **'Pansahi'**, **'Nargori'**, and **'Mungo'** groups of sugarcane.
- *Saccharum barberi:* This is the indigenous cane of India mostly used for jaggery (*gur*) making and it was named after CA Barber who made a detailed study of this cane. It is characterized by short and thin stalks, narrow leaves, low to medium sucrose content and early maturity. The clones of this group are in general possess deep root system with good tillering habit and are moderate in girth and weight, medium in sugar, high in fibre and well adapted to the biotic and abiotic stresses of the subtropical conditions. In fact, Alexander, The Great (327 BC) took this type of canes from the state of Punjab to the west. The cultivar "Chunnee" was taken by Kobus to Java and made history in sugarcane breeding.
- ***Saccharum spontaneum***: The *Kans*, is well known for its wide variability and adaptiveness to diverse climatic and edaphic conditions. It is a polymophic species and diveristy ranges from annual to perennial type with both sexual and asexual reproduction taking place freely. Many forms are highly rhizomatous; rhizomes growing to several meters even. In general, the group as a whole possesses pithy stalk and hardly any extractable juice. Tillering is profuse, and in general exhibits marked resistance to moisture stress, low temperature and to many

pests and diseases. Chromosome numbers vary from 2n=40 to 128 (x=8, most frequent count 2n=64).

The success story of hybrid sugarcane started in 1918 in India with the release of Co 205, a progeny of *S. officinarum* (Vellai) X *S. spontaneum* (Coimbatore) in Punjab.

Some of the species of sugarcane

Species	Other names	Native	Description
S.officinarum	Pondya, Pundia Noble species	New Guinea	Cultivated species. Thick, juicy stalk with high sugar and low fiber. Compressed internodes. Generally resistant to smut, susceptible to mosaic and red rot. Occupies first position in the list of contributors, to the genome (hybrid, complex) of modern cultivated sugarcanes cultivars.
S.barberi	Includes sugarcane group 'Sunnabile'	North-eastern India	Cultivated species. Short and thin stalks. Long internodes. Early maturity. Low to Medium sugar content.
S.sinenes	Includes sugarcane groups 'Nargori, Mungo and Panschi'	North-eastern India	Cultivated species. Long, thin stalks. Early maturity. Low to Medium sugar content. Prominent nodes. Long and zigzag like internodes.
S.spontaneum	Kans grass, Kash	South Asia	Wild species of sugarcane, relative of cultivated cane. Highly resistant to abiotic and biotic stresses. Low sugar content. Occupies second position in the list of contributors, to the genome (hybrid, complex) of modern cultivated sugarcanes cultivars.
S. robustum		New Guinea	Swollen, solid internodes
S. arundinaceum		South Asia	Hardy sugarcane species
S.ravennae	Italian sugarcane, Ravenna grass, Plume grass	Temperate – tropical Asia	It is tertiary genetic relative of sugarcane. Can be used as forage and for erosion control.
S.procerum		–	Solid internodes.
S.edule		–	Partial sterile from cultivated species.

Morphology of Sugarcane:

Sugarcane is a tall perennial plant growing erect even up to 5 or 6 metres and produce multiple stems. The plant is composed of four principal parts, root system, stalk, leaves and inflorescence. Sheath is Green with red blotches; moderate to heavy bloom; scarious border prominent; sheath splitting occasional Clasping; Spines present on the middle of the sheath; deciduous. Blade Joint or Transverse Mark is Purplish green; medium: fair bloom. Ligule: Medium; symmetrical; gradually tapering towards the edges. The inflorescence of sugarcane generally called the 'arrow' is an open panicle. It is long (30 centimeter or more) and tapering. Cane is medium-thick; slightly staggered; slightly oval in cross section, internal tissue yellow with purple tinge: rind hard; pith present as small cavity. Node & buds are slightly depressed; leaf scar slightly inclined. Buds are medium, plumpy, ovate; occasionally hairs at the tip of the bud noticed; inserted at leaf scar. Sugarcane is a C4 plant having high efficiency in storing solar energy and most efficient converter of solar energy to sucrose. Sugarcane has essentially four growth phases:

1.Germination phase, 2. Tillering phase, 3. Grand growth phase, 4. Maturity and ripening phase.

Important regions/ zones for sugarcane cultivation in India: Broadly there are two distinct agro-climatic regions of sugarcane cultivation in India, viz., tropical and subtropical. However, five agro-climatic zones have been identified mainly for the purpose of varietal development. They are (i) North Western Zone (ii) North Central Zone (iii) North Eastern Zone (iv) Peninsular Zone (v) Coastal Zone. Tropical region Shared about 45% and 55% of the total sugarcane area and production in the country, respectively along with the average productivity of 77 t/ha (2011-12). Sub-tropical region accounted for about 55% and 45% of total area and production of sugarcane with an average productivity about 63 t/ha (2011-12)

Tropical Sugarcane region: The tropical sugarcane region consists of sugarcane agro climatic zone 4 (peninsular zone) and 5(Coastal zone) which includes the states of Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Madhya Pradesh, Goa, Pondicherry and Kerala.

Sub-tropical sugarcane region: Around 55 per cent of total cane area in the country is in the sub-tropics. U.P, Bihar, Haryana and Punjab comes under this region.

Planting Seasons of Sugarcane

The duration of sugarcane crop in India ranges from10-18 months. A 12 months crop is most common. Time of planting is governed by weather conditions. Sugarcane requires about 25-32^0 C temperature for good germination. Spring and autumn plantings are two important planting seasons.

Spring Planting: In Northern India spring planting is done in February-March while in Peninsular India it is done in January-February. Spring planted crop is known as suru in Maharashtra and eksali in Gujarat and Andhra Pradesh.

Autumn Planting: This planting is very popular in northern India. This planting is done in September-October while in Bihar and Peninsular India it is done in October-November. Autumn planting is also known as pre-seasonal planting in Maharashtra and Gujarat. The pre-seasonal crop matures in 13-15 months and supplies sugarcane in early crushing period.

Adsali Planting: In Maharashtra and Karnataka, adsali planting is done I n July-August and the crop matures in 16-18 months. Because of extended growing season, there is increase in

yield as well as sugar recovery. Biggest advantage of adsali is that it passes through only one summer season. In the present scenario, area under adsali planting is declining because of less availability of irrigation water.

Late Planting: Because of wheat crop is taken on large area in rabi season in Northern and Central India, planting of sugarcane is delayed until harvesting of wheat in March-April. Research data has been proved conclusively that delay in planting causes considerable yield reduction.

Seasons of Planting: There are three seasons of sugarcane planting :-

i. Adsali – Planted in the months of June/July. This crop remains in the field for 15 to 18 months.

ii. Pre-season – Planted in October – November.

iii. Suru – Planted in January.

Staggering of sugarcane planting in three seasons helps to ensure continuous cane supply to the sugar factories, whose crushing season is 160 to 180 days from mid-October or November onwards.

State and season wise time of sowing and harvesting:
Sugarcane take generally one year to mature in sub tropical states (U.P., Punjab, Haryana, Bihar etc.) called "Eksali" however in some tropical states it matures in 18 months (Andhra Pradesh, Karnataka, Maharashtra etc.) called "Adsali". In India planting Seasons of Sugarcane in subtropical regions are September to October (Autumn) and February to March (spring), whereas in tropical regions it is June to August (Adsali) and January to February and October to November (Eksali). Apart from this in some states like Karnataka and Tamil Nadu sugarcane planting continue throughout the year except few months.

Climate : Sugarcane is basically a tropical crop requiring hot climate. But it also grows well in subtropical climate. Therefore in India, sugarcane is grown right from Punjab and Haryana in the North and Karnataka/TamilNadu in the down South. It has wider adaptability and grows well where temp00erature ranges between 20^0C to 40^0c. It responds well to long period of sunlight (12 to 14 hours), high humidity (above 70%) and high rainfall even upto 1500 mm. If assured irrigation water is available, it can also be grown in areas where rainfall is low upto 500 mm. As sugarcane crop remains in the field for more than 12 months, it withstands temperature variations of winter (6 to 8 deg.cent.) and summer (40 to 42^0C). Optimum temperature for sprouting (germination) of stem cuttings is 32° to 38°c. It slows down below 25°, reaches plateau between 30°-34°. Temperatures above 38° reduce the rate of photosynthesis and increase respiration. For ripening, however, relatively low temperatures in the range of 12° to 14° are desirable. The duration of sugarcane crop in India ranges from10-18 months. A 12 months crop is most common. Time of planting is governed by weather conditions. Sugarcane requires about 25-32^0 C temperature for good germination. Spring and autumn plantings are two important planting seasons.

Sugarcane is grown in the world from alatitude 36.7° N and 31.0° S, from sea level to 1000m of altitude or little more. It is considered as essentially a tropical plant. It is a long duration

crop and thus it encounters all the seasons' viz., rainy, winter and summer during its life cycle.

Principal climatic components that control cane growth, yield and quality are temperature, light and moisture availability. The plant thrives best in tropical hot sunny areas. The "ideal" climate for production of maximum sugar from sugarcane is characterized as:

- A long, warm growing season with a high incidence of solar radiation and adequate moisture (rainfall) - the plant uses from 148 to 300g of water to produce 1.0g of dry substance.
- A fairly dry, sunny and cool, but frost free season for ripening and harvesting - moisture percentage drops steadily throughout the life of the sugarcane plant, from 83% in very young cane to 71% in mature cane, meanwhile sucrose grows from less than 10 to more than 45% of the dry weight.
- Freedom from typhoons and hurricanes

Rainfall: A total rainfall between 1100 and 1500 mm is adequate provided the distribution is right, abundant in the months of vegetative growth followed by a dry period for ripening. During the active growth period rainfall encourages rapid cane growth, cane elongation and internode formation. But during ripening period high rainfall is not desirable because it leads to poor juice quality, encourages vegetative growth, formation of water shoots and increase in the tissue moisture. It also hampers harvesting and transport operations. This seems to be the case in regions of South America, South East Asia and some parts of Southern India.

Temperature: Growth is closely related to temperature. Optimum temperature for sprouting (germination) of stem cuttings is 32° to 38°c. It slows down below 25°, reaches plateau between 30°-34°, is reduced above 35° and practically stops when the temperature is above 38°.Temperatures above 38° reduce the rate of photosynthesis and increase respiration. For ripening, however, relatively low temperatures in the range of 12° to 14° are desirable, since this has a noticeable influence on the reduction of vegetative growth rate and enrichment of sucrose in the cane.

At higher temperatures reversion of sucrose into fructose and glucose may occur besides enhancement of photorespiration thus leading to less accumulation of sugars. Severe cold weather inhibits bud sprouting in ratoon crop and arrests cane growth. Temperatures lower than 0°C induces freezing of less protected parts such as young leaves and lateral buds. The damage depends upon the length of the cold period. Smut initiation and spread is high at ambient temperatures of 25° -30°. Similarly the spread of red not disease is high at higher temperatures (37°-400°) when all other conditions are similar. Rust incidence is high when the minimum temperatures are drastically reduced. Shoot-fly incidence is high in summer when the air temperatures are very high. Also higher shoot fly incidence was observed when the difference between maximum (day) and minimum (night) temperature are low.

Reduction in yield of sugarcane due to rise in temperature:

The sugarcane productivity and juice quality are profoundly influenced by weather conditions prevailing during the various crop-growth sub-periods. Sugar recovery is highest when the weather is dry with low humidity; bright sunshine hours, cooler nights with wide diurnal variations and very little rainfall during ripening period. These conditions favour high sugar

accumulation. The climatic conditions like very high temperature or very low temperature deteriorate the juice quality and thus affecting the sugar quality. Favourable climate like warm and humid climate favour the insect pests and diseases, which cause much damage to the quality and yield of its juice and finally sucrose contents.

Relative humidity: High humidity (80-85%) favours rapid cane elongation during grand growth period. A moderate value of 45-65% coupled with limited water supply is favourable during the ripening phase.

Sunlight: Sugarcane is a sun loving plant. It grows well in areas receiving solar energy from 18 - 36 MJ/m^2. Being a C_4 plant, sugarcane is capable of high photosynthetic rates and the process shows a high saturation range with regards to light. Tillering is affected by intensity and duration of sunshine. High light intensity and long duration promote tillering while cloudy and short days affect it adversely. Stalk growth increases when daylight is within the range of 10 - 14 hours. Increase in leaf area index is rapid during 3rd to 5th month, coinciding the formative phase of the crop and attained its peak values during early grand growth phase (Ramanujam and Venkataramana, 1999).

Optimum climatic requirements

Mean total radiation received in 12 months of growth has been estimated to be around 6350 MJ/m^2. About 60% of this radiation was intercepted by the canopy during formative and grand growth periods. The total dry matter production showed linear relationship with the intercepted PAR and the test of correlation yielded R_2 value of 0.913 (Ramanujam and Venkataramana, 1999).

However, the energy conversion rate in terms of dry matter production per unit of intercepted radiation showed a quadratic response with percent light interception indicating that the rate of energy conversion increased linearly up to 50% light interception and beyond this level, the rate of photosynthetic conversion of solar radiation gets reduced (Ramanujam and Venkataramana, 1999).

In sugarcane crop canopy the upper 6 leaves intercept 70% of the radiation and the photosynthetic rate of the lower leaves decreased due to mutual shading. Therefore, for effective utilization of radiant energy a LAI of 3.0 - 3.5 is considered optimum.

Areas having short growing period benefit from closer spacing to intercept high amount of solar radiation and produce higher yields. But in areas with long growing season wider spacing is better to avoid mutual shading and mortality of shoots.

Effect of climate on sugarcane yields and sugar recovery

The sugarcane productivity and juice quality are profoundly influenced by weather conditions prevailing during the various crop-growth sub-periods.

Sugar recovery is highest when the weather is dry with low humidity; bright sunshine hours, cooler nights with wide diurnal variations and very little rainfall during ripening period. These conditions favour high sugar accumulation.

Soils: Black to medium black soils upto 100 to 150 cm depth with good drainage are most suitable. Sandy loam soils along the river sides are also good for this crop. As the crop remains in the field for 12 to 18 months, good fertile soils are most suitable. Water logged soils which have no drainage are not suitable.

Soil is a medium for plant growth. It provides nutrients, water and anchorage to the growing plants. Maintenance of proper physical, chemical and biological conditions of the soil is necessary for realizing higher growth, yield and quality of sugarcane. Sugarcane does not require any specific type of soil as it can be successfully raised on diverse soil types ranging from sandy soils to clay loams & heavy clays.

A well drained, deep, loamy soil with a bulk density of 1.1 to 1.2 g/cm^3 (1.3-1.4 g/cm^3 in sandy soils) and total porosity, with an adequate balance between pores of various sizes, is higher than 50%; ground water table below 1.5 to 2.0 m from soil surface and an available water holding capacity of 15% or more (15 cm per meter depth of soil is considered ideal for sugarcane cultivation).

The optimum soil pH is about 6.5 but sugarcane can tolerate considerable degree of soil acidity and alkalinity. Hence, it is found growing in soils with pH in the range of 5 to 8.5. Liming is required if pH is less than 5.0, or gypsum application if pH is more than 9.5. Nematode infestations are likely to occur in very sandy soils.

Soil testing before planting is desirable as it helps in determining the optimum quantity of macro and micro nutrient application. Chemical constraints in the soils, such as acidity and low fertility, are relatively easy to correct or control.

Poor physical conditions like soil compaction due to intense mechanization when limiting, are much more difficult to ameliorate. For this reason, physical properties of soil are given as a factor in sugarcane growth. Based on the experience gained in Brazil, a few criteria to define soils, which are apt for sugarcane growing, were suggested

Preparatory tillage: Two ploughings should be given. First ploughing should be 20-25 cm. deep. After applying F.Y.M second ploughing be given across the first ploughing. Then clods should be crushed by suitable implement or machine. Fifty cartloads (20 MT) of F.Y.M. should be given at the time of preparatory tillage, and properly mixed. The ridges and furrows are opened for irrigation. In black soils ridges and furrows should be 1.2 m apart and in medium soils 1.o.m.apart.

Varieties: There are different varieties for three seasons. However, some varieties which have wider adaptability are grown in two or even in all the three seasons.

iv. Adsali – Co – 740, Co-M-88121, Co-86032

v. Pre-season – Co-740, Co-7219, Co-8014

vi. Suru - Co-740, Co-7219, Co-M-7125, Co-7527, Co-M-88121, Co-8014, Co-86032.

Seed rate and Planting:

Sugarcane is vegetatively propagated for commercial cultivation. Different kinds of planting materials viz., cane setts; are used for raising sugarcane crop.

Cane Setts

Stem cuttings or sections of the stalks are called "setts" or seed pieces. Each sett contains one or more buds. Always use fresh, genetically pure, pest and disease free setts as seed material. Generally, three bud setts are used for planting throughout the world, while in some areas two-bud setts are also used.

25,000 sets of three eyebuds per hectare when ridges are 1.2m apart.

30,000 sets of three eyebuds per hectare if ridges are 1 m. apart.

Seed sets should be treated with fungicide before planting. There are two methods of planting sets. 1. Dry method & 2. Wet method. If the soils are heavy and black dry method is followed and if the soils are medium or light, wet method is followed.

Seed rate: Seed rate in sugarcane varies from region to region. Generally higher seed rate are used in north western India (Punjab, Haryana and Rajasthan) because of the lower germination percent and also adverse climatic condition (very hot weather with desiccating winds) during tillering phase. A northern region seed rate generally varies from 35,000 three budded setts per hectares while in southern region it range between 25,000 to 40,000 three budded setts.

Distance: The row spacing in sub tropical part is ranges 60-120 cm whereas, 90-150 cm in tropical regions.

Interculture: As the crop remains in the field for a long period, interculture operations such as weeding/chemical weed control and earthing up are necessary. Pre-emergent sprays of weedicides such Atrizin, Diron or 2-4 D in suitable concentrations may be given. In addition, one or two weedings be given.

Earthing Up

Earthing-up operation is also known as "hilling-up". This operation is carried out in two or three stages.The first earthing-up operation is known partial earthing-up and the second/third operation is known as "full earthing-up".

The partial earthing-up is done at 45 days after planting. In partial earthing-up, little amount of soil from either side of the furrow is taken and placed around the base of the shoots. While doing partial earthing-up, the furrow in which the cane row is present gets partially filled-up.

Full earthing-up is done after 120 days after planting coinciding with the peak tiller population stage. During full earthing-up the soil from the ridge in between is fully removed and placed near the cane on either side. This operation converts the furrows into ridges and ridges into furrows.This operation could be done either manually or by using a bullock-drawn/tractor drawn furrower depending upon the spacing adopted.

Full earthing-up at the end of formative phase (i.e., 120 DAP) checks further tillering, provides sufficient soil volume for root proliferation, promotes better soil aeration and provides a sound anchorage or support to the crop and thus preventing lodging.

One more earthing-up after cane population is stabilized at 180 DAP may be helpful in preventing lodging and water shoots formation. It also improves aeration and helps to control weeds.

Propping

The operation of tying the leaves together using the bottom dry and green leaves is known as propping. It is primarily done to check lodging of cane. Usually the trash without removing from the cane is twisted to form a sort of rope and cane stalks are tied together. This is known as trash-twist propping. Propping can be either done for each row or two rows can be brought together and tied.

In India bamboo poles are used and propping is done in certain pockets, but it is too expensive. In areas where cane top growth is heavy and wind velocities are high, propping is very much necessary to prevent lodging. This is because lodging leads to several problems:

- Cane breakage and thus loss of stalk number at harvest and thus loss of cane yield
- Infestation of certain pests and diseases causing microbes through lodged and damaged canes
- Damage by rats and rodents
- Bud sprouting leading to reduced cane quality
- Aerial root formation which also affects cane quality

Difficulty in inspection of driplines and harvesting

Fertilizers : Sugarcane is a very heavy feeder and hence it requires high doses of fertilizers compared to other perennial crops. Total quantities of N, P & K for sugarcane grown in three seasons are given below:-

Planting season Nitrogen Phosphorus Potash.

	Kg/ha	**kg/ha**	**kg/ha**
a.Adsali	400	170	170
b.Pre-season	340	170	170
c.Suru	250	150	150

These quantities are given in four split doses and at critical growth stages .

First dose - at the time of planting
Second dose - 6 to 8 weeks after planting (tillering iritation stage)
Third dose - 12 to 16 weeks after planting (when full growth is attained).
Fourth dose - when 1-2 internodes are developed and second earthing is given.

Irrigation: Water requirement of sugarcane is the highest of all. The total quantity of water and number of turns to be given are different for the crop of three seasons.

Season	**Water requirement cm.**	**No.of turns**
1. Adsali	350	32
2. Pre-season	250	25
3. Suru	225	22

Prominent sugarcane based cropping system in tropical and subtropical regions of the country

Sub tropical

Paddy- Autumn Sugarcane-ratoon-wheat
Greengram- Autumn Sugarcane-ratoon-wheat
Maiz- Autumn Sugarcane-ratoon-wheat
Kharif Crops-Potato-Spring Sugarcane-ratoon-Wheat
Kharif Crops-Mustard-Spring Sugarcane-ratoon-Wheat
Kharif Crops-Pea/Coriander-Spring Sugarcane-ratoon-Wheat
Kharif Crops-Wheat-late Planted Sugarcane-ratoon-Wheat

Tropical region

Bajra-Sugarcane(pre-seasonal)-Ratoon- wheat
Paddy-Sugarcane-Ratoon- Finger millet
Paddy-Sugarcane-Ratoon- Wheat
Paddy-Sugarcane-Ratoon- gingelly
Paddy-Sugarcane-Ratoon- urd.
Cotton-Sugarcane-Ratoon–wheat
Sugarcane-Ratoon-Kharif rice-Winter rice.

Fertilizer management

An average crop of sugarcane yielding 100 t/ha removes 208kg of N, 53kg of P, 280kg of K, 30 kg of Sulphur, 3.4kg of iron, 1.2 kg of manganese, 0.6 kg of copper respectively from the soil. Hence, soil has to be replenished to maintain the productivity of sugarcane with the said quantities of nutrients. If the soil test value is below the critical value, apply sulphate form of Zn, Cu, Fe and Mn through soil application and foliar spray (The total concentration of salt should be 0.5% for young crop and 2.5% for a grown up crop). The recommendation of NPK for sugarcane crop varies from state to state and varies from region to region. The recommendation of Nitrogen is from 70-400 kg/ha Phosphorus 27-74 kg/ha and Potassium 25-141 kg/ha. The recommended dose of bio-fertilizers for sugarcane crop is 10-12 kg/ha Acetobector, Azotobector, *Azospirillum* (or *Gluconacetobacter*) and PSB are the major bio fertilizers which are being used in Sugarcane crop.

Water management:

In tropical area, irrigations are to be given once in 7 days during germination phase (1 –35 days after planting), once in 10 days during tillering phase (36 – 100 days after planting), again once in 7 days during grand growth phase (101 – 270 days after planting) and once in 15 days during maturity phase (271 days after planting up to harvest) adjusting it to the rain fall pattern of the area. About 30 to 40 irrigations are needed. Whereas in subtropical area about 7-10 irrigations are being given to the sugarcane crop. Sugarcane is a high water requirement crop. About 250 tonnes of water is needed to produce one tonne of sugarcane. Methods like alternate furrow irrigation, drip irrigation and trash mulching could be of use to economize irrigation water during water scarcity periods. Foliar spraying of a solution containing 2.5% urea and 2.5% muriate of potash 3 or 4 times at fortnightly intervals during drought periods would help to reduce the impact of drought on the crop.

Water requirement and applying irrigation at critical stages of growth:

As mentioned earlier, critical stages are those during which sugarcane is affected severely due to water stress and the loss cannot be restituted by adequate water supply at later stages. These stages are: sprouting (germination), formative stage or tillering, ripening and initiation

of sprouting in ratoons. In case of limited water availability, one may sustain sugarcane productivity by irrigating at critical stages of growth.

Weed Management

In sugarcane weeds have been estimated to cause 12 to 72 % reduction in cane yield depending upon the severity of infestation. The nature of weed problem in sugarcane cultivation is quite different from other field crops because of the following reasons:

- Sugarcane is planted with relatively wider row spacing.
- The sugarcane growth is very slow in the initial stages. It takes about 30 – 45 days to complete germination and another 60-75 days for developing full canopy cover.
- The crop is grown under abundant water and nutrient supply conditions.
- ratoon crop very little preparatory tillage is taken up hence weeds that have established in the plant crop tend to flourish well.

The major weeds are Sedges- Cyprus rotundus; Grasses-Cynodon dactylon, Sorghum helepense, Panicum spp, Dactylocternium aegyptium, Broad leaved weeds – Chenapodium album, Convolvulus arvensis L., Amaranthus viridis L., Portulaca oleraceae L., Commelina bengalensis L., Trianthema portulacastrum L. etc.

Integrated weed management

Complete weed control cannot be achieved by using any one method. To have more dependable, economical and desirable weed control without environmental problems, it is advisable to have a proper combination of agronomical, cropping, rotational and biological methods with supplemental use of herbicides.

Weed Management in Pure Crop of Sugarcane

1. Spray Atrazine 2 kg or Oxyflurofen 750 ml/ha mixed in 500 ltr. of water as pre emergence herbicide on the 3rd day of planting, using deflector or fan type nozzle.
2. If pre-emergence spray is not carried out, go in for post-emergence spray of Grammaxone 2.5 litre + 2,4-D sodium salt 2.5 kg/ha in 500 litre of water on 21st day of planting.
3. If the parasitic weed striga is a problem, post-emergence application of 2,4-D sodium salt @ 1.25 kg/ha in 500 litre of water/ha may be done. 2, 4-D spraying should be avoided when neighbouring crop is cotton or bhendi.
4. Apply 20% urea also for the control of striga as direct spray.
5. Pre- plant application of glyphosate at 2.0 kg ha-1 along with 2% ammonium sulphate at 21 days before planting of sugarcane followed by post emergence direct spraying of glyphosate at 2.0 kg ha-1 along with 2% ammonium sulphate with a special hood on 30 DAP suppressed the nut sedges *(Cyperus rotundas*) and provided weed free environment.
6. If herbicide is not applied work the junior-hoe along the ridges on 25, 55 and 85 days after planting for removal of weeds and proper stirring.
7. Remove the weeds along the furrows with hand hoe. Otherwise operate power tiller fitted with tynes for intercultivation.

Harvesting: Harvesting and collection of cane should be either mechanical or manual. It has been found that when cane is harvested and gathered mechanically, by combined harvester, or manually cut and collected and then grab loaded into large trucks/ tractor trolley.

Time of harvest: As far as possible harvesting should be carried out avoiding extremes of weather. In sub tropical of India, it has been shown that spring harvested plant crop-wouldresult in a better ratoon then that obtained by harvesting in the autumn. Sugarcane crop isharvested after attending maturity, generally it starts from the month of Oct and continue tillthe month of May in sub-tropical states where in Tropical states it starts from the month ofDec and continue till the month of May.

Harvesting technique: Harvesting of vegetative stocks, automatically initiates the re generation of ratoon crop, with the removal of apical dominance, the stable is piece is now free to sprout its axillary buds from top downwards. In the manual system of sugarcane harvesting using a straight blade knife at the ground level, then axillary buds which are below the ground level are forced to sprout and rationing. It has been found that knife with a curved blade in much superior to straight knife in harvesting sugarcane sticks in flush with the ground (Meemeduma, 1983).

Yield : Yield depends upon the variety grown, season of planting and cultivation practices followed. If the recommended doses of fertilizers are applied and optimum irrigation is given, then the expected yield varies from 110 MT to 170 MT per hectare.

Mechanization in Sugarcane Cultivation: Sugarcane is a labour intensive crop and shortage of labour and unavailability of labour at reasonable rate is the major concern in sugarcane cultivation. To combat the paucity of labour, mechanized sugarcane cultivation is the only option to carry out all the operations in time. Automated sugarcane cutter-planter machine, FIRB Planter, trench opener, Ratoon management device (RMD), power weeder, sugarcane setts cutting machine, ring pit digger, trash shredder, tractor mounted ridger, power sprayer equipments are in vague. The sugarcane harvester is also using in tropical parts of the country.

Ratooning: Sugarcane stem has an inherent ability of giving out new shoots from underground stems. If proper care is taken, these shoots develop into normal cane. This method of raising crop is called ratooning. Taking ratoon crop Is economical because it saves labour on preparatory tillage, opening ridges and furrows and planting. It also saves expenditure on seed material, as new sets are not required to be planted. If proper care is taken of ratoon crops as is taken of regular crop, ratoon crop also gives as much yield as ratoon crop. On account of these advantages, ratooning has become very popular among sugarcane growers. Of the total area under sugarcane in Maharashtra 40% is under ratooning.

Ratooning in Sugarcane

Ratooning is a practice of growing a crop from the stubbles of previous crop. Ratooning is a method where the lower parts of the plants along with the roots are left uncut at the time of harvesting gives sprouting of ratoon. In ratoon crops, there is a saving in cost of cultivation in terms of land preparation, seed canes, etc. If ratoons are well maintained, they give high yields. But, for a better ratoon crop, a better plant crop is necessary. Within a week after harvesting the plant crop, ratoon management practices like stubble shaving, off baring, gap filling, fertigation etc., should be initiated.

Different Practices Followed in Ratoon Sugarcane Crop:

- The sugarcane crop whose ratoon is to be kept should be harvested at ground level.
- Generally all trash and dried canes should be removed from the harvested field but, in case of lack of moisture in soil trash is kept as such in field for mulching.

- Irrigation should not be given for a period of 4 to 6 weeks.
- The emerging shoots should be cut close to the ground to encourage shoots from lower internodes and to have uniform stand of the crop.
- Soil has to be loosened before starting irrigation.
- A plough is worked first to break the sides of the ridges and then middle portion is loosened by working an iron grubber or kudali.
- This operation provides aeration and pruning of old, non functional roots.
- One or two harrowing are done and land is left to dry up for 2 to 3 weeks before starting the irrigation.
- The dose of manure for ratoon is 25 to 30 tons FYM, 250 kg N 125 kg P and 125 kg K/ha.

Time of Application	N (kg)	P (kg)	K (kg)	FYM (ton)
At first irrigation	75	125	125	25-30
6 week after first irrigation	75	----	------	----
At earthing up	100	------	-------	------
Total	250	125	125	25-30

- First irrigation is given at 6 weeks after the harvest of the previous crop and then regular schedule of irrigation is followed as in suru cane.
- Intercultivation and earthing up operations are followed as in case of plant cane.
- Ratoon crop matures earlier than the plant cane and gives about 90 to 100 tons/ha. yield.

Tobacco

Scientific name: Nicotiana tabaccum

Family: Solanacae

Economic importance of tobacco:

1) Employment: Growers and curers of tobacco are 6.5 million, in cigarette 5 million and in bidi industry are 30 million.
2) Exporting to the foreign countries. It gives an amount roughly Rs.1000crore.

Uses: (i) Cigerette, bidi, pipe, cigar, snuff, quid (chewing tobacco), hookah
(ii) Extraction of Nicotine Sulphate (imp. Insecticide)

Origin: *N.tabaccum*: South America (Central America & Mexico)
N.rustica: Peru

History: The red Indians used to inhale its smoke from burning leaf through the nostrils by means of a hollow cane & the name of the instrument was given to the plant which came to be known as ‘ Tobbaco’ in Spanish and ‘Tobacco’ in English. The French ambassador ‘Jean Nicot’ introduced tobacco in the French Court in 1560. The botanical name & word nicotin was derived from his name.

Distribution: It is introduced into India by the Portuguese in the early 17th century A.D.

World: Major producing countries are India, China, U.S.A, Brazil, Zimbabwe and Tukey. China ranks 1st in tobacco production followed by India.

India: Important states are A.P, Gujarat, Karnataka, Parts of Orissa, Bihar and W.B
Maximum area of production: A.P
Maximum productivity: Gujarat

Classification:

	N.tabaccum	**N.rustica**
Height	>150cm	90-120cm
Leaf	Narrow, large, sessile and petiolate	Broad and large petiolate
Flower colour	Red, pink and white	Greenish yellow
Used	Manufacture of cigerette, cigar, bidi, chewing & snuff purpose	Hookah, Chewing & snuff
Cross between	*N.sylvestris* & a member of *Tomentosae* family	N. undulata & N. paniculata

Botanical Description: It is an annual herbaceous plant grown primarily for leaves with shallow root system and simple cylindrical stem. Leaves of ***N.tabaccum*** are broad, ovate, linear, leaf texture with a Nicotine content of 0.5-5.5%. However ***N. rustica*** has petiolate shape of ovate, leaf texture is leathery and Nicotine content is 3.5-8.0%.

Inflorescence: Raceme type

Flower: Complete & perfect, corolla contains 5 petals, it has 5 anthers; Pistil is compound & matures into a capsule type of fruit. It is a self pollinated crop. If cross pollination occurs it is mediated by insect. Cross pollination may be 4-10%.

Types of tobacco & area of distribution in India:

1. Flue cured verginia tobacco: Andhra Pradesh, Karnataka
2. Bidi Tobacco: Gujarat & Nipani area of Karnataka
3. Cigar & cherrot: Tamil Nadu, West Bengal
4. Hookah Tobacco: Assam, West Bengal, Bihar, U.P and Punjab
5. Chewing & snuff tobacco: T.N, W.B, Assam, Bihar, U.P and Punjab
6. Natu,barly and Lanka tobacco: Andhra Pradesh
7. Pikka tobacco: Orissa

Soil: Well drained light and properly aerated soil is ideal for tobacco cultivation. Plant is highly susceptible to flooding. Sandy loam to clay loam-soil is best for its cultivation. pH varies from 5.0 to 6.0, but in many parts of the country it can be grown upto a pH about 8.0.

Climate:

- Temperature, Rainfall, relative humidity and sunshine hours have excessive mark on growth and flowering metabolism of tobacco plant.
- Tobacco is tropical in origin but it is grown successfully under tropical, sub-tropical & temperate climate.
- It requires 100-120days frost free climate with a temperature of 26°C. Tobacco seeds require about 21°C temperature for germination. Temperatures between 27-32C are desirable for rapid uniform germination. It matures rapidly when average temperatures are about 25C. Very cold weather causes slow growth and also affects its quality. Similarly hot weather and high temperature there is loss of moisture from the tissues of the plant and the leaves become thicker with stronger aroma which means there is more gum formation, does not ferment well and are inferior in taste and aroma.

- In South India the crop is cultivated in winter from Oct.-March, when temperature is moderate. In Punjab it is during summer, whereas in East & west parts it is in September to January.

Raising of tobacco seedlings: Tobacco seeds are small, tiny, and delicate therefore it should not be shown directly to the main field. It should be shown first in nursery/seedbed, where the seedlings are tilled and attained a particular size, and then transplanted to the main field.

Selection of site for nursery preparation:

Nursery bed – good internal & surface drainage, located at higher spot to avoid flooding at any time. It is advisable to change the place of nursery every year to avoid the occurrence of soil born disease and pest.

Rabbing: Partial sterilization of soil that aids in the destruction of weed seeds, soil born diseases, soil inhibiting insects, improves soil structure & soil fertility status.

(For rabbing organic residues such as tobacco stalks, paddy husk, and sugarcane trash are spread on soil at a height of 15-20cm and are burnt from the leeward side.)

Field preparation: A clean, well pulverized seed bed with good drainage system of good tilth is needed for transplanting of tobacco seedling. Beds are 100-200cm wide to facilitate hand weeding and watering.

Nursery raising: Optimum time of sowing in nursery is 2nd fortnight of August, with a seed rate of 3-5 kg/ha.

- For quick and satisfactory germination, seeds should be soaked overnight in water & then keeping it moist in wet gunny bags, the seed coat starts splitting in 3-6 days, thereafter seeds should be sown in nursery.
- Seeds are mixed with sand & distributed uniformly and are pressed slightly with hand to ensure uniformity.
- First ten days very critical for the development of seedlings, mulching can be done which can protect the tender seedlings from strong heat and rains, conserve moisture.
- Weekly application of Blitox or endosulfan 35 EC may prevent the crop from the attack of disease & pest.

Transplanting:

- It should be done at the end of 7th week, i.e. when seedlings are 10-15cm length.
- It should be done with proper care. The Nursery beds should be well watered for easy removal of seedlings.
- Transplanting time: Winter crops- Middle of October to middle November
  Summer crops- End of March to beginning of April
- Spacing: 90×90 cm^2

Manures & Fertilizers:

Nitrogen: Quality in tobacco particularly in smoking types depends on the balance of the nutrients in the leaf. Heavy manuring with N increases yield but has an adverse effect on quality. Excess N supply, the carbohydrate-N ratio get reduced. Therefore, Adequate N is required for optimum growth & development.

The high value product like FCV requires low N, therefore N level should be reduced. Generally for heavy black soil 30kg N, whereas for light red soil it is 50kg/ha is optimum.

Potassium: High K content in leaf improve colour retention, leaf burning reduces nicotine content in tobacco smoke, thus making it less hazardous. However, potassium should be applied in the form K_2SO_4 not in chloride form as it gives poor results.

Phosphorus: P requirement is very low in case of tobacco crop.

Among secondary nutrient Ca, Mg and S plays an important role in controlling the yield and quality of tobacco. Among micronutrients, Cl influences leaf quality and leaf burn.

Fertilizer Schedule: N_2:P_2O_5:K_2O kg/ha

- FCV tobacco- 30:60:80 for black soil and 50:60:80 for red soil.
- Hookah & chewing type -150:150:0 (N should be applied in two splits as basal and at 50 DAT), F.Y.M @ 25t/ha.
- Wrapper Type- 125:100:200 (N should be applied in two splits as basal and at 40 DAT), FYM @25t/ha

Water Management: Tobacco can't tolerate water logging condition and at the same time plant can't withstand severe drought also. Therefore, light & frequent irrigation should be given to the crop. However the interval & number of irrigations depend upon soil type, weather, type of tobacco grown, etc. Generally **6 irrigations** are recommended on light soils for flue cured tobacco. Water requirement for flue cured tobacco is **500mm**.

Crop can be divided into three phases:

- 1st phase: 2-5 weeks after transplanting, plant is sensitive to excess soil moisture therefore small amount of water is needed.
- 2nd phase: Development phase (emergence to expansion of leaves i.e. knee height to bloom) here water requirement is highest.
- 3rd phase: Maturity phase: Water requirement decreases due to removal of leaves and their senescence.

In case of cigar and cheroot tobaccos more frequent light irrigations are needed. In Tamil Nadu about 20-22 irrigations are required for chewing and cigar tobaccos. In Bihar 2-3 irrigations at monthly intervals are required for chewing and hookah tobaccos. In Punjab around 12-13 irrigations at the interval of 5-7 days are given for hookah tobacco. In West Bengal one or two irrigations are required for cigar filler, cigar wrapper and hookah tobaccos.

Topping: When flower heads begin to show, the plants are topped by removing off the top of the plant. It consists in removal of the terminal bud with or without some of the small top leaves just or after the emergence of the flower head. This practice stimulates the development of the remaining leaves. It is very important operation for the quality of tobacco leaves. It gives a uniform quality and prevents excessive coarseness in the leaf.

De-suckering: After topping dormant buds become active and they produces branches known as 'suckers' to get full benefit of topping. The suckers are to be removed periodically and generally they are removed after 7 days of topping & thereafter 2-3 successive de-suckering are necessary. Manual de-suckering is laborious & time consuming.

- Application of Coconut oil to the top 6 axils, suppresses the suckers.
- 2% Malic Hydrazide/IBA.

The main aim of topping and de-suckering operations is to divert the energy and nutrients of the plant from flower head to leaves which influence the yield and quality of tobacco.

Weeding: First 60 DAT is very critical for crop weed competition. Application of herbicide Fluchloralin @ 2-3 Kg a.i/ha before planting the seedling in the main fields very effective.

- Tobacco is very often infested by **Orobanche** (broom rape) a total root parasite which may be controlled by pre plant application of EPTC@ 6kg a.i/ha or post planting application of 2,4-D.

Insect & Pest

1. Cutworm (*Agrotis ipsilon*)

Larvae feeds on tender leaves & damages stem.

Control: Summer ploughing, spraying of Endosulfan 35EC @2ml/lit can be effective.

2. Tobacco caterpillar (*Spodoptera litura*)

Larva feed on the chlorophyll of the leaves.

Control: Spray endosulfan 35EC @30ml or Carbaryl 50% WP @50gm in 22 lit of water.

1st spray should be at 3-4 weeks after sowing followed by 2nd spray at 8-10days after sowing.

3. Stem Borer

It feeds on the tissue inside the stem and midribs causes swelling and mostly seen in the nursery.

Contrl: Endosulfan 35EC @2ml/lit can be effective.

Disease:

1. Damping off (Caused by fungus ***Pythium aphanidermatum*.**)

It appears in the nursery bed with decay of seedlings at the soil surface.

Control: Seed bed should have good drainage system, overcrowding of seedling should be avoided and affected seedlings should be removed. Spraying of Bordo-mixture 0.4% can be effective.

2. Root knot (***Meloidogyne incognita***)

It is a nematode and the affected plants are stunted and wilted, when pulled up roots show galls.

Control: Crop rotation, flooding, spraying of Methyl bromide, Vapum (fumigant) are very effective.

Crop rotation can be done with Tobacco–Bajra, Tobacco-Chilli, Tobacco-Arhar and Tobacco-cotton.

Harvesting: Right stage is when the leaves are matures i.e. when the normal green colour changes to yellowish green and become thick and spotted with sticky to touch. If such leaves are bent under thumb a cracking sound is produced. There two methods of harvesting-

1. Priming: Harvesting is done by removing a few leaves as and when they mature. Generally lower leaves mature first followed by the upper ones. This method of harvesting is called priming and 2-4 leaves are harvested in each priming subsequently at one week interval. In total 5-6 primings are required for total harvesting. Soon after harvest the leaves are strung on bamboo sticks@ 100 leaves per stick and loaded in the barn for curing. This method is adapted for cigarette and wrapper tobacco.

2. Stalk cut method: In case of stalk cut method plants consisting of all the leaves intact are cut closed to the ground with a sickle and left in the field overnight for wilting. Hookah, bidi, cigar, cheroot and chewing tobacco are harvested by this method.

Yield: Hooka Tobacco: 750-850 Kg cured leaves/ha

Vilayati 1200-1600 kg

Curing: It is the process by which the harvested leaves are made ready for marketing. It is the process of drying, decomposition of chlorophyll from the harvested leaves, hydrolysis of

starch into sugar & fermentation of sugar thereafter.

Objective: To produce dried leaves of suitable physical & chemical property that is the final product has adequate colour, texture and aroma.

Types: Flue curing, Air curing, Fire curing and Sun curing.

1. **Flue curing:** The flue curing tobacco is raised with low level of N and harvested by priming method. The leaves are strung and stacked into barn. The barn is artificially heated. Green leaves are loaded in the upper half of the barn and the lighter one in the lower half. This curing process consists of three stages:

a. Yellowing: During yellowing leaf is kept at a low temperature (32-35°C) and high humidity for about 30-40 hours till it attains a bright lemon yellow colour.

b. Fixing colour: After yellowing the temperature is raised gradually and humidity of barn is lowered by opening the ventilators. Great care is required in raising the temperature during this stage. It is raised by not more than 1-2°F every hour. It takes about 16-24 hours.

c. Drying: This is the last stage in flue curing process which may last from 28-42 hours. The ventilators are closed and temperature is again gradually raised to 160°F to dry the veins and midribs of the leaves. After this the ventilators are opened to cool down the barn. The leaves are left in barn overnight for absorbing moisture and to come to normal condition for handling the storage.

2. **Air curing:** Two types of tobaccos, the Lanka tobacco in Andhra Pradesh and wrapper tobacco in West-Bengal are air cured. The leaves are cured under atmospheric temperature. Relative humidity of 70-80% is maintained by sprinkling water inside the barn. The entire process is over in about 5-6 weeks. During this process the leaves turn yellowish brown and after this the leaves are placed in a pit for 24 hours and then transferred to the second pit for 48 hours and then back to the first pit for 24-48 hours. After curing the leaves attain adark brown colour.
3. **Fire curing:** This method is adapted in case of chewing type of tobaccos. The leaves are harvested in such a way that a small portion of stem remains attached to the leaves. The leaves are wilted for few hours in the field, then tied into bundles and hung in a smoke hut. They are smoked for about 12 hours by burning dried leaves of trees locally available. After the smoke treatment, the leaf is fermented in bulks for three to four weeks. The fermented leaves are given treatment with salt water or with jiggery.
4. **Sun curing:** There are several modifications in sun curing method-
   - **a.** Curing whole plants on racks as in cigar and chewing tobaccos. After initial wilting in the field the plants are strung on bamboo poles and cured in sun. The entire process takes about 15-20 days.
   - **b.** Curing whole plant on the ground as in bidi and hookah tobacco. In this curing the leaves are allowed to dry in sun on the ground and are turned over twice a day. This process continues for about a week and then heaps are made which are opened the next day and re-heaped. This process of heaping, opening of heaps, spreading and re-heaping continues for about 10-15 days. By the end of this process leaves become completely cured.

Medicinal and Aromatic Plants

Medicinal and aromatic plants form a numerically large group of economically important plants which provide basic raw materials for medicines, perfumes, flavours and cosmetics. These plants and their products not only serve as valuable source of income for small land holders farmers and entrepreneurs but also earn valuable foreign exchange by way of export. India possesses a rich and diverse variety of plant resources to meet the growing demand for plant-based drugs, perfumery and flavour items. Availability of wide variation in soil and climate in our country offers great potential for cultivation of these plants in the country. During the last decades there has been a renewed interest in recognizing plants as a source of drugs, perfumes and cosmetics which may be due to little or no side effects associated with their application and user friendly and environment friendly products. It is therefore necessary to collect, conserve and evaluate germplasm and to develop agro technologies for medicinal and aromatic plants with potential for farming.

There are two distinct areas of health management i.e. (i) Modern System of Medicine system (ii) Traditional Systems of Medicine. Presently, about 130 clinically useful prescription drugs of known chemical structure are used in Modern System of Medicine and solely derived from about 100 species of higher plants. The traditional system of medicine continues to cater in to the medicinal needs of the about 80% world population. India has a unique position in the world where a number of Traditional Systems of Medicine are practiced such as Ayurveda, Siddha, Unani, Homeopathy, Yoga and Naturopathy for the total health care. These systems of medicine are heavily dependent upon the medicinal plants. India and China are two great producers of medicinal plants and has capabilities to earn by export of herbs and herbal products of more than Rs. 5000 crores with generation of employment to 1.5 crore people.

Definition of Aromatic plants

These plants possess essential oil in them. These essential oils are the odoriferous steam volatile constituents of the aromatic plants. The essential oil also called the volatile oils, ethereal oils, or aetherolea, or simply as the "oil of" the plant from which they were extracted. Oil is "essential" in the sense that it carries a distinctive scent, or essence, of the plant. Essential oils do not form a distinctive category for any medical, pharmacological, or culinary purpose. The essential oil contains secondary metabolite-terpenoids, don’t play apparent role in direct primary metabolism of the plant, but are used in perfumery, cosmetic and pharmaceutical industries.

Definition of Medicinal plants

Medicinal plants are those plants rich in secondary metabolites and are potential source of drugs. The secondary metabolites include alkaloids, flavonoids, steroids, coumarins, glycosides. They form the main base of drugs in Indian System of Medicine.

Aromatic Plants
Cymbopogon spp.
Family: Germinae

It is an important genus of aromatic grasses with about 121 species and of which nearly 27 species occur in India. They include cultivated, semi wild, wild species. Various essential oils are present the species which are used in perfumery, cosmetics and pharmaceutical preparations. The commonly grown Cymbopogon species, their popular name and oil constituent are as under:-

Common name	Scientific name	Oil % on dry wt. basis	Major constituent in oil
East Indian lemon grass	*C. flexuosus*	1.0-1.2	Citral (80%)
West Indian lemon grass	*C. citratus*	1.0	Citral (75-80%)
Jammu or North Indian lemon grass	*C. pendulus*	0.75	Citral (75-80%)
Palmarosa	*C. martinii var. motia*	0.49	Geraniol (95%)
Ceylon citronella grass	*C. nardus*	0.70	Citornellal (20-25%)
Java citronella grass	*C. winterianus*	1.2-1.5	Citornellal (30-38%)

In India lemon grass, citronella and palmarosa grasses are cultivated to greater extent. Their cultivation practices are given as under:-

Lemon Grass

In India three types of lemon grasses are mostly cultivated viz., East Indian lemon grass, West Indian lemon grass and Jammu lemon grass as a main source of citral.

Lemon grass is grown commercially in Kerala and nearby adjacent states. Its oil is popularly known as Cochin oil. Indian is annually producing 12000 MT per year and its export earns Rs. More than 5 crores.

Uses

1. Citral is main constituent, which is used in flavours, cosmetics, perfumes. It gets also used in manufacturing synthetic vitamin A.
2. Oil has bactericidal, insect repellent and medicinal uses.
3. Spent grass is good source of cattle feed.
4. Spent grass are also useful for manufacturing cardboards, paper or as fuel

Climate and soil

The plants are hardy, prefers moist, humid and warm climate with plenty of sunshine. Regarding soil, it can be grown on poor soils, sloppy hills. Soil pH ranging from 4.6-7.5 is ideal**.**

Cultivars

OD-19, SD-68 (CIMAP) = Herbage yield 50-55 t/ha/year, oil yield-80-85 kg/ha/year and oil recovery is 1-1.5%

CKP-25 (RRL Jammu) = These are hybrid strains, and are capable to yield more than OD-19 and SD-68.

Nursery

15-20 kg seeds are required for raising seedlings of one hectare. Line sowing at 10 cm interval in the beds and covered with cut grass material. Seedlings of about 2 months (12-15 cm) high are ready for transplanting.

Field preparation

Pits of 5 cm are made at spacing 15 x 10 cm, and then transplanting should be done.

Manure and Fertilizers

60-80 kg N: 50 kg P: 35 kg K is recommended.

Harvesting

The crop comes to harvest after 90 days of planting and subsequently it is harvested at 50 days interval. The grass is cut 10 cm above the ground level and 5-6 cuttings can be taken/year. The crop can be retained in the field for about 5-6 years.

Yield/year

25 kg oil/ (first year) 80 – 100 kg oil (2^{nd}-6^{th} year)

Citronella Grass

Citronella Grass Java citronella (*C. winterianus*) and ceylon citronella (*C. nardus*) are two important primary source of citronella oil. Among these, Java type is considered to be the best source of citronella oil and its cultivation has become popular. In India, it is grown mostly in Assam and to some extent in states like U.P., AP., Karnataka, Gujrat and Tamil Nadu.

Uses

The oil is used extensively as a source of perfumery chemicals such as citronellal, citronella and geraniol.These chemicals find extensive use in soap, candles and incense, perfumery, cosmetic and flavouring industries throughout the world. Research also shows that citronella oil has strong antifungal properties, is effective in calming barking dogs, and has even been used as a successful spray-on deterrent against pets destroying household items.

Climate and soil

The crop prefers warmer climate with good sunshine hrs. and an annual rainfall of 250 cm spread throughout year. Grows well in plains and also in hills of 900 m. Places with humidity of 75-90 per cent favours the growth and moisture in atmosphere is more important than soil, as the plant is moisture loving. Rich sandy loam soils are most suitable, whereas heavy soils are not good. It grows within the pH Range 5.0-6.5.

Cultivars

The RRL at Johrat has developed some good strains (RRL-JOR-3-1970) giving 50% high leaf yield. NBPGR, Delhi has also identified two improved strains viz. IW 31243 and IW31245. BCKV, Kalyani (W.B) has also developed selection viz. KSCW-SI.

Preparation of land

Land should be prepared well and beds and channels are formed in plains. Rooted slips (6-12 months older) from clump are used as planting material and planting commences during April/May after the onset of monsoon. A spacing of 90 cm between rows and 60 cm within rows is followed and two slips are planted in each hole taken to depth of 15 cm.

Manure and Fertilizers

Citronella grass is soil exhaustive crop and requires liberal application of fertilizers.
N: 125 Kg/ha (applied in equal splits one after every cutting)
P: 62 and K: 50 kg/ha (Both should be applied as basal dose at the time of planting.

Harvesting

Generally plant grows at slower rate till five months after planting and thereafter they start growing at faster rate. Ist cutting may be ready 4-5 months after planting and thereafter cuttings are taken at 2 months interval before winter period. Ideal technique involves cutting the leaves just above the growing point.

Oil yield

Ist year = 140 kg/ha
2^{nd} to 3^{rd} year = 200-300 kg/ha
4^{th} Year =200 kg/ha
5^{th} year =100 kg/ha

The spent grass will be useful as a mulch material and also as organic manure. It can also be used for making paper boards etc.

NB*Apart from citronellal, this oil also contains geranial (12-18%), geranial acetate (3-8%), which can be converted into may other products as synthetic menthol, esters of geranial and citronellal.

Difference between Citronella and Lemongrass

Citronella and Lemongrass are cousins. They almost look the same, they grow the same way, and as essential oils, they are processed the same manner. But do you know how to distinguish **Citronella from Lemongrass?** Citronella has pseudo stems that are collared reddish. Lemongrass, on the other hand, is green.

Palmarosa Grass

Oil of Palmarosa, also known as Rusa or Rosha is the essential oil obtained from the aromatic grass *Cymbopogon martinii* Var. motia. The oil obtained from other form Viz., *C. martinii* var. sofia is known as ginger grass oil.

Difference between Motia and Sofia grass

Motia and sofia grasses are almost identical and difficult to distinguish when they are in early growth stages.

Motia grass: It has fine yellow stem with dark green leaves and they attain the height of 2.45 meters.

Sofia grass: It has purple stem, shorter (90-120 cm) than motia grass.

Uses

The oils are used to base for the fine perfumery and are valuable because of their geranoil content. The oil is useful in imparting rose like aroma to vide variety of soaps, taboco products. The oil of palmarosa is commercially preferred to ginger oil. Palmarosa oil has been shown to be an effective insect repellent when applied to stored grain and beans, an antihelmintic against nematodes, and an antifungal and mosquito repellent.

Climate and soil

Palmarosa is hardy plant and can grow in varying altitude right from sea level. It stands well in places receiving rainfall from 75 to 150 cm. It also requires bright sun light and does not perform well under shady conditions.

The crop prefers well drained soil of neutral to alkaline reaction and can be grown in poor sandy to heavy fertile soils of arid tracts, saline soils conditions and also in marginal and sub-marginal lands.

Varieties

The NBPGR has identifies superior selection viz. IW 31244 and RRL.

RRL (B)-77 and RRL (B)-71 for commercial cultivation.

CIMAP has developed high yielding variety “TRISHNA”. It has registered 40% more oil yield and geranoil content as high as 95%.

Land preparation

Nursery bed should t e prepared out well pulverised soil and at raised level. Leaf mould or FYM should be mixed well within the nursery bed.

Seed rate and Sowing

Seed rate of 2.5 kg/ha is recommended. Sowing is usually done from April to September. Seedlings become ready for transplanting at about 15 cm height ie., just after 4 weeks after seed sowing. The main field should be well pulverised 3-4 times, followed by forming ridges and furrows at 90 cm apart. The seedlings are transplanted at 60 cm spacing in the ridges.

Fertilization

FYM 10 t/ha and NPK at 60:40:40 kg/ha are required. Application of $ZnSO_4$ 25kg/ha will increase the yield.

Harvesting

If transplanting is done in May-June, the grass comes to first harvest after six months. Harvesting consist of cutting of upper third of stem along with leaves.

Yield

Herbage-20-30t/ha/year
Oil-50-60 Kg/year

Opium
Botanical Name: *Papaver somniferum* L.
Family: Papaveraceae

Opium poppy is the species of plant from which opium and poppy seeds are derived. Opium is the source of many narcotics, including morphine (and its derivative heroin), thebaine, codeine, papaverine, and noscapine. The Latin botanical name means the "sleep-bringing poppy", referring to the sedative properties of some of these opiates.
The opium is an outstanding medicinal plant, the products of which viz. opium and codeine are important medicines used for their analgesic and hypnotic effects. A synthetic derivative of this drug from morphine known as heroin has led to worldwide social; problems but attempts to find a synthetic drug which would replace morphine and codeine have not been fruitful so far. Its cultivation in India is confined to states of Madhya Pradesh, Rajasthan and Uttar Pradesh.

Climate and Soil

It is a crop of temperate climate but can be grown successfully during winter in subtropical regions. Cool climate favours higher yield, while, higher day / night temperature generally affects the yield. Frosty or desiccating, temperature, cloudy or rainy weather tends to reduce not only the quantity but also the quality of opimum. Optimum, poppy prefers a well-drained, highly fertile, light or loam soil with an optimum pH around 7.0.

Varieties

A large number of races of optimum followed by their local names are reported to grow in India. They usually vary in leaf characters, floral characters or capsular characters. **Telia, Dholia** are some of the local races recommended for commercial cultivation.

Sowing

The seed is either sown broadcast or in lines. Before sowing, the seeds may be treated with fungicides like dithane M-45 @ 4 g per kg of seeds. Seed .is usually mixed with fine sand before broadcasting to ensure uniform spread in the bed. Line sowing is preferred to broadcasting as the latter method has many drawbacks like higher seed fate, poor crop stand and difficulty in carrying out inter cultural operations. The best time for sowing is late October or early November. Seed rate is 7-8 kg/ha for broadcast method and 4-5 kg/ha for line. Spacing of 30 cm between lines and 30 cm between plants is normally adopted.

Manures and Manuring: Opium poppy responds remarkably to the application of manures and fertilizers which increase both the yield and quality of opium. Farm yard manure @ 20-

30 t/ha is generally applied by broadcasting while the field is prepared for sowing. Besides,

60-80 kg of N and 40-50 kg of $P_2 0_5$ per ha is recommended. No potash is applied. Half of N and entire P are applied at sowing time through placement and remaining half of N Placed at rosette stage.

Irrigation

A careful irrigation management schedule is essential to get a good crop of poppy. A light irrigation is given immediately after sowing followed by another light irrigation after 7 days when the seeds start germinating. Three irrigations at an interval of 12-15 days are given till pre-flowering stage and then irrigation frequency is reduced at 8-10 days during flowering and capsule formation stage.

Lancing and Latex Collection

Opium starts flowering in 95-115 days after sowing. The petals start shedding after 3-4 days of flowering. The capsules mature after 15-20 days of flowering. Lancing of the capsules exudes maximum latex at this stage. This stage can be visually judged by the compactness and a change in the colour from greenish to light green coloured ring in the capsule. The stage is called as industrial maturity.

Harvesting and Threshing and Yield

The crop is left for drying for about 20-25 days when the last lancing on the capsules stops exudation of latex. The capsules are then picked up and the plant is; removed with sickles. Harvested capsules are dried *in* open yard and seeds are collected by beating with a wooden rod. The yield of raw opium varies from 50 to 60 kg/ha.

Mint

Local Name: Pudina

Botanical Name: *Mentha arvensis, Mentha citrita*

Family: Lamiaceae (Mint family)

The genus *Mentha* consists of about 25 species, of which better known species of commerce are

- Japanese mint (*M. arvensis* L.)
- Pepper mint (*M. piperita* L.)
- Common or Spear mint (*M. spicata* L.)
- Scotch spear mint *(M. cardiaca)*
- Bergamot mint *(M. citrata)*

Uses

Mint essential oil and menthol are extensively used as flavourings in breath fresheners, drinks, antiseptic mouth rinses, toothpaste, chewing gum, desserts, and candies, such as mint (candy) and mint chocolate. The substances that give the mints their characteristic aromas and flavours are menthol (the main aroma of peppermint and Japanese peppermint).

Mint was originally used as a medicinal herb to treat stomach ache and chest pains. There are several uses in traditional medicine and preliminary research for possible use in treating irritable bowel syndrome

Soils

Deep soils, loam to sandy loam well drained, well aerated and loose textured soil. Clay soils are not suitable.

Climate

All mints prefer, and thrive near pools of water, lakes, rivers, cool, moist spots in partial shade. (Temperate climatic condition), tropical climate is not suitable, plentiful rainfall during growth and good sunshine during harvest is best suitable during crop growth.

Tillage

Bring the soil to fine tilth by ploughing and 2 cross harrowing. FYM 50 cart loads of compost per hectare while preparing the land.

Varieties

Japanese mint:

CIMAP/Hybrid-77 (High yielding menthol rich variety, produces 350 kg essential oil/ha).
RRL 118/3 (Possess higher herbage yield and high menthol content (80-90%)

Pepper mint:

No named variety is available; one exotic introduction is available EC.41911 is recommended, since it has higher menthol content.

Spear mint

Kiran (239 kg oil/ha with linalool 48% and linalyl acetate 37%). The variety has been developed by CIMAP.

Propagation

Suckers, (runners or Rhizomes).

Planting Season

Jan, Feb in Tarsi areas or before the start of rainy season

Planting

Approximately 500 kg suckers are required to plant one ha area. Suckers should be set in furrows 5-1 cm deep with a spacing of 60-75. Plant the suckers end to end. Cut the suckers into 10-12 cm length before sowing. Plants should be spaced 30 cm apart in rows 60 cm apart.

Inter-culture

In order to keep the top soil loose for better penetration of water, air, sun light and weed free Mentha needs frequent inter culturing weeding and hoeing.

Irrigation

Mentha crop requires considerable moisture well distributed throughout the entire growing season. As roots do not penetrate deep in the soil, light and frequent irrigations are recommended. During summer irrigate the crop weekly.

Fertilizers

50 kg N + 75 kg $P_2$05 + 37 kg $K_2$0 per hectare is given as basal dose and 75 kg of N per hectare as top dressing in three equal doses should be applied.

Harvesting

Normally 2-3 times in a year (120 days)

1. First crop should be harvested before the onset on monsoon (May-June).
2. Second harvesting well after monsoon is over (September-October).
3. Third harvesting (November-December)

Yield

Approximately 60-150 kg of oil per hectare during the first year and subsequently oil yield gets increased per hectare under good management.

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