CROP IMPROVEMENT-I

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Study in respect of origin, distribution of species, wild relatives and forms

RICE (*Oryza sativa*) 2n = 24

Rice is the world's most important food crop grown in more than hundred countries of the world.

Origin: S.E. Asia

Distribution:

It is grown in humid tropical and subtropical climate and 90 per cent of the rice is produced and consumed in S.E. Asia. Rice producing countries are China, India, Japan, Korea, Pakistan, Bangladesh and other S.E. Asian countries. In India A.P, Karnataka, Tamilnadu, Orissa etc.

Rice is one of the oldest cultivated crops. The two cultivated species of rice are

i) *Oryza sativa* - Asian rice

ii) *O. glaberrima* - African rice.

i.**Polyphyletic**: Originated from several species. According to this theory, the two forms of cultivated rice *viz.,* Asian rice *O.sativa* and African rice *O.glaberrima* have evolved independently in their respective regions from several species.

ii. **Monophyletic** : According to this theory both Asian rice and African rice arose from a common parent (*O.perennis*). This view is the most accepted one because both Asian rice and African rice are similar except in glume pubescence, ligule size and colour of pericarp which is red in African rice.

According to polyphyletic origin the present day rice varieties have originated from several species. According to monophyletic origin a single species has given rise to all varieties of cultivated rice. *viz., Oryza sativa, Oryza glaberrima* most of the modern rice workers believe that origin of cultivated rice monophyletic. From *oryza perennis* rose the Asian rice in South East tropical Asia and African rice in the upper valley of Niger River in Africa.

Species in the genus oryza:

According to the latest view the genus *oryza* include 20 wild species. Out of these two are cultivated diploids *viz. O.sativa* and *O.glaberrima* and rest are wild species which include both diploid and tetraploid forms.

Botanical name	**Chromosome No.**	**Genome**	**Origin**
O.sativa	24	AA	Asia
O.nivara	24	AA	Asia
O.meridionalis	24	-	Australia
O.longistaminata	24	AA	Africa
O.rufipogan	24	AA	Asia
O.glumaepatula	24	-	America
O. grandig lumis	48	CCDD	America
O.glaberrima	24	AA	Africa

O.barthii	24	AA	Africa
O.australiensis	24	EE	Australia
O.latifolia	48	CCDD	America
O.alata	48	CCDD	America
O.eichingeri	24	CC	Africa
O.minuta	48	BBCC	Asia
O.punctata	48	BBCC	Asia
O.officinalis	24	CC	Asia
O.granulata	24	-	Asia
O.meyeriane	24	-	Asia
O.ridleyi	48	-	Asian
O.longiglumis	48	-	New Guninea
O.brachantha	24	FF	Africa
O.schlechter	-	-	New Guinea

RICE

Related species of rice and their contributing characters in rice improvement

Species	**Genome**	**Useful traits**
O.alata	CCDD	High biomass production
O.australiensis	EE	Drought tolerance, BPH resistance
O.barthii	AA	Drought avoidance, BLB resistance
O.brachyantha	FF	Yellow stem borer and leaf resistance
O.eichengeri	CC	BPH, GLH, WBPH resistance
O.grandi glumis	CCDD	High biomass production
O.granulata	unknown	Shade tolerance, adaptation to acrobic soils
O.latifolia	CCDD	High biomass production
O.longistaminata	AA	Drought tolerance
O.meridionalies	AA	Elongationa bility
O.meyeriana	Unknown	Shade tolerance, adaptation to aerobic soils
O.minuta	BBCC	BPH, GLH, WBPH, BLB and blast resistance
O.nivara	AA	Grassy stunt virus resistance
O.officina lis	CC,BB,CC	BPH, GLH, WBPH resistance
O.prnetate	BB, BBCC BPH	BPH resistance
O.ridleyi	unknown	Shade tolerance, stemborer,

WHEAT – (*Triticum aestivum*) 2n = 6x = 42

Wheat is the most important cereal in the world, giving about one -third of the total production, followed closely by rice. In temperate regions it is the major source of food. The chief use of wheat is, the flour for making bread. Wheat is grown in all the continents except Antartica. It is the staple food of the 1/3rd of the world's population.

Place of origin:

Diploid (2n=14) : Asia minor

Tetraploid (2n=28) : Abyssinia, North Africa
Hexaploid (2n=42) : CentralAsia

Distribution:

USA, Canada, Latin America, Europe, China, Japan, Argentina, Mexico, India, Pakistan. Every month of the year a crop of wheat is harvested some where in the world. In India extensively cultivated in North West India, Eastern part, Central plain to some extent Southern peninsular zone.

Fourteen species of wheat according to Vavilov:

1. *T.boeoticum*
2. *T.monococcum*
3. *T.dicoccoides*
4. *T.dicoccum*
5. *T.durum,*
6. *T.persicum,*
7. *T.turgidum 8. T.polonicum,*
9. *T.timopheevi,*
10. *T.aestivum,*
11. *T.sphaerococcum,*
12. *T.compactu m,*
13. *T.spelta,*
14. *T.macha* .

Origin of diploid wheat:

(Wild einkorn) *T.boeticum* (*T.aegilopoides*)

↓

Natural mutation and selection

↓

T.monoccocum Cultivated diploid **AA** (2n = 14)

Origin o f Tetraploid wheats:

T .monoccocum *x* Unknown species (*Aegilops spelltoides)*

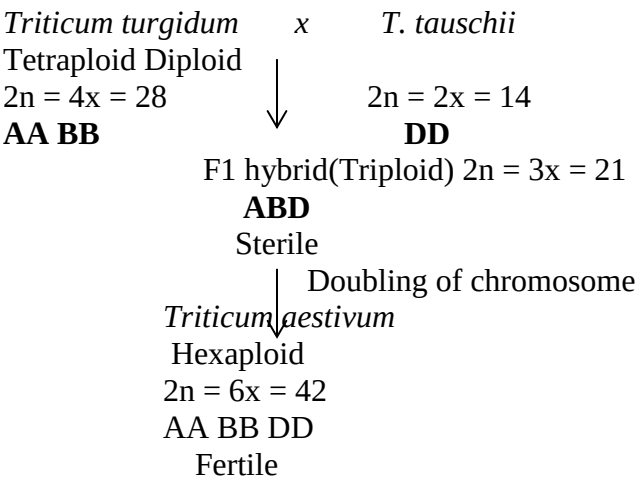
Wild Diploid (2n = 14) **AA** ↓ Diploid (2n=14) **BB**

F1 hybrid
Diploid (2n=14)
AB(Sterile)

↓ Chromosome doubling

Triticum turgidum
Amphidiploid / Allotetraploid
(2n=28)
AA BB
Fertile

Origin of hexaploid wheat:



MAIZE (*Zea mays*) 2n = 20

Corn is the queen of cereals and it is the important crop next to rice and wheat with regard to total area and production. It is studied to a much wider range of climatical conditions than rice and wheat, because of its greater adoptability.

Origin: Central America

Distribution: USA, China, Russia, Canada and many south Asian countries

Progenitors: *Zea tunicata*

Z. teosinte

It belongs to the tribe Maydeae of family gramineae.

Wild relative: Teosinte: There are three species of teosinte of which *Zea mexicana* is annual diploid (2n = 20) like maize. Gamma grass another close relative belongs to genus *Tripsacum*

The genes *Zea* characterized by male terminal inflorescences with paired staminate spikelets and lateral female inflorescences with single or paired pistil late spike lets *Genus Zea* contains four species

1. *Zea mays* (2n = 2x = 20) = Corn
2. *Zea mexicana* (2n = 2x = 20) = Annual teosinte
3. *Zea perennis* (2n = 4x = 40) = Perennial tetraploid teosinte
4. *Zea diploperennis* (2n = 2x = 20) Perennial diploid teosinte

SORGHUM (*Sorghum bicolor*) 2n = 2x = 20

Sorghum is one of the most important food crops in a semi – arid tropics.

Origin: S.E. Africa

Distribution:

A number of land races, wild forms found in S.E. Africa, says the origin Ethiopia in Africa from there it spread to other parts of world. It is grown in Africa, south and central India, China, Argentina, Australia and south and central plains of US.

Progenitor of sorghum

1. *S.arundinaceum*
2. *S.verticilliflorum*
3. *S.sudanense*
4. *S.aethiopicum*

PEARL MILLET (*Penisetum americanum)*

(Bajra – Bulrush Millet) (2n=14)
Pearl millet is also known as Bajra, is an important food crop of semi arid tropics. It is also grown as fodder crop
Origin: W. Africa
Distribution:
Africa, India, Pakistan, South East Asia, USA and Europe
Taxonomy : The genus *Pennisetum* is having more than 140 species. Stapf (1954) has divided the genus *Pennisetum* in to five sections *viz.,*
1. Gymnothrix
2. Eupennisetum
3. Penicillaria
4. Heterostachya
5. Brevivalvula

The cultivated *Pennisetum glaucum* belongs to the section penicillaria.
Progenitors :
1. Pennisetum purpureum
2. P.qumulatum
3. P. orientale
Origin and putative parents.
Stapf included 32 species is *Penicillaria*. Of these 32 species found is Africa, six annuals are considered wild and probable ancestors of the cultivated one. They are
1. *P perottettii*
2. *P. molllissimum*
3. *P. violaceum*
4. *P. versicolor*
5. *P. adonense*
6. *P. gymnothrix*

The cultivated species of pennisetum is believed to have originated thro' hybridization with in these six species.

FINGER MILLET (*Elusine coracana)* (2n = 36) Ragi

The common name finger millet to derived from finger like branching of panicle – Ragi is derived from Sanskrit worel Ragika.
Origin: According to vavilor – Africa
According to Decandole – India
Distribution: India, Africa, Pakistan.
Progenitors : *E. indica* is wild in India and Africa
E. stricta is wild only in Africa

Wild relatives :
The genus *Eleusine* comprises of 11 species of which 6 are diploids and 5 are tetraploids.
1. *Eleusine indica*
2. *Eleusine oligostachya*
3. *E.tristachya*
4. *E. poranansis*
5. *E. jaegeri*
6. *E. flacifolia* (2n = 36)
1. *Eleusine coracana*
2. *E. africana*
3. *E. longipoides*
4. *E. verticillata*
5. E. cagopoides

Sugarcane (*Saccharum officinarum*) 2n = 80

Origin: India
The word sugarcane is derived from Sanskrit word 'sharkara' meaning sugar. It includes 3 cultivated species like *S. officinarum, S. barberi,* and *S. sinense.*
Wild species
1. *S. spontaneum,*
2. *S. robustum.*
Cultivated species:
S. officinarum (2n = 80)
S. sinense (2n = 118)
S. barberi (2n = 82 – 124)
S. officinarum is also known as noble cane. The term noble was given by Dutch scientists in Java to tall, handsome, large barelled and colourful canes of this species. The canes of this species have thick stem, soft rind, low fibre, high sugar content, high cane yield, and resistance to smut.
1. *S. robustum* ⟶ *S. officianarum* (New Guinea)
2. *S. officinarum* X *S. spontaneum* ⟶ *S. barberi* and *S. sinense (*North India).
Origin of cultivated species:
The wild progenitor for *S. officinarum* is *S. robustum*
S. officinarum x *S. sponataneum*

Mutation, ↓ selection, hybridization

S. spontaneum

↓

S. barberi

Distribution : India, Brazil, Cuba, China, USA, Mexico, France, Germany and Australia. In India, Uttar Pradesh, Maharashtra, Haryana, Andhra Pradesh, Tamilnadu, Karnataka, Bihar and Punjab. India stands first in sugar and sugarcane production in world

RED GRAM (*Cajanus cajan)* (2n = 22)

Pigeon pea / Red gram is an important pulse crop next to chickpea in India. India is a largest producer i.e. 90% of the world's production

Origin: Africa and India

Distribution: India, Uganda, Kenya, West Indies, Burma etc. In India, Maharashtra, Uttar Pradesh, Madhya Pradesh, Karnataka, Gujarat and Andhra Pradesh and under irrigated belt in Punjab, Haryana and Rajasthan.

Progenitor: *Cajanus cajanifolius, Atylosia lineate*

Genus *Cajanus* and *Atylosia* and have many similarities. *Cajanus* has more than 30 species. The view is that *Cajanus* arose from *Atylosia* . In western ghats, West Bengal and Orissa,

Atylosia species are known as wildtur. Now this genes has been included in *Cajanus.*

SOYBEAN (*Glycine max*) 2n = 4 0

One of the important oil yielding crop of world it is miracle crop giving 42 – 45 per cent protein and 19-20 per cent oil it belongs to family leguminoseae

Origin: China

Distribution: USA, Brazil, China, Argentina and India.

Progenitors: *G. usuriensis*
G. tomentolla
G. tabacina
G gracilis

Glycine max is originated from *G. usuriensis and G. tomentolla*

GREEN GRAM (*Vigna radiata*) 2n = 22

Also known as mung bean

Origin: India

Distribution : India, Pakistan, Bangladesh, Srilanka, Philippines, Taiwan, Thailand, Nepal and Southern Asian countries. In India, Maharashtra, UP, MP, Karnataka, Gujarat A.P, Tamil Nadu and Rajasthan.

Progenitor: *Vigna radiata* var: *sublobata*

Black gram (*Vigna mungo*) 2n = 22

Origin: India

Distribution: India, Pakistan, Sirlanka, and South Asian countries. In India, Maharashtra, UP, MP, Karnataka, Gujarat A.P, Tamil Nadu and Rajasthan.

Progenitor: *Vigna mungo* var *silvestris*

Vigna radiata var sublobata – common progenitor of green gram and black gram

Bengal Gram – Chickpea (*Cicer arietinum*) 2n = 16

The most important pulse crop India is the largest producer of chickpea in the world.

Origin: According to Vavilov (1926) – S.W. Africa and Mediterranean region Later, Vander Maesun (1984) – Turkey and Syria

Distribution: India, Pakistan, Mexico, Turkey, Ethiopia, Burma and Maynmar. In India M.P.

U.P. Rajasthan, Haryana accounts 75-80% of the India's production other states are Maharashtra, Bihar, West Bengal and Andhra Pradesh.

Progenitors :
Cicer bijugum
C. echinospermum
C. reticulatum
Genus *Cicer* has 49 species, out of these nine are annual and forty are perennial

GROUND NUT (*Arachis hypogcaea*) (2n = 40)

It is important oil seed crops in India, grown in subtropical and warm temperate zone also called as peanut or monkey nut. It contains 45-55 per cent oil and 25-30 per cent protein.
Origin: Brazil
Distribution:
India, China, USA, Africa, South and South East Asia In India, Gujarath, Andhra Pradesh, Karnataka and Tamil Nadu Maharashtra, Madhya Pradesh, Rajasthan Uttar Prdesh, Punjab.

Progenitor:
Arachis monticola
A – prostrata
A – silvestres

SESAME (*Sesamum indicum*) (2n=26)

It is an ancient oil seed crop of tropics and warm sub-tropics. It is also called as gingelly.
Origin: India, and Ethopia (Africa)
Distribution: India, Pakistan, Africa, China, Mexico, Iran, Iraq etc.
Progenitors: Sesamum angustifolium
S. radiatum
S. alatum
Wild species utilised in breeding programme
1. S.*alatum* 2n = 26
Resistant to phyllody *S.alatum* x *S.indicum* alatum is having dormancy.
2. S.*malabaricum* (2n = 26) Occurs in Travancore of Kerala. It freely crosses with cultivated gingelly. Oil content is low 32% It is utilised to induce male sterility in cultivated sesame.
3. *S.laciniatum* 2n = 32
Tolerant to phyllody, drought and jassid resistant.
Fertile auto allopoly ploid produced by crossing *S.indicum* x S.*laciniatum*
Sterile, Double.
4. *S.prostratum* occurs in S.India (2n = 26)
Tolerant to drought.

SUNFLOWER (*Helianthus annuus*) (2n=34)

It is an important oil seed crop. Oil content ranges from 46-52 per cent and is of high quality having non-cholesteral properties.
Origin: America

Distribution: USSR, Romania, Canada, USA In India this crop is introduced in 1969 from USSR. In India it is cultivated in Tamil Nadu Karnataka, Maharashtra and Andhra Pradesh, Punjab and Haryana
Progenitors: *Helianthus petiolaris*
H. gigants
Wild species: *H hirsutus*
H rigidus
The genus *Helianthus* comprises of 67 species. Two species *H .annuus* and *H. tuberosus* are cultivated as food plants genus has basic chromosome number of 17 and diploid, tetraploid and hexaploid species are found.

SAFFLOWER (*Carthamus tinctories*) (2n=24)

Safflower is an important oil seed crop of India. The oil is edible but best used in industry particularly in the manufacture of paints and varnishes. It is also used for its reddish dye called carethamine extracted from florets oil is excellent source of unsaturated fatty acid. Oil content is 32 per cent of which above 72 per cent is Linoleic the factor which reduces the blood chotesterol. It belongs to the family compositeae
Origin: Africa and Afghanistan
Distribution
Afghanistan, India, Pakistan, USA, Egypt middle east in India, Maharashtra, Andhra Pradesh, Karnataka together accounts for more than 90 per cent of country's area
Progenitor *Carthamus oxycantha*
C. lunatus
Related species : The wild species *Carthamus oxycanthus* is found in many parts of Punjab. It is a
dwarf bushy plant, very spiny, forming small achenes. The oil content is 15 to 16 percent

CASTOR (*Ricinus communis*) (2n=20)

It is an oil seed crop. It belong to the family Euphorbiaceac. Its oil is mainly used as lubricant, in industry or as a medicinal purpose. It requires warm climate
Origin: Africa
Distribution: African countries (Egypt), China, India, middle East etc. In India Andhra Pradesh, Karnataka, Maharashtra
Classification: Monotypic, all varieties of castor from giant perennials to short internode dwarf have the same chromosome number.
Zugovosky (1962) has described three species in the genus *Ricinus*
1. *R. communis*
2. *R. macrocarpus*
3. *R. microcarpus*
But this is not accepted by Botanists.
There are sub species which are considered to be ecological extreme varieties i.e. polymorphic of cultivated type. They are
R. communis subsp *persicus* (Persian)
ssp. *chinensis* (chinese species)
ssp. *zanzi barensis (* Zanzibar)

ssp. *sanguinens* (Crimson species)
ssp. *africanus* (African)
ssp. *mexicanus* (Mexican)
Red castor varieties (Popova 1930)
Subsp *gibsoni*
subsp c*ambogenisis*

MUSTARD *(Brassica nigra)* (2n=16, 18, 20, 22, 36)

Important oil seed crop grown in cool season sub tropics, higher elevations and winter crops. Seeds contain 40 – 45 per cent oil and 38-41 per cent protein.

Origin: India

Distribution:

China, Canada, India, Europe, Pakistan, collectively contribute 90 per cent of the global production. In India Uttar Pradesh, Rajasthan, Punjab, Assam, Bihar and West Bengal.

Progenitor: Exact progenitor is not known.

The genus *Brassica* contains more than 3000 species of which 40 are of economic importance. Cultivated *Brassica* can be broadly divided in to two distinct types *viz.*

Vegetable type : cabbage, cauliflower, turnip

Oil seed type - rape seed and mustard.

Cotton (*Gossypium sps*) (2n = 2x = 26

69

2n = 4x = 52)

Cotton is grown in tropical and sub-tropical regions of more than 80 countries of the world.

Origin: Central Africa

Distribution: China, USA, India, Pakistan, Egypt. In India Rajasthan, Maharashtra, M.P. Gujarat, A.P. Karnataka and Tamil Nadu.

Progenitors: *Gossypium africanum*
G. raimondii
Gossypium africanum – reached India by traders and travelers and differentiated into two species *G. herbaceum* and *G. arboreum*

Cultivated Species:

I. Asiatic cottons or old world cotton (Diploid cotton – 2n = 26)

1. *G. arboreum* –
2. *G. herbaceum* –

II. New world cotton (Tetraploid cottons – 2n = 52)

3. *G. hirsutum* – American / upland cotton
4. *G. barbadense* – Egyption / sea island cotton

G. hirsutum is predominant species whic h contributes about 90% to the current world production. Besides cultivated species there are about 46 wild species India is the only country where all the 4 cultivated species are grown for commercial cultivation.

JUTE

Corchorus sp (2n=14)
Tiliaceae

The genus *Corchorus* includes about 40 species. In India only 8 species occur. Two

cultivated species are
C.capsularis : White jute 50 races occur in this
C.olitorius : Tossa jute 8 races occur in this.
Both the species are not crossable. Among the two *olitorius* yields more fibre/unit area.
The fibre is finer, softer, more, lustrous and less rooty than *capsularis*. *Olitorius* occupies about 25% of jute area in India. One of the draw backs of **Tossa** jute is pre mature flowering if the varieties are sown earlier in March-April in early monsoon rains. The pre mature flowering leads to profuse branching and deterioration in fibre quality.

MESTA, KENAF, BIMLI JUTE, DECCAN HEMP *Hibiscus cannabinus (*2n=36)
ROSELLE / JAMAICAN SORREL *Hibiscus sabdariffa (*2n=36, 72)

Both the species are important jute supplements and show wide adaptability unlike jute.
At present both the species are known as **Mesta.**
Place of origin :
H.cannabinus have its possible origin in Africa and *H.sabadariffia* - Asia. Kenaf is used for making ropes, twines, fishing nets and also in the paper pulp making
from kenaf stalks especially fine paper, structural boards.
H.*cannabinus* : **mesta**
Compared to jute mesta is of inferior in quality in respect of fineness, lusture, and colour.
Mesta varieties show poor performance in spinning because the fibre is coarse, stiff, brittle and irregular in cross section mesta alone cannot be spun in jute machines unless it is mixed with jute in some proportion.
H.sabadarifra var.*altissima (***Roselle** *)*
Roselle is an useful substitute to jute. It is also called as *Siamijute* two types are available.
i. Tall non branching types cultivated for fibre.
ii. Dwarf, bushy wild type used as green and edible calyx as pickle

Tomato (*Lycopersicon esculentum*) (2n=24)
Tomato is one of the most important vegetable crops grow n throughout the world.
Origin: Peru and Mexico
Distribution: Europe, USA, India, Japan and China. In India it is grown in all the states
Other species:
L. pimpinellifolium - Fusarium wilt, early blight resistant
L. peruvianum - Leaf curl virus resistant
L. cheesmanii - Salt resistant
L. hirsutum - Fruit borer resistant
L. pennellii - Drought tolerant

Chilli (*Capsicum annuum*) (2n=24)
Chillies are also called as pungent pepper grown all over the world except in colder climates. Bell peppers are constituents of many foods, add flavour, colour, vitamin C and pungency.
Origin: Tropical America
Distribution: Mainly cultivated in Brazil, Mexico, Spain South and Central America China and India. In India, Andhra Pradesh, Maharashtra, Karnataka, Tamilnadu and H.P etc.

Five major cultivated species in the Genus Capsicum

1. *Capsicum annuum*
2. *C. frutescens*
3. *C. chinense*
4. *C. pendulum*
5. *C. pubescens.*

Brinjal / Egg Plant (*Solanum melongena*) (2n=24)

Brinjal is an important commercial vegetable crop grown in India.

Origin: Indo-Burma

Distribution: India, Japan, Indonesia, China, Bulgaria, Italy, France, USA and African countrie s. In India all the states grow brinjal

Wild species: *Solanum torvum*

S. nigrum

S. indicum

S. mamosum

OKRA Lady's finger (*Abelmoschus esculentus*) (2n=130)

Okra is a common vegetable crop grown in warmer climate,

Origin: India

Distribution: Asia, Europe, Africa and United States and Brazil. In India it is grown in Gujarat, Maharashtra, Andhra Pradesh, Uttar Pradesh, Tamil Nadu, Karnataka, Haryana and Punjab.

Species of Abelmeschus

Abelmoschus angulosus

A. crinitus

A. ficulneus

Cucumber (*Cucumis sativus*) (2n=14)

Cucumber is one of the Asiatic species and member of the cucurbitaceae which has 90 genera and 750 species.

Origin: India – It is considered as home of cucumber

Distribution: China, USA, Africa, Europe. In India it is grown in north and south and lower as well as higher hills

CHRYSANTHEMUM (*Chrysanthemum moniliformin*) (2n=36)

Florist's chrysanthemum (*Chrysanthemum morifolium*, Ramat) ranks second among commercial flowers in the world. In India it occupies third position, with jasmine and rose standing first and second. It is grown in wide range of environment, suitable for various pur poses

e.g. pot culture, field culture, for garland making or cut flowers or simply bedding purpose, long post harvest life, predicable response to environment and amenability to different attractive training methods or styles. However, the most important of all factors is the immense number and diversity of shape, size and colour displayed by its cultivars. Breeding has played a pivotal role in augmenting this diversity during the long history of its evolution.

Origin: China

Distribution: China, Japan, France, USA, Australia, Europe, and Asia. In India all the states.

Species of chrysanthemum

Genus *Chrysanthemum* belongs to the family Compositeae which is second largest family among flowering plants comprising about 20, 000 species, largest being *Orchidaceae.*

1. *Chrysanthemum morifolium*
2. *C. sinense*
3. *C. indicum*
4. *C. japonicum*
5. *C. arnatum*
6. *C. satsumense*
7. *C. boreale*

Indigenous species

C. indicum– Native to India, Florist chrysanthemum

Wild species

1. *C. stilliszkai, C. rkhtsria, C. atkinsoni and C. leucanthemum* as wild species in the Indo-Tibetan border.

Introduced species / Exotic species

1. *C. caronanium* (Garland chrysanthemum)
2. *C. carinatum* (Tricolour chrysanthemum)
3. *C. rubellum* (for hardiness)
4. *C. sagetum* (Corn marigold (or) pot plant)
5. *C. boreale* (Evolution of florif, chrysanthemum)
6. *C. cinerarifolium* (Used as insecticide)
7. *C. coccineum* (Perennial, seed propagated)
8. *C. manifolium* (Florist chrysanthemum)

MARI GOLD (*Tagetes erecta* L). (2n = 24)

Introduction

Marigold (*Tagetes erecta* L., Asteraceae) is grown as an ornamental crop for loose flowers and as a landscape plant, as well as source of pigment for poultry feed. Flowers are sold in the market as loose or after making into garlands. Other than loose flowers, it can also be used as cut flowers. Marigold especially is used for beautification and also in landscape plans due to its variable height and colour of flowers. It is highly suitable as a bedding plant, in a herbaceous border and is also ideal for newly pla nted shrubbery to provide colour and fill spaces. French marigold is ideal for rockeries, edging, hanging baskets and window boxes.

Origin: Mexico

Distribution: USA, Europe India etc. In India Maharashtra, West Bengal, Karnataka, Tamil Nadu and Andhra Pradesh.

Species, Types and Cultivars

Species: There are about 33 species of the genus *Tagetes.* The characters of important species (Bailey, 1963) are given below:

***Tagetes erecta* (African marigold):** The plant is hardy, annual about 90 cm tall, erect and branched. Leaves are pinnately divided and leaflets are lanceolate and serrated. Flowers are single to fully double and large sized with globular heads. The florets are either 2-lipped or quilled. Flower colour varies from lemon yellow to yellow, golden yellow or orange.

***Targets patulo* (French marigold):** A hardy annual, about 30 cm tall, forming a bushy plant. Foliage is dark green with reddish stem. Leaves are pinnately divided and leaflets are linear

lanceolate and serrated. Flowers are small, either single or double, borne on proportionately long peduncles. The flower colour varies from yellow to mahogany-red.

***Tagetes tenuifolia* (Syn. Tagetes signata):** It is an annual with a branching habit. Leaves are pinnately divided into 12 oblong, linear, sharply serrated segments. Flowers have 5 rays, yellow, roundish and obovate. *Tagetes signata* cv. *Pumila* is a dwarf, brushy and grows less than 30 cm. Flowers are bright yellow and small but numerous.

***Tagetes lucida* (Sweet scented marigold):** The plants of this species are tender, perennial. Leaves are sessile, small and lanceolate. Flowers usually are 2-3 rayed, produced in dense, terminal corymbs. The flowers have much more agreeable odour than other species.

Tagetes lacra: It was discovered in California. The plant grows upto 120-150 cm in height and flowers profusely. Flowers are yellow in colour.

Tagetes lemmonii: It is a shrubby plant, grows up to 60-70 cm. Leaves are slender, opposite; leaflets about 2-3 cm long. Flowers are showy and 2-3 cm in diameter.

The other species grown in gardens are *Tagetes minuta, Tagetes pusilla* and *Tagetes corymbosa.* In India, however, the cultivation of *Tagetes erecta* and *Tagetes patula* dominates.

ROSE (*Rosa indica*) 2n = 14

The rose is the world's most favourite and popular romantic flower. History and symbolism, colour and fragrance, and sheer elegance of from-all combine to give the rose its preeminent

position. Even the thorns have romantic associations. The rose is one of the important crops grown for its cut flowers. It belongs to the family Rosaceae and all species of this flower, with minor exceptions, belong to the genus Rosa. The genus Rosa comprises 120 species and there are more than 30,000 cultivars which are extensively distributed in the temperate and subtropical parts of both the hemispheres.

All the present day remarkable changes in growth habit, flowering and flower shape, from, colour, size and fragrance of modem roses have been due to chance crossing, selective crossing, bud sports, induced mutations, molecular breeding and selections.

Origin: Europe

Distribution: Extensively grown in colder parts, Canada, America, Russia and Japan. In India extensively grown in all northern states. To a little extent in southern states.

Species / Cultivars

R. eglanteria syn. *R. rubiginosa:* Sweet Brier
R. foetida syn. *R. lutea, R. eglanteria:* Austrian Briar rose
R. gallica syn. *R. rubra:* French rose
R. gigantean syn. *R. odorata* var. *gigantean:* Manipur Tea rose
R. hugonis: Father Hugo rose, Golden rose of China
R. kordesii (R. rugosa x *R. Wichuraiana)*
R. laevigate: Cherokee rose
R. moschata : Muse rose
R. multiflora

GERBERA *(Gerbera jamesonii)*

Gerbera commonly known as Transvaal Daisy, Barbeton Daisy or African daisy. It is highly suitable for beds, borders pots and rock gardens. The wide range of colours and the attractive shape of flowers suit very well in flower arrangements. The cur blooms have long vase life.

The breeding of gerbera started in 1887 when R.I. Lynch crossed *Gerbera jamesonii* and *Gerbera viridifolia* . The hybrid was named *Gerbera contabrigensis* known today also as *Gerbera hybida*. Majority of the present commercial cultivated varieties originated from crossing the progenies of these two species.

Mango (*Mangifera indica*) (2n=40)

Origin: Tropical Himalayas

Mango is described as king of all fruits according to Decandole Mango is in cultivation for the last 4000 years supposed to be originated from Himalayas in the areas of Burma, China and Malayan Peninsula. The number of varieties grown in India are about one thousand. Every variety has its own distinct taste, flavour, pulp consistency and yield potential.

Distribution:

It is extensively cultivated in India, Indo-China warm parts of Australia, Philippines, Pacific Islands, Himalayas. In India Andhra Pradesh, Uttar Pradesh, Bihar, Karnataka, Maharashtra, West Bengal and Gujarat

GUAVA (*Psidium guajava*) (2n=22)

In guava, most ofthe commercial varieties are reported to be diploids, the chromosome number being 2n=22, while the seedless varieties are triploids.

Origin: Tropical America / West Indies

Distribution: America, Canada, Australia, India, Burma, Indonesia, Bangladesh etc. In India Uttar Pradesh, Andhra Pradesh, Maharashtra, Karnataka etc.

Banana (*Musa paradisica*) – Fruit variety (*Musa sapientum*) – Vegetable variety (2n=22, 33, 44)

Origin: Tropical Asia

Distribution: USA, Canada, Europe, Brazil, India, Pakistan, Bangladesh, Indonesia, Burma and China. In India Andhra Pradesh, Assam, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orrisa and West Bengal.

The edible cultivated parthenocarpic bananas belong to the section 'Eumusa' which are derived from *Musa acuminata* and *M bulbisiana*. They have 22, 33 or 44 chromosomes; the basic number being n= 11 so that these cultivars are respectively diploids, triploids and tetraploids. Triploid cultivars are generally the most numerous, diploid somewhat less and tetraploids are very rare. Simmonds and Shepherd (1955) devised a method of indicating the relative contributions of these two wild species to the constitution of a cultivar. This involves a scoring technique using 15 morphological characters and applying the derived information to distinguish the

M acuminata types from those of *M balbisinana.*

Depending upon the contribution of these parents to the constitution of the progeny and their chromosomal status, the naturally occurring edible bananas fall into seven groups; two diploids (AA, BB), three triploids (AAA, AAB, ABB) and two tetraploid (AAAA, AAAB).

(i) **Principal clones:** There is a wide range of diversity in the clonal cultivars ranging from edible diploid *M acuminata* (AA) types, nurtured only in sheltered and humid environments, to the hardy hybrid triploids (ABB) which can tolerate seasonal monsoon as well as dry conditions prevailing in most part of the country. There are many synonyms and the classification of the

Indian AAB and ABB groups is exceedingly complex. With possible exception of Dwarf Cavendish, all the important clones are of Indian origin. The important clones are given below.
AB Group : Ney Poovan, Thaen Kunnan, Kunnan, Adakka Kunnan, Nattu Poovan
AA Group : Anaikomban, Matti, Sanna Chenkadali, Kadali, Surya Kadali, Namarai, Pisang Lilin, Tongat
AAAA Group : BodIes Altafort
ABBB Group : Klue Teparod, Sawai (synthetic hybrid)
AAA Group : Amritsagar, Gros Michel, Cavendish, Giant Cavendish, Robusta, Lacatan, Wather, Red Banana, Chakkarakeli, . Manoranjitham
AAB Group : Poovan, Rasthali (Silk), Sugandhi, Pachanadan, Rajapuri, Virupakshi, Nendrapadthai, Nendran
ABB Group : Nalla Bontha, Monthan, Karibontha (S), Ney Vannan (S), Peyan (S), Karpuravalli, Bhimkol, Enn Beman (S), Kallu Monthan (S)

Plant genetic resources, its utilization and conservation

The sum total of genes in a crop species is referred to as genetic resources.

or

Gene pool refers to a whole library of different alleles of a species

or

Germplasm may be defined as the sum total of hereditary material i.e., all the alleles of various genes present in a crop species and its wild relatives. Also known as gene pool or genetic stock or germplasm or genetic resources. Germplasm or gene pool is the basic material with which a plant breeder has to initiate his breeding programme.

Important features of plant genetic resources are:
1. Gene pool represents the entire genetic variability or diversity available in a crop species.
2. Germplasm consists of land races, modern cultivars, obsolete cultivars, breeding stocks, wild forms and wild species of cultivated crops.
3. Germplasm includes both cultivated and wild species or relatives of crop plants.
4. Germplasm is collected from the centres of diversity, gene banks, gene sanctuaries, farmers fields, markets and seed companies.
5. Germplasm is the basic material for launching a crop improvement programme.
6. Germplasm may be indigenous (collected with in country) or exotic (collected from foreign countries)

Kinds of Germplasm:
The germplasm consists of various plant materials of a crop such as
(1) Land races (4) Advanced (homozygous), breeding materials,
(2) Obsolete cultivars (5) Wild forms of cultivated species
(3) Modern cultivars (6) Wild relatives (7) Mutants
These are briefly discussed below :

1. Land races:
These are nothing but primitive cultivars which were selected and cultivated by the farmers for many generations without systematic plant breeding efforts.

- Land races were not deliberately bred like modern cultivars. They evolved under subsistence agriculture.
- Land races have high level of genetic diversity which provides them high degree of resistance to biotic and abiotic stresses.
- Land races have broad genetic base which again provides them wider adaptability.
- The main drawbacks of land races are that they are less uniform and low yielders.
- Land races were first collected and studied by N.I. Vavilor in rice.

2. Obsolete Cultivars:
These are the varieties developed by systematic breeding effort which were popular earlier and now have been replaced by new varieties. Improved varieties of recent past are known as obsolete cultivars.
- Obsolete varieties have several desirable characters they constitute an important part of gene pool. Example : Wheat varieties K65, K68, pb 591 were most popular traditional tall varieties before introduction of high yielding dwarf Mexican wheat varieties. Now these varieties are no more cultivated. They are good genetic resources and have been widely used in wheat breeding programmes for improvement of grain quality. Now such old varieties are found in the genepool only.

3. Modern cultivars:
The currently cultivated high yielding varieties are referred to as modern cultivars. They are also known as improved cultivars or advanced cultivars.
- These varieties have high yield potential and uniformity as compared to obsolete varieties land races.
- They constitute a major part of working collections and are extensively used as parents in the breeding programmes. - As these are good sources of genes for yield and quality, can be introduced in a new area and directly released.
- However, these have narrow genetic base and low adoptability as compared to land races

4. Advanced breeding lines:
These are pre -released plants which have been developed by plant breeders in modern scientific breeding programmes. These are known as advanced lines, cultures and stocks. This group includes, nearly homozygous lines, lines derived from biotechnology programmes i.e. transgenic plants and mutant lines etc. These lines which are not yet ready for release to farmers. They often contain valuable gene combinations.

5. Wild forms of cultivated species:
Wild forms of cultivated species are available in many crop plants. Such plants have generally high degree of resistance to biotic and abiotic stresses and are utilized in breeding programmes. They can easily cross with cultivated species. Wild forms of many crop species are extinct.

6. Wild Relatives
Those naturally occurring plant species which have common ancestry with crops and can cross with crop species are referred to as wild relatives or wild species. Wild relatives include all other species, which are related to the crop species by descent during their evolution. Both these groups are sources of valuable genes for biotic and abiotic stress and for quality traits and yield.

7. Mutants:
Mutation breeding is used when the desired character is not found in the genetic stocks of cultivated species and their wild relatives. Mutations do occur in nature as well as can be induced through the use of physical and chemical mutagens. The extra variability which is created through induced mutations constitutes important components of genepool. Mutant for various characters sometimes may not be released as a variety, but they are added in the genepool. The germplasm includes those carrying gene mutations, chromosomal aberrations and markers genes etc. are considered special genetic stocks. They are useful in breeding programmes.

The gene pool system of classification:
The pool of a crop includes all cultivars, wild species and wild relatives containing all the genes available for breeding use. Based on degree of relationship, the gene pool of crops can be divided into three groups (Harland and Dewet, 1971) , *viz.*,

1. Primary gene pool
2. Secondary Gene pool
3. Tertiary gene pool

These are briefly discussed below :
1. Primary gene pool (GP1) : This is also known as gene pool one (GP1). The gene pool in which intermating is easy and leads to production of fertile hybrids is known as primary gene pool. It includes plants of the same species or of closely related species which produce completely fertile offspring on intermating. In such gene pool, genes can be exchanged between lines simply by making normal crosses. This is the material of prime breeding importance.

2. Secondary gene pool (GP2) : This type of gene pool is also known as gene pool two (GP2). The genetic material that leads to partial fertility on crossing with GP1 is referred to as secondary gene pool. It includes plants that belong to related species. Such material can be crossed with primary gene pool, but usually the hybrids are sterile and some of the progeny to some extent are fertile. Transfer of gene from such material to primary gene pool is possible but difficult.

3.Tertiary gene pool (GP3): The genetic material which leads to production of sterile hybrids on crossing with primary gene pool is termed as tertiary gene pool or gene pool three (GP3). It includes material which can be crossed with GP1, but the hybrids are sterile. Transfer of genes from such material to primary gene pool is possible with the help of special techniques.

Types of seed collections:
Based on the use and duration of conservation, seed collections are of three types
1. Base collections
2. Active collections
3. Working collections

1. Base collections: It is also known as principal collection. These consist of all the accessions present in the germplasm of a crop. They are stored at about -180C or -200C with 5 + 1%

moisture content; they are disturbed only for regeneration. When the germination of an accession falls below, usually, 95% of its germination at the start of storage, the accession is regenerated. For reasons of safety, duplicates of base collections should be conserved in other germplasm banks as well. High quality orthodox seeds can maintain good viability upto 100 years.

2. Active collections : The accessions in an active collection are stored at temperatures below 150C (often near 00C), and the seed moisture is kept at 5%. The storage is for medium duration, i.e., 10-15 years. These collections are actively utilized in breeding programme. These collections are used for evaluation, multiplication and distribution of the accessions. They are usually maintained by multiplying the seeds of their own accessions. But from time to time, base collection material should be used for regeneration of these collections. Germination test is carried out after every 5-10 years to assess the reduction in seed viability.

3. Working collections : The accessions being actively used in crop improvement programmes constitute working collection. Their seeds are stored for 3-5 years at less than 150C and they usually contain about 10% moisture. These collections are maintained by the breeders using them.

Core collection:
The concept of core collection was proposed by Franked it refers to a subset of base collection which represents the large collection. Or a limited set of accessions derived from an existing germplasm collections.

Germplasm activities
There are six important activities related to plant genetic resources.

1. Exploration and collection
2. Conservation
3. Evaluation
4. Documentation
5. Multiplication and Distribution
6. Utilization

Exploration:
Exploration refers to collection trips and collection refer to tapping of genetic diversity from various sources and assembling the same at one place. The exploration and collection is a highly scientific process. This process takes into account six important items, *viz*, (1) sources of collection, (2) priority of collection, (3) agencies of collection, (4) methods of collection, (5) methods of sampling and (6) sample size.

Merits and Demerits:
There are several merits and demerits of exploration and collection of germplasm, some of which are as discussed below:
Merits:
1. Collection helps in tapping crop genetic diversity and assembling the same at one place.
2. It reduces the loss of genetic diversity due to genetic erosion.
3. Sometimes, we get material of special interest during exploration trips.
4. Collection also helps in saving certain genotypes from extinction.

Demerits:

1.Collection of germplasm especially from other countries, sometimes leads to entry of new diseases, new insects and new weeds.
2. Collection is a tedious job.
3. Collector, sometimes has encounter with wild animals like elephants, tigers etc.
4. Transportation of huge collections also poses difficulties in the exploration and collection.

2. Germplasm conservation:
Conservation refers to protection of genetic diversity of crop plants from genetic erosion. There are two important methods of germplasm conservation or preservation. Or Germplasm conservation refers to maintain the collected germplasm in such a state that there is minimum risk for its loss and that either it can be planted directly in the field or it can be prepare for planting with relative ease when ever necessary. There are two important methods of germplasm conservation or preservation *viz.,*
1. In situ conservation 2. Ex situ conservation

1. ***In situ*** **conservation:**
Conservation of germplasm under natural habitat is referred to as in situ conservation. This is achieved by protecting this area from human interference : such an area is often called as natural park, biosphere reserve or gene sanctuary. A gene sanctuary is best located withinthe centre of origin of crop species concerned, preferably covering the microcenter with in the centre of origin. NBPGR, New Delhi is making attempts to establish gene sanctuaries in Meghalaya for Citrus and in the North-Eastern region for *Musa, Citrus, Oryza, Saccharum* and *Megifera.*
This method of preservation has following main disadvantages 1) Each protected area will cover only ve ry small portion of total diversity of a crop species, hence several areas will have to be conserved for a single species. 2) The management of such areas also poses several problems. 3) This is a costly method of germplasm conservation

Merits : Gene sanctuaries offer the following two advantages.
1. A gene sanctuary not only conserves the existing genetic diversity present in the population, it also allows evolution to continue. As a result, new alleles and new gene combinations would appear with time.
2. The risks associated with ex situ conservation are not operative.

2. *Ex situ* conservation: Conservation of germplasm away from its natural habitat is called ex situ germplasm conservation. This method has following three advantages.
1) It is possible to preserve entire genetic diversity of a crop species at one place.
2) Handling of germplasm is also easy
3) This is a cheap method of germplasm conservation
Preservation in the form of seed is the most common and easy method, relatively safe, requires minimum space and easy to maintain. Glass, tin or plastic containers are used for preservation and storage of seeds. The seed can be conserved under long term, medium term and short term storage conditions. Roberts in 1973 classified seeds on the basis of their storability, into two major groups. *viz.,*
1. Orthodox seeds 2. Recalcitrant seeds

1. Orthodox Seeds : Seeds of this type can be dried to low moisture content of 5% and stored at a low temperature without losing their viability are known as orthodox seeds. Most crop seeds belong to this category. Such seeds can be easily stored for long periods; their longevity increases in response to lower humidity and storage temperature. Eg. Wheat, Rice, Corn, Chickpea, Cotton, Sunflower

2. Recalcitrant seeds : The viability of this group of seeds drops drastically if their moisture content is reduced below 12-30%. Seeds of many forest and fruit trees, and of several tropically crops like Citrus, cocoa, coffee, rubber, oil palm, mango, jackfruit, etc. belong to this group. Such seeds present considerable difficulties in storage. They require *in situ* conservation.

3. Evaluation:
Evaluation refers to screening of germplasm in respect of morphological, genetical, economic, biochemical, physiological, pathological and entomological attributes. Evaluation requires a team of specialists from the disciplines of plant breeding, physiology, biochemistry, pathology and entomology. First of all a list of descriptors (characters) for which evaluation has to be done is prepared. This task is completed by a team of experts from IPGRI, Rome, Italy. The descriptors are ready for various crops. The evaluation of germplasm is down in three different places, *viz.*, (1) in the field, (2) in green house, and (3) in the laboratory.

4. Documentation:
It refers to compilation, analysis, classification storage and dissemination of information. In plant genetic resources, documentation means dissemination of information about various activities such as collection, evaluation, conservation, storage and retrieval of data. Now the term documentation is more appropriately known as information system. Documentation is one of the important activities of genetic resources. Large number of accessions are available in maize, rice, wheat, sorghum, potato and other major crops. About 7.3 million germplasm accessions are available in 200 crops species. Handling of such huge germplasm information is only possible through electronic computers.

5. Distribution:
The specific germplasm lines are supplied to the users on demand for utilization in the crop improvement programmes.
1. Distribution of germplasm is the responsibility of the gene bank centres
2. The germplasm is usually supplied to the workers who are engaged in research work of a particular crop species.
3. Supplied free of cost to avoid cumbersome work of book keeping.
4. The quantity of seed samples depends on the availability of seed material and demands
5. Proper records are maintained about the distribution of material.
6. It helps in acclimatization and purification of the material.

6. Utilization:
It refers to use of germplasm in crop improvement programmes. The germplasm can be utilized in various ways. The uses of cultivated and wild species of germplasm are briefly discussed below:

a) Cultivated Germplasm
It can be used in three main ways: (1) as a variety, (2) as a parent in the hybridization, and (3) as a variant in the gene pool.
b) Wild Germplasm
it is used to transfer resistance to biotic and abiotic stresses, wider adaptability and sometimes quality such as fibre strength in cotton.

Organizations associated with Germplasm:
IPGRI – International Plant Genetic Resources Institute
NBPGR – National Bureau of Plant Genetic Resources

Study of genetics of Qualitative and Quantitative characters

The phenotype of any individual can be classified into two types:
1) Qualitative characters and 2) Quantitative characters

1. Qualitative characters: The characters that show discontinuous variation and which cannot be measured easily are known as qualitative characters. These are also known as classical mendelian traits.
Eg: Corolla colour – Red white or pink no continuous variation
Seed shape – Round wrinkled variation is not continuous
2. Quantitative characters are those showing continuous variation and which can be measured easily. These characters are also known as metric traits. The data obtained from such characters is known as quantitative data. This data can be subjected to statistical analysis and the branch of science which deals with such analysis is known as quantitative genetics or biometrical genetics.
Eg: Yield, Plant height

Differences between quantitative and qualitative characters

	Quantitative characters	**Qualitative characters**
Deals with	Traits of degree Eg: Plant height, seed weight, yield etc.	Traits of kind Eg: Corolla colour, seed shape, appearance etc
Variation	Continuous	Discontinuous
Effect of individual gene	Small and undetectable	Large and detectable
No. of genes involved	Several (polygenic)	one or few (mono /oligogenic)
Grouping into distinct Classes	Not possible	Possible
Effect of environment	High	Low
Metric measurement	Possible	Not Possible
Statistical analysis	Based on mean, variance, standard deviation etc	Based on ratios and frequencies
Stability	Low	High
Transgressive segregation of F 2	Yes	No
Dominance effect	No	Yes

Cumulative effect of each gene	Yes	No

Important concepts of breeding Self pollinated, Cross pollinated and Vegetatively propagated crops:

MODES OF POLLINATION:

Pollination refers to the transfer of pollen grains from anthers to stigmas. Pollen from an anther may fall on to the stigma of the same flower leading to self-pollination or Autogamy. When pollen from flowers of one plant are transmitted to the stigmas of flowers of another plant, it is known as cross-pollination or allogamy. A third situation, geitonogamy, results when pollen from a flower of one plant falls on the stigmas of other flowers of the same plant, e.g., in Maize. The genetic consequences of geitonogamy are the same as those of autogamy.

Self-pollination:

Many cultivated plant species reproduce by self-pollination. Self-pollination species are believed to have originated from cross-pollinated ancestors. These species, as a rule, must have hermaphrodite flowers. But in most of these species, self -pollination is not complete and cross -pollination may occur up to 5%. The degree of cross-pollination in Self pollinated species is affected by several factors, e.g., variety environmental conditions like temperature and humidity, and location.

Mechanisms promoting self-pollination:

The various mechanisms that promote selfpollination are generally more efficient than those promoting cross -pollination. These mechanisms are listed below.

1. Cleistogamy: In this case, flowers do not open at all. This ensures complete self pollination since foreign pollen cannot reach the stigma of a closed flower. Cleistogamy occurs in some varieties of wheat, oats, barley and in a number of other grasses.

2. In some species, the flowers open, but only after pollination has taken place. This occurs in many cereals, such as, wheat, barley, rice and oats. Since the flower does open, some cross-pollination may occur.

3. In crops like tomato and brinjal, the stigmas are closely surrounded by anthers. Pollination generally occurs after the flowers open. But the position of anthers in relation to stigmas ensures self-pollination.

4. In some species, flowers open but the stamens and the sigma are hidden by other floral organs. In several legumes, e.g., pea, mung, urd, Soybean and gram the stamens and the stigma are enclosed by the two petals forming a keel.

5. In a few species, stigmas become receptive and elongate through staminal columns. This ensures predominant self -pollination.

Genetic Consequences of Self-Pollination:

Self-pollination leads to a very rapid increase in homozygosity. Therefore, populations of self-pollinated species are highly homozygous, self-pollinated species do not show inbreeding

depression, but may exhibit considerable heterosis. Therefore, the aim of breeding methods generally is to develop homozygous varieties.

Cross-Pollination:
In cross-pollinating species, the transfer of pollen from a flower to the stigmas of the others may be brought about by wind (*anemophily*). Many of the crop plants are naturally cross-pollinated. In many species, a small amount (up to 5-10 percent) of selfing
may occur.

Mechanisms promoting cross pollination:
There are several mechanism that facilitate crosspollination; these mechanisms are described briefly.
1. **Dicliny :** *Dicliny* or *unisexuality* is a condition in which the flowers are either staminate (male) or pistillate (female).
a) **Monoecy:** Staminate and pistillate flowers occur in the same plant, either in the same inflorescene, *e.g.,* Castor, mango and coconut, or in separate inflorescences, chestnut, strawberries, rubber, grapes and cassava.
b) **Dioecy.** The male and female flowers are present on different plants, *i.e.,* the plants in such species are either male or female, *e.g.,* papaya, date, hemp, asparagus, and spinach. In general, the sex is governed by a single gene, e.g., asparagus and papaya. In some cases, there are hermaphrodite plants in addition to males and females, and a number of intermediate forms may also occur.
2. Stamens and pistils of hermaphrodite flowers may mature at different times facilitating cross - pollination.
a) **Protogyny**. In crop species like bajra, pistils mature before stamens.
b) **Protandry.** in crops like Maize and sugarbeets, stamens mature before pistils.
3. In Lucerne or alfalfa, stigmas are covered with a waxy film. The stigma does not become receptive until this waxy film is broken. The waxy membrane is broken by the visit of honey bees which also effect cross-pollination.
4. A combination of two or more of the above mechanisms may occur in some species. This improves the efficiency of the system in promoting cross-pollination. For example, Maize exhibits both monoecy and protandry.
5. **Self-Incompatibility**: It refers to the failure of pollen from a flower to fertilize the same flower or other flowers on the same plant. Self-incompatibility is of two types : sporophytic and gametophytic. In both the cases, flowers do not set seed on selfing. Self-incompatibility is common in several species of Brassica, some species of Nicotiana, radish, rye and many grasses. It is highly effective in preventing selfpollination.
6. **Male Sterility**: Male sterility refers to the absence of functional pollen grains in otherwise hermaphrodite flowers. Male sterility is not common is natural populations. But it is of great value in experimental populations, particularly in theproduction of hybrid seed. Male sterility is of two types : genetic and Cytoplasmic.

Cytoplasmic male sterility is termed Cytoplasmic-genetic when restorer genes are known. In view of the importance of self-incompatibility and male sterility, a more detailed discussion on them follows later.

Genetic Consequences of Cross-Pollination: Cross-pollination preserves and promotes heterozygosity in a population. Cross-pollinated species are highly heterozygous and show mild to severe inbreeding depression and a considerable amount of heterosis. The breeding methods in such species aim at improving the crop species without reducing heterozygosity to an appreciable degree. Usually, hybrid or synthetic varieties are the aim of breeder wherever the seed production of such varieties is economically feasible.

Often Cross-Pollinated Species:
In many crop plants, cross -pollination often exc eeds 5 per cent and may reach 30 per cent. Such species are generally known as often cross-pollinated species, e.g., Jowar, Cotton, arhar, safflower etc. The genetic architecture of such crops is intermediate between self-pollinated and cross-pollinated species. Con-sequently, in such species breeding methods suitable for both of them may be profitably applied. But often hybrid varieties are superior to others.

Major Objectives of Plant Breeding :
1. Higher yield : The ultimate aim of plant breeding is to improve the yield of economic produce. It may be grain yield, fodder yield, fibre yield, tuber yield, cane yield or oil yield depending upon the crop species. Improvement in yield can be achieved either by evolving high yielding varieties or hybrids.

2. Improved quality: Quality of produce is another important objective in plant breeding. The quality characters vary from crop to crop. Eg. grain size, colour, milling and backing quality in wheat. Cooking quality in rice, malting quality in barley, size, colour and size of fruits, nutritive and keeping quality in vegetables, protein content in pulses, oil content in oilseeds, fibre length, strength and fineness in cotton.

3. Abiotic resistance: Crop plants also suffer from abiotic factors such as drought, soil salinity, extreme temperatures, heat, wind, cold and frost, breeder has to develop resistant varieties for such environmental conditions.

4. Biotic resistance: Crop plants are attacked by various diseases and insects, resulting in considerable yield losses. Genetic resistance is the cheapest and the best method of minimizing such losses. Resistant varieties are developed through the use of resistant donor parents available in the gene pool.

5. Change in maturity Duration/ Earliness: Earliness is the most desirable character which has several advantages. It requires less crop management period, less insecticidal sprays, permits new crop rotations and often extends the crop area. Development of wheat varieties suitable for late planting has permitted rice-wheat rotation. Thus breeding for early maturing crop varieties, or varieties suitable for different dates of planting may be an important objective. Maturity has been reduced from 270 days to 170 days in cotton, from 270 days to 120 days in pigeonpea, from 360 days to 270 days in sugarcane.

6. Determinate Growth : Development of varieties with determinate growth is desirable in crops like Mung, Pigeon Pea (*Cajanus cajan*), Cotton (*Gossypium sp.*), etc.

7. Dormancy: In some crops, seeds germinate even before harvesting in the standing crop if there are rains at the time of maturity, e.g., Greengram, Blackgram, Barley and Pea, etc. A period of dormancy has to be introduced in these crops to check loss due to germinatio n. In some other cases, however, it may be desirable to remove dormancy.

8. Desirable Agronomic Characteristics: It includes plant height, branching, tillering capacity, growth habit, erect or trailing habit etc., is often desirable. For example, dwarf ness in cereals is generally associated with lodging resistance and better fertilizer response. Tallness, high tillering and profuse branching are desirable characters in fodder crops.

9. Elimination of Toxic Substances : It is essential to develop varieties free from toxic compounds in some crops to make them safe for human consumption. For example, removal of neurotoxin in Khesari (*Lathyruys sativus*) which leads to paralysis of lower limbs, erucic acid from *Brassica* which is harmful for human health, and gossypol from the seed of cotton is necessary to make them fit for human consumption. Removal of such toxic substances would increase the nutritional value of these crops.

10. Non-shattering characteristics: The shattering of pods is serious problem in green gram. Hence resistance to shattering is an important objective in green gram.

11.Synchronous Maturity : It refers to maturity of a crop species at one time. The character is highly desirable in crops like Greengram, Cowpea, and Cotton where several pickings are required for crop harvest.

12.Photo and Thermo insensitivity: Development of varieties insensitive to light and temperature helps in crossing the cultivation boundaries of crop plants. Photo and thermo-insensitive varieties of wheat and rice has permitted their cultivation in new areas. Rice is now cultivated in Punjab, while wheat is a major *rabi* crop in West Bengal.

13.Wider adaptability : Adaptability refers to suitability of a variety for general cultivation over a wide range of environmental conditions. Adaptability is an important objective in plant breeding because it helps in stabilizing the crop production over regions and seasons.

14.Varieties for New Seasons : Traditionally Maize is a *kharif* crop. But scientists are now able to grow Maize as *rabi* and *zaid* crops. Similarly, mung is grown as a summer crop in addition to the main *kharif* crop.

Scope of plant breeding (Future Prospects)

From times immemorial, the plant breeding has been helping the mankind. With knowledge of classical genetics, number of varieties have been evolved in different crop plants. In order to combat the global alarm created by population explosion, the food front has to be strengthened which is serious challenge to those scientists concerned with agriculture. Advances in molecular

biology have sharpened the tools of the breeders, and brighten the prospects of confidence to serve the humanity. The application of biotechnology to field crop has already led to the field testing of genetically modified crop plants. Genetically engineered Rice, Maize, Soybean, Cotton, Oilseeds Rape, Sugar Beet and Alfalfa cultivars are expected to be commercialized before the close of 20th century. Genes from varied organisms may be expected to boost the performance of crops especially with regard to their resistance to biotic and abiotic stresses. In addition, crop plants are likely to be cultivated for recovery of valuable compounds like pharmaceuticals produced by genes introduced into them through genetic engineering. It may be pointed out that in Europe hirudin, an anti-thrombin protein is already being produced from transgenic *Brassica napus.*

Undesirable effects:
Plant breeding has several useful applications in the improvement of crop plants. However, it has five main undesirable effects on crop plants.
1. Reduction in Diversity : Modern improved varieties are more uniform than land races. Thus plant breeding leads to reduction in diversity. The uniform varieties are more prone to the new races of pathogen than land races which have high genetic diversity.
2. Narrow genetic base : Uniform varieties have narrow genetic base. Such varieties generally have poor adaptability.
3. Danger of Uniformity : Most of the improved varieties have some common parents in the pedigree which may cause danger of uniformity.
4. Undesirable combinations : Sometimes, plant breeding leads to undesirable combinations. The examples of manmade crops having undesirable combination of characters are *Raphano brassica* and Pomato.
5. Increased susceptibility to minor diseases and pests : Due to emphasis on breeding for resistance to major diseases and insect pests often resulted in an increased susceptibility to minor diseases and pests. These have gained importance and, in some cases, produced severe epidemics. The epidemic caused by *Botrytis cinerea* (grey mold) in chickpea during 1980-82 Punjab, Haryana. The severe infection by Karnal bunt (*Tilletia sp.*) on some wheat varieties, infestation of mealy bugs in Bt cotton.

Breeding procedures including conventional and modern innovative approaches for development of hybrids and varieties for yield, adaptability,stability:

ADAPTABILITY : is the ability of a genotype to produce a relatively narrow range of phenotypes in different environments. It is the result of genetic homeostatis, refers to the buffering capacity of a genotype to environmental fluctuations.

STABILITY: It refers to its performance with respective changing environmental factors overtime within a given location. This means that a stable variety is less sensitive to the temporal environmental changes that may take place

DIFFERENT METHODS OF PLANT BREEDING

Various approaches (*viz.*, selection, hybridization, mutation, etc) that are used for genetic improvement of crop plants are referred to as plant breeding methods or plant breeding procedures or plant breeding techniques. The choice of breeding methods mainly depends on the mode of pollination, mode of reproduction, gene action and breeding objective of crop species. Plant breeding methods are generally classified on the basis of application of crop improvement (general methods, special methods and population improvement approaches) and hybridization (methods involving hybridization and methods not involving hybridization). Various breeding procedures that are more commonly used for the genetic improvement of various crop plants are known as general breeding methods. Such breeding methods include introduction, selection (pure line selection, mass selection, progeny selection), hybridization (pedigree, bulk and backcross methods), heterosis breeding, synthetic and composite breeding. On the other hand, those breeding procedures that are rarely used for improvement of crop plants are referred to as special breeding methods. Such methods include: mutation breeding, polyploidy breeding, wide crossing or distant hybridization and biotechnology. Four breeding approaches, *viz.*, recurrent selection, disruptive mating and selection, diallel selective mating system and biparental mating are used mainly for population improvement.

Classification of Plant Breeding Methods
Basis of classification and
Types of methods
Breeding methods included
A. Application in crop improvement

(1) General Methods Plant introduction, Pureline selection, massselection, progeny selection, pedigree method, bulk method, back cross method, SSD, clonal selection, heterosis breeding, synthetics and composites.
(2) Special Methods Mutation breeding, Polyploidy breeding, transgenic breeding, molecular breeding.
(3) Population Improvement Recurrent selection, disruptive selection, diallel selective approaches mating system, biparental mating.
B. Hybridization
(1) Methods involving hybridization Pedigree, bulk, backcross and SSD Methods: heterosis breeding, and population improvement approaches and molecular breeding (marker aided selection).
(2) Methods not involving hybridization Plant Introduction, pureline selection, mass selection, progeny selection, clonal selection, mutation breeding and transgenic breeding. There are some differences in the breeding methods used for self pollinated and cross pollinated species. Self pollinated species are homozygous, hence we can start hybridization directly. Cross pollinated species, on the other hand, are highly heterozygous. Hence we cannot start hybridization directly. First we have to develop inbred lines by selfing or inbreeding and then only hybridization can be taken up. We have to exploit homozygosity in self pollinated crops and heterozygosity in cross pollinated species. Asexually propagated species such as sugarcane, potato, sweet potato, etc., are highly heterozygous. Hence, F1 hybrids in such crops exhibit segregation and selection can be practiced in *F1* generation. The superior clones are identified and further multiplied. The maintenance or conservation of hybrid vigour is easy in such crops because of asexually propagation.

Methods of Breeding Autogamous species:
Plant breeding methods that are used for genetic improvement of self pollinated or autogamous species include:
1. Plant Introduction
2. Pureline selection
3. Mass selection
4. Pedigree method
5. Bulk method
6. Single seed descent method
7. Backcross method
8. Heterosis breeding
9. Mutation breeding
10. Polyploidy breeding
11. Distant hybridization
12. Transgenic breeding.

Four breeding approaches, *viz.*, recurrent selection, disruptive selection, diallele selective mating, and biparental mating are used for population improvement.

Methods or Breeding Allogamous species:
Breeding methods that are used for genetic improvement of cross pollinated or allogamous species include
(1) Plant introduction
(2) Mass and progeny selection
(3) Backcross method
(4) Heterosis breeding
(5) Synthetic breeding
(6) Composite breeding
(7) Polyploidy breeding
(8) Distant hybridization
(9) Transgenic breeding

Mutation breeding is rarely used in allogamous species. Three breeding approaches *viz.*, recurrent selection, disruptive mating and biparental meting are used for population improvement.

Methods of Breeding Asexually Propagated Species:
Important breeding methods applicable to asexually propagated species are
(1) Plant Introduction
(2) Clonal selection
(3) Mass selection
(4) Heterosis breeding
(5) Mutation breeding
(6) Polyploidy breeding
(7) Distant hybridization
(8) Transgenic breedin g.

Mass selection is rarely used in asexually propagated species.

Brief account of breeding methods:

Plant introduction is applicable to all three groups of crop plants, *viz.*, self pollinated, cross pollinated and asexually propagated species. It is an old est and rapid method of crop improvement. The introduced material may be used in three ways *viz.*,

(1) Directly as a variety
(2) As a variety after selection
(3) As a parent in the hybridization for development of variety or hybrid

Pureline selection is applicable to self pollinated species. It is also used sometimes in cross pollinated species for development of inbred lines. A single best pure line is released as a variety. Thus a pureline variety is homozygous and homogeneous population. Mass selection is common in cross pollinated species and rare in self pollinated and asexually propagates species. In self pollinated crops, a mass selected variety is a mixture of several purelines. Thus it is a homozygous but heterogeneous population.

In cross pollinated species, a **mass selected variety** is a mixture of several hetero and homozygotes. Thus, it is a heterozygous and heterogeneous population. Progeny selection is used in cross pollinated species. A variety developed by this method is heterozygous and heterogeneous population because it consists of several hetero and homozygotes. Pedigree method is applicable to both self and cross pollinated species. In self pollinated crops progeny of a single best homozygote is released as a variety. Thus a variety developed by this method has a homozygous and homogeneous population. In cross pollinated species, it is used for developed of inbred lines.

Bulk and **single seed descent methods** are used in self pollinated species. Progeny of a single best homozygote is release as a variety by these methods. Thus, varieties developed by these methods are homozygous and homogeneous.

Backcross method is applicable in all three groups of crop species. This method is used for transfer of oligogenic characters from a donor source to a well adapted variety. This method is also used for development of multilines, Isogenic lines and transfer of male sterility. This method is more effective in transferring oligogenic characters than polygenic traits. The end product of backcross method is similar to parent variety expect for the character which has to be transferred from the donor source. Multiline varieties are developed in self pollinated species. They are mixture of several Isogenic lines, closely related lines or unrelated lines. Thus a multiline variety is a homozygous but heterogeneous population.

Clonal selection is used in asexually propagated species. In this method progeny of a single best clone is released as a variety. Such variety has heterozygous but homogeneous population.

Heterosis breeding is used in/all the three groups. However, it is common in cross pollinated and asexually propagated species and rare in self pollinated species. A hybrid variety has homogeneous but heterozygous population.

Synthetic and composite varieties are developed in cross pollinated species. Such varieties consist of several homozygotes and heterozygotes and thus constitute a heterogeneous population.

Mutation breeding is common in self pollinated and asexually propagated species and rare in cross pollinated species. A mutant variety differs from parent variety in one or few characters. A mutant differs from a segregant in two main ways. Firstly, the frequency of segregants is very

high and that of mutant is extremely low (0.1%). Secondly, mutant differs from parent variety in one or few characters, where as a segregant differs from parent material in several characters.
Polyploidy breeding is common in asexually propagated species and rare in self and cross pollinated species. A polyploidy variety differs from parent variety in chromosome numbers and exhibit gigant morphological characters.
Distant hybridization is used in all the three types of crop species. However, this method is used for transferring some desirable genes from wild species to the cultivated ones. Generally, backcross method is used for transfer of oligogenic characters and **pedigree** method for transfer of polygenic characters.

Transgenic breeding is applicable to all three types of crop species. This method is used to solve specific problems which cannot be solved by conventional breeding techniques. This method will serve as a tool and cannot be used as a substitute for conventional breeding methods.
Recurrent selection is common in cross pollinated species and rare in other two groups. It is used for accumulating favourable genes in a population *i.e.*, for population improvement. Other approaches which are used for population improvement include disruptive mating, diallel selective mating (DSM) and biparental mating. DSM is used in self pollinated species and other two techniques can be used both in self and cross pollinated species.

BREEDING FOR BIOTIC STRESS RESISTANCE

DISEASE RESISTANCE:

Stress: Constraining influence, force, pressure or adverse conditions for crop growth caused by biological or environmental factors.
Biotic (living) : Adverse effects due to pests and diseases abiotic stresses
Abiotic (non living) : Adverse effects on host due to environmental factors eg: Drought, water logging, heat, cold, salinity, alkalinity and air pollution etc.
Host : Plant effected by a disease or which can accommodate pathogen.
Pathogen : An organism that produces the disease
Disease : an abnormal conditions in the plant caused by an organism (pathogen)
Pathogenicity : The ability of a pathogen to infect a host strain
Virulence : Capacity of a pathogen to incite a disease
Avirulence : The inability of a pathogen to cause or incite a disease
Physiological race : Strains of a single pathogen species with identical or similar morphology but differ in pathogenic capabilities.
Pathotype : Strains of a pathogen classified on the basis of their virulence to known resistance genes present in the host.
Epidemic : Severe and sudden outbreak of disease beginning from a low level of infection.
Variability in fungal pathogens:
a) **Hybridization:** Recombination of genes of the two parental nuclei takes place in the zygote, and the haploid nuclei or gametes resulting after meiosis are different both from gametes that produced the zygote and from each other. Thus every diploid pathogen individual is genetically different from any other pathogen even within the same species and variability of the new individual pathogens is continued indefinitely.
e.g., Phytophthora infestans.
b) **Heterokaryosis:** Condition in which fungal hyphae that are genetically different come together in the same cell to form heterokaryons.

c) **Parasexualism** : Parasexuality – re-assortment of genetic material both in haploid and diploid condition, ready for natural and artificial selection. Mixtures of races grown together on a susceptible host combine genetically to produce new races e.g. *phytophthora infestans*
d) **Mutation:** The rate at which new variants of a pathogen are produced will depend on the mutation rate of the genes at a particular locus. The mutation rate varies from gene to gene and from pathogen to pathogen.
e.g. *Melampsora lini* – new race produced with UV rays (Flor 1956)
e) **Cytoplasmic adaptation:** There are several examples of cytoplasmic inheritance of important characteristics such as growth rate and virulence (Jinks 1966).
Virulence of *P.graminis f. sp. Avenae*, carrying gene E, is maternally inherited and may be controlled by single plasma gene (Johnson *et al* 1967)

MECHANISMS OF DISEASE RESISTANCE:
There are different ways of disease resistance *viz.,* disease escape, disease endurance or tolerance disease resistance and immunity

1. **Disease escape**: The ability of susceptible host plants to avoid attack of disease due to environmental conditions factors, early varieties, charge in the date of plating, change in the site of planting; balanced application of NPK etc. Eg. Early varietie s of groundnut and potato may escape 'Tikka' and 'Late blight' diseases respectively since they mature before the disease epidemic occurs. Changing planting season in sugarcane from June to October has successfully escaped leaf-rust. Virus free seed potato is produced by sowing the crop in October in Jullundher and other places instead of November, the normal planting time.

2. **Disease endurance or tolerance** : The ability of the plants to tolerate the invasion of the pathogen without showing much damage. This endurance is brought about by the influence of external characters. Generally, tolerance is difficult to measure since it is confounded with partial resistance and disease escape. To estimate tolerance the loss in yield and some other trait of several host varieties having the same amount of disease eg., leaf area covered by disease etc., is compared. Eg. In Barley the variety Proctor shows 13% yield loss as compared to 20% loss in the varieties Zephy and Sultan.
· Wheat varieties when fertilized with potash and phosphorus are more tolerant to the rust and mildew infection. · The Rice crop fertilized with silicate is resistant to blast infection in Japan.

3. **Disease Resistance** : The ability of plants to withstand, oppose or overcome the attack of pathogens. Resistance is a relative term and it generally refers to any retardation in the development of the attacking pathogen. In case of resistance, disease symptoms to develop and the rate of reproduction is never zero i.e., r? o but it is sufficiently lower than 1 (the rate of reproduction on the susceptible variety) to be useful. The inhibition of growth of the pathogen is believed to be nutrional in nature and in some cases chemical growth inhibitors may be involved. Resistance is largely controlled by inherited characters i) may be controlled by single dominant gene in Ottawa 770 B, Newland flax variety, wheat all rusts NP 809

4. **Immunity**: When the host does not show the symptoms of disease it is known as immune reaction. Immunity may result from prevention of the pathogen to reach the appropriate parts of the host e.g. exclusion of spores of ovary infecting fungi by closed flowering habit of wheat and

barley. It is more generally produced by hypersensitive reaction of the host usually immediately after the infection was occurred. In immune reaction the rate of reproduction in zero i.e. r = 0

5. **Hypersensitivity:** Immediately after the infection several host cells surrounding the point of infection are so sensitive that they will die. This leads to the death of the pathogen because the rust mycelium cannot grow through the dead cells. This super sensitivity (hypersensitivity) behaves as a resistant response for all practical purposes. Phytoalexins are specific polyphenolic or terpenoid chemicals and are produced by the host in response to the infe ction by a pathogen. More than 30 different phytoalexins have been identified. Phytoalexins are either fungicidal or fungistatic. Eg. Rust fungi and virus attack.

Factors for disease resistance (Causes of Disease resistance)

The disease resistance may be caused due to

1. Morphological, structural and functional characteristics which prevents the entrance of the pathogen *i.e.* prevents the first stage of infection.
2. Biochemical or anatomic al properties of tissue which prevent the establishment of parasitic relationship.

a. Morphological characters

Certain morphological features of the host may prevent infection.

Eg. Resistance to Jassid attack in cotton has been shown to be correlated with the hariness of varieties : hairy type resists the attack more, than glabrous types.

Failure to germinate rust spores on the leaves of the barley due to waxy coating.

Young sugarbeet leaves practically immune to attack of the circos pora because the stomata size is very small.

b. Physiological characters

Protoplasmic factors or chemical interactions :

By virtues of its chemical composition the protoplasm may exert an inhibitory influence on the pathogen bringing about the desired resistance in the plant.

Eg. : Resistance of grape to powdery mildew is highly correlated with the acidity of cell sap.

Presence of toxic substance in the red pigment in the coloured onions. The outer scales resist the smudge fungus attack when the scales are removed they become susceptible.

c. Anatomical: More secondary thickening of the cell walls of resistant potato varieties which resists the mechanical puncture of the invading *Pythium* pathogen.

d. Nutritional factors : Reduction in growth and in spore production is generally supposed to be due to unfavourable physiological conditions within the host. Most likely a resistant host does not fulfill the nutritional requirements of the pathogen and thereby limits its growth and reproduction.

e. Environmental factors : In addition to the above the environmental factors have marked effect on the pathogen attack. Temperature, moisture, humidity and soil PH and fertility status of the soil effects the pathogen reaction greatly.

Genetic basis of disease resistance

The first study on genetics of disease resistance was done by Biffen in 1905. He reported the inheritance of resistance to leaf rust of wheat variety Rivet in crosses with some susceptible varieties. In F2 there were 3 susceptible : 1 resistant plants indicating that resistance was controlled by a single recessive gene. Most of the earlier studies were conducted without taking

into consideration the physiological specialization (pathotype differentiation) of the pathogen which can materially influence the conclusions drawn. It is now recognized that disease resistance may be inherited in three different ways :
Oligogenic
Polygenic and
Cytoplasmic inheritance

Oligogenic inheritance:

The disease resistance is governed by one or few major genes and resistance is generally dominant to the susceptible reaction. The action of major resistance genes may be altered by modifying genes in many cases. Eg. bunt resistance in Wheat. Oligogenes generally produce immune reaction. The chief characteristic of the oligogenic disease resistance is pathotypespecificity, i.e. resistant gene is effective against some pathogens, while it is ineffective against the others. In most cases, there are a number of major genes that determines resistance to a particular disease Eg. more than 20 different resistance genes are known for leaf rust of wheat, while those for stem rust resistance exceed 30. The genetics of oligoganic resistance has advanced by two events *viz.*,
1. Discovery of a resistance gene to the prevalent pathotype and
2. Evolution of a pathotype virulent to the new resistance gene.
Oligogenic resistance is synonymous to vertical resistance.

Gene for gene hypothesis:

The concept of gene for hypothesis was first developed by Flor in 1956 based on his studies of host pathogen interaction in flax rust caused by *Malampsora lini.* The gene for gene hypothesis states that for each gene controlling resistance in the host, there is a corresponding gene controlling pathogenicity in the pathogen. The resistance of host is governed by dominant genes and virulence of pathogen by recessive genes. The genotype of host and pathogen determine the disease reaction. When genes in host and pathogen match for all the loci, then only the host will show susceptible reaction. If some gene loci remain unmatched, the host will show resistant reaction. Now gene-for -gene relationship has been reported in several other crops like potato, *Sorghum,* wheat etc. The gene for gene hypothesis is known as "Flor Hypothesis".

Varieties	***Host genotype***	***Pathogen genotypes***	***Disease Reaction***
1. One gene pair	AA	aa	Susceptible
	Aa		
	BB	bb	Susceptible
	Bb		
2. Two gene pair	AA CC	aa	Resistant
	Aa CC	cc	Resistant
	Aa Cc	aacc	Susceptible
3. Three gene pair	AA BB CC	aa bb	Resistant
	Aa Bb Cc	aa bb cc	Susceptible

Vertifolia Effect : Vander plank introduced the term vertifolia effect and refers to epidemic development in a variety carrying vertical resistance genes (oligogenes) leading to heavy

economic losses. Total failure of vertical resistance leading to a disease epidemic is known as vertioalia effect. This failure occurs because of two reasons :
1. The level of horizontal resistance in varieties carrying oligogenes is usually low and
2. The pathogen is able to evolve new virulent pathotypes.

Polygenic inheritance:
In this type the disease resistance is governed by many genes with small effects and a continuous variation for disease reaction is produced. The genes show additive and non additive effects and the environmental effect is also observed. The polygenic resistance does not show pathotype specificity as against the oligogenic resistance. It is almost same as horizontal resistance. In some cases the polygenic inheritance may have a oligogenic component, the oligogenes acting in an additive manner eg. bacterial blight resistance in cotton

Cytoplasmic inheritance :
Resistance in some cases is determined by cytoplasmic genes or plasma gene(s).
Eg. The T-male sterilizy cytoplasm (cms-T) in maize is extreamly susceptible to *Helminthosporium* leafblight, while the non-T cytoblasms are resistant to this disease.

Vertical and Horizontal Resistance (Vander plank):

Feature	***Vertical resistance***	***Horizontal resistance***
1. Pathotype – specificity	Specific	Non specific
2. Nature of gene action	Oligogenic	Polygenic; rarely oligogenic
3. Response to pathogen	Usually, hypersensitive	Resistant response
4. Phenotypic expression	Qualitative	Quantitative
5. Stage of expression	Seedling to maturity	Expression increases as plant matures
6. Selection and evaluation	Relatively easy	Difficult
7. Host pathogen interaction	Present	Absent
8. Commonly used, synonyms	Major: gene, race -specific seedling, monogenic, pathotype specific resistance	Polygenic, race nonspecific, pathotype-nonspecific, mature plant, adult plant, field uniform resistance
9. Efficiency	Highly efficient against specific races	Variable, but operates against all Races

Sources of Disease Resistance
Resistance to diseases may be obtained from four different sources :
1. A known variety
2. Germplasm collection
3. Related species
4. Through mutations
1. **A known variety:** Disease reactions of most of the cultivated varieties are documented and a breeder may find the resistance he needs in a cultivated variety. Resistant plants were also lated from commercial varieties as in the case of cabbage yellows in cabbage

curlytop resistance etc. These provide the basis for new resistance varieties.
2. **Germplasm collection :** When resistance to a new disease or a new pathotype of a disease is not known in a cultivated variety germplasm collection should be screened. Several instances disease resistance were found from the germplasm collections. Eg. resistance to neckblotch in barley resistance to wilt in watermelon
3. **Related species :** Often the resistance to a disease may be found in related species and transferred through interspecific hybridization.
Eg. Resistance to stem, leaf & stripe rusts of wheat
4. **Mutation :** Resistance to diseases may be obtained through mutation arising spontaneously or induced through mutagenic treatments. Eg. 1. Resistance to Victoria blight in oats was induced by irradiation with x-rays or thermal neutrons / also produced spontaneously
2. Resistance to stripe rust in wheat
3. Resistance to brown rust in oats
4. Resistance to mildew in barley
5. Resistance to rust in linseed
6. Resistance to tikka leaf spot and stem root in groundnut

Vertical and Horizontal Resistance (Van der plank)
Vertical Resistance is generally d etermined by major genes and is characterized by pathotype specificity. Clearly immune or susceptible response in the case of vertical resistance depends on the presence of virulent pathotype. When virulent pathotype becomes frequent, epidemics are common in the cases of vertical resistance. Thus an avirulent pathotype will produce an immune response i.e. r=0 or close to 0 but the virulent pathotype will lead to susceptible reaction i.e. r=1. It is also known as race specific, pathotype specific or simply specific resistance.

Horizontal Resistance
Race non-specific, pathotype -nonspecific and partial, general or field resistance. Horizontal resistance is generally controlled by polygenes i.e. many genes with small effects and it is pathotype nonspecific. In this case, the reproduction rate is not zero but it is less than one. Poly genes, govern horizontal resistance.

Methods of Breeding for Disease Resistance
The methods of breeding for disease resistance are essentially same as those used for other agronomic traits. They are :
1. Introduction
2. Selection
3. Hybridization
4. Budding & Grafting
5. Mutation Breeding
6. Biotechnological methods.
1. **Introduction :** Resistant varieties may be introduced for cultivation in a new area.
Eg. · Early varieties of groundnut introduced from USA have been resistant to leaf spot (Tikka)
· Kalyanasona and Sonalika wheat varieties originated from segregating material introduced from CIMMYT, Mexico, were rust resistant.
· African bajra introductions have been used in developing downy mildew resistant cms lines.
2. **Selection :** Selection of resistant plants from commercial varieties is easiest method.

Eg. Kufri Red potato is selection from Darjeeling Red round
· Pusa Sawani behind (yellow mosaic) selection from a collection obtained from Bihar
· MCU I was selection from CO4 for black arm resistance in cotton
3. **Hybridization :** Transfering disease resistance from one variety or species to the other.
a.Pedigree method is quite suitable for horizontal resistance. Artificial disease epiphytolics are produced to help in selection for disease resistance.
Eg. In wheat Kalyana Sona, Sonalaka, Malvika 12, Malvika 37, Malavika 206, Malavika 234
Laxmi in Cotton (Gadag 1 x CO2) for leaf blight resistance
b. Backcross method is used to transfer resistance genes from an undersirable agronomic variety to a susceptible, widely adoptable and is agronomically highly desirable variety. If the resistant parent is a wholly unadapted variety, backcross method is a logical choice. If resistant variety also possess some good qualities then chose pedigree method of handling segregating material.

4. **Budding & Grafting :** The disease resistance in vegetatively propogated material is transferred by adopting either by budding or grafting. By grafting or budding the resistant material, the resistance can be transferred.

5. **Mutation Breeding :** When adequate resistance is not available in the germplasm; Mutation breeding is resorted to induce resistance. This is also us ed to break the linkages between desirable resistant genes and other desirable genes.

Precautions
1. The donor parent must possess the required amount of resistance
2. It must be simply inherited without any linkage
3. The recovery in the recipient parent should be more
4. Proper condition for full expression of the resistant genes has to be provided

Advantages with breeding for disease resistance
1. Helps in reducing the losses caused by pathogens
2. Reduces the high cost of disease control by chemical treatment
3. Helps to avoid the use of poisonous fungicides
4. Only method available to some specific diseases like viruses, wilt etc.

Limitations
1. Linkage of resistant genes with genes of inferior quality
2. Occurrence of physiological races of varying capacities
3. Self sterility in host plants

Utilization and achievements
1. Rice ADT 10 x Co4 (resistant to blast)
2. Potato *Solanum* tuberosum x *Solanum* demissum (susceptible to late blight) (wild resistant to late blight)
F1 backcrossed with *Sol. tuberosum (*Resistant variety)

Varieties resistant to different diseases
Rice : Blast Co25, Co26,

Wheat : all three rusts : NP 809
Yellow rust : NP 785, NM86
Black rust : NP 789
Brown rust : NP 783, NP 784
Sugarcane : Red rot Co 419, Co 421, Co 527
Cotton : Wilt Vijay, Kalyan, Suyog
Groundnut : Tikka leafspot Ah 45
Chilli : Mosaic resistant Pusa red, Pusa orange

INSECT RESISTANCE

Global average loss due to insect pests is 14%. Estimated losses in individual crops vary from 5% in wheat to 26.7% in rice and still more in crops like cotton & sugarcane.

Insect Resistance :
1. The ability of a plant to withstand, oppose or overcome the attack of an insect in known as insect resistance.
2. It is the property of a variety or a host crop due to whic h it is attacked by an insect pest to a significantly lower degree than are other varieties of the same host.
Biotypes : Strains of a species of an insect pest, differing in their ability to attack different varieties of the same host species (syn: Physiological races) Host Habitation :
1. Polyphagy 3. Seasonal Oligophagy
2. Oligophagy 4. Monophagy

1. Polyphagy: Insects feed on a vide range of hosts avoiding few plant species. Eg. Scales & moths.
2. **Oligophagy :** Live on one taxonomic unit only. Eg. Hessianfly on wheat
3. Seasonal oligophagy : Insects may live on many species in one part of the year and on few in another part of the year. Eg : Aphids.
4. Monophagy : Avoid all hosts except one particular species or variety Eg. Boll weevil on cotton.

Mechanism of Insect Resistance :
Insect resistance is grouped into four categories :
1. Non preference 2. Antibiosis
3. Tolerance 4. Avoidance

1. **Non preference** : Host Varieties exhibiting this type of resistance are unattractive or unsuitable for colonization, oviposition or both by an insect pest. This type of resistance in also termed as non-acceptance and anti-xenosis. Non preference involves various morphological and biochemical features of host plants such as – color, hairness, leaf angle, taste etc.

2. **Antibiosis** : Antibiosis refers to an adverse effect of feeding on a resistant host plant on the development and/or reproduction of the insect pest. In severe cases, it may even lead to the death of the insect pest. Antibiosis may involve morphological, physiological or biochemical features of the host plant; some cases of insect resistance involve a combination of features. Eg. Resistance to BPT is due to antibiosis & non preference

3. **Tolerance** : An insect tolerant variety is attacked by the insect pest to the same degree as a susceptible variety. But at the same level of infestation, a tolerant variety produces a higher yield than a susceptible variety. Ability of the host plant to withstand the insect population to a certain extent which might have damaged a more susceptible host. Tolerance is mainly a host character and it may be because of greater recovery from pest damage. Eg. Rice varieties tolerant to stem borer/gall midge produce additional tillers to compensate yield losses (as in stem borer in sorghum) or due to the ability of host to suffer less damage by the pest eg. aphid tolerance in Sugarbeet & Brassica sps. and green bugs tolerance in cereals. Inheritance of tolerance is complex in many cases and is supposed to be governed by polygenes.

4. **Avoidance** : Pest avoidance is the same as disease escape , and as such it is not a case of true resistance Mostly insect avoidance result from the host plants being at a much less susceptible developmental stage when the pest population is at its peak. Eg. 1. Early maturing cotton varieties escape pinkboll worm infestation, which occurs late in the season.

Nature of Insect Resistance / Factors for insect -resistance

Insect resistance may involve :
1. Morphological
2. Physiological (or)
3. Biochemical features of the host plant

1. **Morphological features** : Morphological factors like, hairiness, colour, thickness and toughness of tissues etc. are known to confer insect resistance.
a) Hairiness of leaves is associated with resistance to many insect pests leaf beetle in cereals, in cotton to Jassids , in turnip to turnip aphid.
b) Colour of plant : Color may contribute to non preference in some cases.
For example : Red cabbage, Red leaved brussel's sprouts are less favored than green varieties by butterflies and certain Lepidoptera for oviposit ion. Boll worms prefer green cotton plants to red ones.
c) Thickness and Toughness of plant – Tissues prevent mechanical obstruction to feeding and oviposition and thereby lead to non-preference as well as antibiosis.
Eg.1. Thick leaf lamina in cotton contributes to Jassid resistance
2. Solid stem in wheat confers resistance to wheat stem sawfly
3. Thick and tough rind of cotton bolls makes it difficult for the boll worm larve to bore holes and enter the bolls.
Other characters : also contribute to insect resistance.
Eg. 1. *Gossypium arboretum* varieties with narrow lobed and leathery leaves are more resistant to Jassids than are those with broad lobed and succulent leaves.
2. Cotton varieties with longer pedicels are more resistant to boll worms.

2. Physiological Factors : Osmotic concentration of cell sap, various exudates etc; may be associated with insect resistance.
Eg. 1) Leaf hairs of some *solanum sps*. secrete gummy exudates. Aphids and coloradobeetles get trapped in these exudates.

2) Exudates from secondary trichomes of *Medicago disciformis* leaves have antibiotic effects on alfalfa weevil.
3) Cotton- High osmotic concentration of cell sap is associated with Jassid resistance.

3. **Biochemical Factors** : Several biochemical factors are associated with insect resistance in many crops. It is believed that biochemical factors are more important than morphological and physiological factors in conferring non-preference and antibiosis.
Eg.
1) High concentrations of gossypol is associated with resistance in several insect pests in cotton.
2) In rice – high silica content in shoots gives resistance to shoot borer

Genetics of Insect Resistance
Insect resistance is governed by -
1. Oligogenes 2. Polygenes 3. Cytoplasmic genes
1. **Oligogenic Resistance** : Insect resistance is governed by one or few major genes or oligogenes, each gene having a large and identifiable individual effect on resistance. Oligogenic resistance may be conditioned by the dominant or the recessive allele of the concerned gene. The differences between resistant and susceptible plants are generally large and clear-cut. In several cases, resistance is governed by a single gene (monogenic resistance)
Eg. In wheat to green bugs In cotton to Jassids
In apple to woolly aphis In rice to plant & leaf hopper

2. **Polygenic Resistance** : It is governed by several genes, each gene producing a small and usually cumulative effect. Such cases of resistance.
1) Involve more than one feature of the host plant
2) Are much more durable than the cases of oligogenic resistance.
3) Difference between resistance & susceptible plants are not clear cut
4) Transfer of resistance is much more difficult
Examples for polygenic resistance:
1) In wheat to cereal leaf beetle
2) In alfalfa to spotted aphid
3) In rice to stem borer
4) In maize to ear worm and leaf aphid
Evolution of resistance breaking biotypes is almost rare.

3. **Cytoplasmic Resistance :** governed by plasmagenes
Eg. 1. Resistance to European corn borer in maize
2. Resistance to root aphid in lettuce

Sources of Insect Resistance
1. A cultivated variety 3. A related wild species
2. Germplasm collections. 4. An unrelated organisms
1. Cultivated variety : Resistance to many insect pests may be found among the cultivated varieties of the concerned crop. Varieties SRT 1, Khand waz ; DNJ 286 and B 1007 of *G. hirsuturn* are good sources of resistance to Jassids.

2. Germplasm collection :
Eg. 1) In apples for rosy apple aphid, green apple, apple maker and apple saw-fly.
2) In cotton, several strains resistant to Jassids.
3. Related wild species :
Eg. 1) Resistance to both the species of potato nematodes has been transferred fro *Solanum vernei* to potato
2) Jassid resistances is known in wild relatives of cotton *G. tomentosum; G.anomalum* and *G.armourianum*
4. An unrelated organism : It is done through recombinant DNA technology
a) T he 'Cry' gene of *Bacillus thuringiensis* is the most successful example.
Other genes of importance are the
b) Protease inhibitor encoding genes found in many plants eg. the cowpea pea, trypsin inhibitor (cp TI) gene.

Breeding Methods for Insect Resistance
1. Introduction 2. Selection
3. Hybridization 4. Genetic Engineering

1. Introduction :
Eg. *Phylloxera vertifoliae* resistance grape root-stocks from U.S.A. into france.

2. Selection :
Eg. 1) Resistance to potato leaf hopper
2) Resistance to spotted alfalfa aphid

3. Hybridization : Pedigree oligogenic characters
Back cross Polygenic characters

4. Genetic Engineering : *B.theningiensis* (cry gene) resistance in maize, soybean, cotton etc.

Screening Techniques for determining resistance
The most crucial and, perhaps , the most difficult task in breeding for insect resistance is the identification of insect resistant plant during segregation generations. There are two types of screeings
1. Field Screening 2. Glass house screening

Field Screening :
The techniques designed to promote uniform infestation by an insect pest in the field are
1. Inter planting a row of known susceptible variety between two rows of testing material.
2. Screening in highly prone areas
3. in case Soil insect pests to be tested in sick plots only
4. Testing in a particular season when the infestation is very high.
Eg. Rice stem borer in off season.
5. Transferring manually equal number of eggs or larvae to each test plant.

Glass house screening:

Result from glass house tests are much more reliable than those from field tests since both the environment and the initial level of infestations are more or less uniform for all the plants being tested.

Problems in Breeding for Insect Resistance :

1. Breeding for resistance to are insect pest may leads to the susceptibility to another pest.
Eg. Glabrous strains of cotton are resistant to bollworms but susceptible to Jassids.
2. Reduction is quality or make unfit for consumption.
3. Linkage between desirable & undesirable genes. Inter specific varieties are generally low yielding and their produce is often of inferior quality.
4. Screening for resistance is the most critical and difficult step is a breeding programme it necessitates a close co-ordination among scientists belonging to different disciplines.
5. It is a long term programme

Achievements

INDIA

1. India – cotton varieties – G 27, MCU 7, LRK 516 – resistant to boll worms.
2. Rice – variety vijaya – resistant to leaf hopper
Rice – TKM 6, Ratna – Stemborer
Rice –Vajram, chaitanya, Pratibha – BPH

BREEDING FOR ABIOTIC STRESS RESISTANCE

DROUGHT RESISTANCE:

Drought: Scarcity of moisture (soil moisture) which restricts the expression of full genetic yield potential of a plant.

Drought resistance: The ability of crop plants to grow, develop and reproduce normally under moisture stress.

Mechanisms of drought resistance

There are 4 mechanisms of drought resistance.

1.Drought Escapes : It is due to ability of a genotype to mature early, before occurrence of drought. Drought escape is most common is plants grown is desert region. Eg. Early maturing varieties of sorghum, maize, bajra, wheat, rice etc; give more yield than late maturing under drought.

2. **Drought Avoidance** (Dehydration avoidance) : It is due to the ability of plants to maintain favourable water balance even under stress. The plants which avoid drought retain high moisture content is their tissues and lose less water. This is possible either because of : i) Increased water uptake (due to increase in root development) plants are called water spenders.(or) ii) Reduced water loss (due to reduction in growth of aerial parts are called water savers (i.e. to avoid transpiration) Dehydration avoidance is interpreted as the ability of genotypes to maintain high leaf water potential when grown under soil moisture stress: Several traits contribute to dehydration avoidance Such as : Leaf rolling, folding and reflectance narrow leaves, increased

pubescence on aerial organs , presence of awns, osmatic adjustment of stomata, cuticular wax, increased water uptake ;
Reduced Transpiration : Increase is concentration of Abscisic Acid (ABA), closure of stomata, ABA plays role in reduction of leaf expansion, Promotion of root growth etc.

3. **Drought Tolerance** (Dehydration tolerance) : Ability of plants to produce higher yield even under 'low water potential'. In cereals drought tolerance generally occur during reproductive phase. Tolerant cultivars exhibit better germination, seedling growth and photosynthesis. Drought tolerance may be because of i. high proline accumulation
ii. maintenance of membrane integrity
4. **Drought Resistance** : It is the sum total of avoidance and Tolerance. It refers to the genetic ability of plants to give good yield under moisture stress conditions.

Various morphological, physiological and biochemical features / parameters associated with drought resistance

a. Morphological

1. Earliness
2. Reduced tillering
3. Leaf characters : Leaf rolling , Leaf folding, Leaf shedding, Leaf reflectance
4. Reduced leaf area : Narrow leaf, Change in leaf angle
5. Hairiness (presence of hairs on leaf and other parts, lowers leaf temperature and reduce transpiration)
6. Colour of leaves
7. Wax content
8. Awns (eg. wheat and barley)
9. Root system (rooting depth and intensity)

b. Physiological

1. Photosynthesis (efficient system like C4) under stress, photosynthetic efficiency is reduced due to chloroplast damage.
2. Reduced Transpiration and reduced respiration losses
3. Stomatal behavior (closure of stomata, also change in size and number of stomata)
4. Osmotic adjustment
5. Leaf enlargement (increase in thickness)
6. Leaf cuticle wax (increases)

c. Biochemical

1. Accumulation of proline and betaine
2. Increase in Abscisic acid (barley) and Ethylene (maize & wheat)
3. Protein synthesis (increases under stress)
4. Nitrate – reductase activity

Sources of drought resistance

1. Cultivated varieties
2. Land (old or desi primitive varieties)
3. Wild relatives (reported in several crops)

For example :

S.No. Crop Wild sps Resistant to

i Wheat *Aegilops. variabilis* drought
Aegilops speltoides "
Aegilops umbellulata "
Aegilops squarrosa "
ii Sugarcane *Sacharum. spontaneam* Drought & salinity

4. Transgenes :

Eg. 'Rab' (Responsive to abscisic acid) in rice

Screening / Evaluation

1. Field Env. Highly desirable
2. Green house Env. More precisely controlled than field

Breeding Methods and Approaches

It is important that drought resistance be incorporate in material with high genetic potential for yield. 1. Yield and yield components are best evaluated under non stress / optimal environments, While 2. Drought resistance must be evaluated under water stress.

Breeding methods : Methods are same as for yield and other economic characters. Breeding for drought resistance refers to breeding for yield under moisture stress, i.e. developing varieties which can give high yields under stress. The common methods are

1. Introduction
2. Selection
3. Hybridization
4. Mutation
5. Biotechnology

Limitations :

1. Generally resistant varieties have low yield
2. Do not have much wider adaptability (as abiotic resistant is location specific)
3. Drought resistant genes may have linkage with undesirable genes.
4. Transfer of resistant genes from wild types may post problem.
5. Drought resistance is a consequence of a combination of characters and single character can be used for selection.
6. Measurement of many drought resistant traits is difficult and problematic, since virtually all the useful drought resistant traits are under polygenic control. (So pedigree method most common). But if resistant genes is from agronomically inferior race then 1-2 backcrossing with cultivated type in made. If resistance gene is from wild species-go for backcrossing breeding. Generally selection is performed on individual plant progenies instead of individual plants (i.e. similar to line breeding)
7. Creation of controlled moisture stress Environments
8. Selection require considerable resources

WATER LOGGING

As per Levitt (1980 b) flooding (i.e. water logging) is the presence of water in soil excess of field capacity. It leads to deficiency of O2 and buildup of Co2, Ethylene and other toxic gases and this leads to reduction in aerobic respiration.

Effects of water logging:

1. Once soil becomes water logged, air space in soil is displaced with water, the O2 in the soil in dissolved in water. i.e. O2 decreases; Co2 ethylene and other toxic gases increases.
2. O2 replacement in the soil is very inefficient. Diffusion of atmospheric O2 into the water logged soils is very inefficient (because of the slow diffusion of atmospheric O2 to water logged soil).
3. Root systems are suddenly plunged into an anaerobic condition. This switching from aerobic to anaerobic respiration disrupts root metabolism.
4. Carbohydrates level get depleted it is due to
a. Dissipation of metabolism
b. High water temperature
c. Low light

Characteristics of plants in response to water logging stress :

1. Reduced growth / elongation.
2. Chlorosis, senescence and abscission of lower leaves
3. Wilting & leaf curling
4. Hypertrophy (increase in size of organ due to increase in cell size)
5. Epinasty (downward growth of petioles)

Mechanisms of tolerance:

1. Adventitious root formation on lower part of stem (close to surface so that O2 tension is quickly restored after transient water logging) eg. Tomato
2. Lenticel (i.e. raised pores in the stem of plants) formation
3. Aerenchyma formation (soft plant tissue continues air spaces found in acquatic plants) in the cortex that provide canal paralled to the axis of the root through which gases can diffuse longitudinally (eg. rice)
4. Elongation capacity (In rice – best elongation response give 100% recovery from submergence and poorest elongation gives upto 49% recovery) Scoring for elongation can be done between booting and flowering stage after flooding the crop to varying depths. In sugarcane, *S. spontaneum* has more tolerance to flooding. Some canes gave upto 70% of their production potential when in continuous flood for 5 months (in an east at canal point Florida, USA)

Ideotype for flooded areas : The postulated ideotype for flooded areas should have the following characterstics.

1. Capacity to carry out functional activity at low O2 concentration (i.e. High cytochrome activity)
2. Ability for photosynthesis under low light intensity
3. Capacity to synthesis food rapidly
4. Regeneration capacity of shoots when damaged by flood
5. Ability to withstand drought at later growth stage
6. Deep root system
7. Narrow, medium long and dark green leaves with high sugar and protein content.

Breeding methods : Same as in other stresses.

BREEDING FOR SALT TOLERANCE

Salt Tolerance: refers to the ability of plants to prevent, reduce or overcome injurious effects of soluble salts present in their root zone. It is a global problem as saline and alkali soils are fond in almost all the countries of the world, more in Semi Arid Tropic (SAT) of world.

Problem of salinity can be overcome by two ways:
1. Soil reclaimation : costly, time consuming and short lived
2. Res istant varieties : less costly, more effective, long lasting require longer period to develop.

Behavior / characteristics of plants to salt :
1. Land races more tolerant than High yielding varieties. Tolerant plants varieties are found is salt affected areas
2. Salt tolerance capacity differs from species to species. Also genetic differences exist among cultivars for their salt tolerance capacity.
3. Different crop plants show differential response to salinity

Salinity Crops
a. Highly tolerant crops Sugarbeat, sunflower, barley (grain), cotton, datepalm, asparagus
b. Moderately Tolerant crops Barley (Forage), rye, soghum, wheat, safflower, soybean
c. moderately sensitive Rice, corn, foxtail millet, cow pea, peanut, sugarcane, tomato, potato, sweet potato, radish,
alfalfa, cabbage
d. Extremely sensitive Citrus, straw berry, melon, peas, other legumes, apple, rajmabean, carrot, okra, onion (orange)
4. Higher ploidy level crops are more tolerant than lower ploidy level crops.
Eg. Hexaploid wheat more tolerant than tetraploid
Tetraploid Brassica more tolerant than diploid Brassica
5. In rice tall, coarse grained, late maturing varieties- more tolerant
6. In sugarcane different strains have differential tolerance Barley more tolerant than wheat.

Symptoms of plants to salt stress :
1. Retardation / cessation of growth
2. Necrosis
3. Leaf abscession
4. Loss of turgor
5. Ultimate death of plant

Mechanisms of salt tolerance :
2 types of mechanisms
1. **Salt Tolerance** : Plants respond to salinity stress by accumulating salt, generally in their cells or glands and roots etc.
2. **Salt avoidance** : plants avoid salt stress by maintaining their cell salt concentration unchanged either by water absorption eg. Rice, chenopodiaceae family or by salt exclusion eg. Tomato, soybean, citrus, wheat grass.
Glycophytes (Non-halophytes) plants owe their resistance primarily to avoidance. Eg. Barley
Hallophytes (plants that grew in salty or alkaline soils) show tolerance by ion accumulation mechanism

Breeding methods:
Breeding methods are same but breeding strategies are
1. Breeding for yield potential should have greater emphasis than breeding for salt resistance per se (As screening is done on the basis of yield reduction in stress environment as compared to non-stress Environment.).
2. Selection should be done is stresses target environments (As abiotic stress resistance is an important part of Environ. Fitness & is bound to be location specific i.e. it is related to narrow adaptation.

Screening Techniques:
Common methods are
1. Sand culture by using nuturient solution in sand & irrigation with saline water
2. Solution culture by using solution culture tanks (Hydroponic culture)
3. Microplot techniques by using small microplots
Microplot Techniques: By using small microplots of size 6 x 3 x 1 m (CSSRI, Karnal, Haryana) at central soil salinity Research Institute.
Then Multilocation Trial (MLT) conducted over seasons to get more reliable results.
Genotypes which survive better under salinity are considered tolerant & tested further.

Selection criteria:
1. Germination (%) is saline medium
2. Dry matter accumulation (seeding / plant dry wt.) / Early vigour
3. Leaf senescence or death – Estimated by total dead leaf area or No. of dead leaves
4. Leaf necrosis
5. Leaf ion content
6. Osmoregulation (Determined as maintenance of turgor under stress) Measured as proline or CHo accumulation or accumulation of glycine, betaine etc.
7. Yield – Economic yield

Problems:
1. Creation of reliable controlled salinity Env.
2. Scoring for salinity resistance
3. Genetic control – it is complex & polygenic
4. Mechanisms of resistance poorly understood. Salinity may have interaction with other stresses.

COLD TOLERANCE

When temperatures remain above-freezing *i.e.* >00C to <100-150C it is called chilling
When temperature. remain below freezing *i.e.*<00C it is called Freezing.

A. Chilling Resistance:
Chilling sensitive plants are typically tropical plants. Temperate plants are generally tolerant to chilling injury.

Effects of chilling stress on plants :

1. Reduced germination
2. Poor seedling establishment
3. Stunted growth
4. Wilting
5. Chlorosis
6. Necrosis
7. Pollen sterility
8. Poor fruit set / seed formation
9. Reduced root growth
10. Locked open stomato
11. ABA accumulation

At subcellular level

12. Reduces membrane stability
13. Poor chlorophyll synthesis (affected)
14. Reduced photosynthesis & respiration
15. Toxicity due to H2O2 formation

Chilling Tolerance

Ability of some genotypes to survive / perform better under chilling stress than other genotypes is called chilling tolerance. It is because of chilling hardening, *i.e.* an earlier exposure to a near chilling temperature for a specifie d period as a result of which chilling tolerance of the concerned plants increases.

Mechanisms of chilling tolerance:

1. Membrane lipid un-saturation
2. Reduced sensitivity of photosynthesis
3. Increased chlorophyll accumulation
4. Improved germination
5. Improved fruit / seed set
6. Pollen fertility

Sources of chilling Tolerance :

1. Late adopted breeding populations eg. maize
2. Germplasm (eg. That collected from high altitude , low temperature geographic regions)
3. Induced mutants for cold tolerance
4. Cold tolerant somaclonal variants
5. Related wild species eg. Tomato

Selection criteria

Based on -

1. Germination test
2. Growth under stress (measured as plant dry matter accumulation)
3. Chlorophyll Loss under chilling stress eg. rice, cucumber, tomato (measured as seedling colour)
4. Membrane stability : (Assayed in terms of solute leakage from tissues)

5. Photosynthesis : Chilling injury to photosynthesis is assayed as variable chlorophyll fluorescence at 685 nm
6. Seedling mortality
7. Seed / Fruit set
8. Pollen fertility (apply during injury at PMC)

B. Freezing Resistance
Freezing injury / Frost injury / cryo injury
Freezing Stress : Dormant state is conducive to freezing resistance, while resistance in actively growing tissue is rare : Thus Freezing resistance largely involves surviving freezing stress in such a manner as to enable subsequent regrowth when the temperature rises.
As water in plants cools below 00C, it may either
1. Freeze *i.e*. form ice or 2. Super cool without forming ice.

Effects of freezing stress:
1. Ice formation : Two types Intercellular ice formation
Intracellular ice formation &Intercellular Ice formation: Initiation of ice formation on plant surface is sufficient to induce freezing of the internal (intercellular & xylem vessels etc.) water is most plant species.
Intracellular ice formation: It is more lethal may be due to physical disruption of subcellular structure by ice crysta l. Intracellular ice formation is the major and terminal freezing stress.
Extracellular ice formation in a cases the concentrations of extracellular solutes, the re by water is withdrawn from the cells during extracellular ice formation. This creates waterstress in the frozen tissue / plant.

2. Membrane disruptions :
· Freezing causes disruptions is and / or alter the semipermeable properties of plasma membrane
· Loss of solutes from the cells occur
· Cells remain plasmolyzed even after thawaing which is often called as frost plasmolysis
· Cells may become highly turiel due to uptake of excess water.

3. Suspercooling :
Cooling of water below 00C without ice crystal formation is called supercooling
· In plants water may cooldown to -1 to-150C is herbeceour sps and to -40 to -450C in hardy trees.
· This becomes possible apparently because internal ice-nucleators are absence in such cases.
· This is regarded as an important. Mechanism of freezing avoidance
4. Stress due to external factors : Consequent to freezing
1) Ice sheet formation below and above the ground causes reserve depletion anoxia etc. in plants.
2) Tissues killed during freeze-thaw are highly prone to pathogen attacks
3) Auto toxicity may occur

Mechanism of Freezing Resistance :

The ability of a genotype to survive freezing stress and to recover and re grow after thawing is known as freezing resistance. Freezing resistance is a complex trait involving physiological, chemical & physical processes at the tissue and cell level.

Mechanism of Freezing resistance.

1. **Freezing avoidance** : The ability of plant tissues / or genes (but the whole plants) to avoid ice formation at sub zero temperature is called freezing avoidance Supercooling is a mechanism of freezing avoidance it is controlled by

1. Lack of ice-nucleators 2. Small cell size 3. Little or no intercellular space 4. Low moisture content 5. Barriers against external nucleators 6. Presence of antinucleators

2. **Freezing Tolerance** : Ability of plants to survive the stresses generated by extra cellular ice formation and to recover and regrow after thawing is known as freezing tolerance. The various components of freezing tolerance are as follows:

1) Osmotic adjustment
2) Amount of bound water
3) Plasma membrane stability
4) Cell wall components properties
5) Cold-responsive proteins Eg. ABA

Sources of freezing tolerance

1. Cultivated varieties
2. Germplasm lines
3. Induced Mutations
4. Related wild species Eg. Wheat *Agropyron* sps; rye

Barley – *H. jubatum, H.brachyantherum x H.bogdanii, H.jubatum x H.compressum*
Oats – Avena sterilis

5. Transgenes : Eg. chemical Synthe sized antifreeze protein gene, ala 3, in tobacco

Selection criteria:

Based on

1. Field survival
2. Freezing test in laboratory
3. Cryo freezing
4. Osmoregulation

Problems in breeding for freezing tolerance

1. Freezing Tolerance is a complex trait & involves several components. So, it is not ready measurable under field conditions
2. Breeding work under field conditions is highly influenced by other environ factors and biotic stresses
3. Due to large G X E for the trait field survival shows poor heritability
4. Freezing tolerance also shows a large GXE interaction which limits progress under selection
5. Laboratory tests are yet to be developed to screen large breeding population

BREEDING FOR QUALITY CHARACTERS

Rice:

Several aspects of rice kernel are taken into consideration for determining quality. These include appearance of endosperm, length and shape of kernel, milling quality, cooking quality, aroma, protein content, etc. Generally, a transparent type of endosperm is preferred to opaque (chalky, white belly, white chore) ones. The opaque character is due to loose packing of starch grains and affects the appearance and milling quality. Opaqueness disappears after cooking and does not affect palatability. The heritability of this character is low and agronomic practices and pre-harvest handling influence this character. The waxy type of endosperm also gives a chalky appearance but is not common in Indian cultivars (except in traditional and few released cultivars of north-east India). Waxy endosperm is governed by a single pair of recessive genes. Preference for grain length and shape (length / breadth) varies from country to country, region and even within the economic classes of a region. In India, rice varieties are classified into five categories (long bold, long slender, medium slender, short bold, short slender) based on length / breadth ratio of the kernel. In India, Pakistan and West Asia, long slender grains fetch a premium price in the market. Grain length and shape are quantitatively inherited characters, are independent of each other and can be combined desired except probably the long and bold characters. These characters can, however, be fixed in early generations in a breeding programme and little segregation takes place in later generations (Jennings *et al.,* 1979) The total rice recovery varies from 70.4 to 79.2 per cent and head rice recovery 23.8 to 74.5 per cent. Both the characters are influenced by environmental factors and are independent of each other. The latter is, however, of great concern to millers and, at the same time, more influenced by environmental factors.

Cooking quality : The amylose content and gelatinisation temperature of starch determine the cooking quality of rice. The gelatinisation temperature indicates the temperature at which the starch grains swell irreversibly when boiled in water. The proportion of amylose and amylopectin - two kinds of starch grains present in rice endosperm - is associated with stickiness of cooked rice, glutinous (Waxy) rice has up to 2 percent amylose. When cooked, water absorption and volume expansion of glutinous rice is low and the grains remain sticky. In India, glutinous types are used only in northeast India in preparation of cakes, sweets, etc. The starchy types can be grouped into low amylose (20 per cent) types. The varieties with high amylose types cook dry and fluffy but become hard on cooling. The Indian varieties have generally high amylose types. The high and low amylose types are governed by a single gene pair through modified by environmental factors. The gelatinisation temperature varies from 56 to 790C. Rice with high gelatinisation temperature requires more water and time to cook than those with low gelatinisation temperature. The gelatinisation temperature thus reflects the hardness of the starch granules.

Wheat :

The quality criteria of wheat is milling quality, baking quality for bread making, biscut making which again depends upon loaf volume, doughing, expansion of dough, loaf volume, degree of kernel hardness, colour etc. The quality is mainly dependtant on the protein content of the flour: The simultaneous improvement in grain yield and grain protein content through breeding is considered difficult because of negative association between these traits (Jennes *et al* 1991). This suggested that selecting the genotype with both high yield and high protein content fro breeding

purposes. It has been proposed that wild relatives are a useful source of genetic variation for increasing grain protein percentage. (*T.turgidum* var. *dicoccoides*). Cox *et al* 1990 reported that direct introgression of genes from diploid Aegilops squarrosa into bread wheat conferred an improvement in protein percentage. Similarly high grain protein percentage of a tetraploid (wild) emmer wheat (*T.dicoccoides*) has been transferred into bread wheat (Grammer *et al*. 1984).

Pearl millet :
High heritability and significant correlation have been observed in selectedgenotype for protein, calcium, phosphate and total minerals of the grain. The genetic analysis reveled that high heritable differences exist for total lipids, free fatty acids, total carbohydrates and total soluble sugars. The protein content and the total lipids were negatively correlated to carbohydrates but positively influenced by sugar content and longer duration. The additive gene effects were higher than non additive effects for the quality traits of protein, lipids and free fatty acids.

Maize :
Flint varieties are preferred compared to dent. The biological value of protein in normal maize is limited for monogastric animals and human because of its unfavorable amino acids composition. Dudley (1997) reported that theoretical limit to selection occurred between grain yield and protein content in the grains of IHP strains. These IHP lines are used in breeding programmes to improve protein lines always accompanied for high oil content. The first major break through was the discovery of the effects of Opaque - 2 and Floury - 2 mutants on lysine and tryptophan content in maize endosperm protein. Backcross programme helped very much to transfer these characters to cultivated maize. Special hybrids are also produced for Hi-starch content for specific industrial purpose. These characters are controlled by major genes with high heritability.

Small millets :
The grain quality parameters namely, colour, grain hardiness and water absorption in small millets.

Pulses :
In pulses breeding for quality improvement mainly based on improvement of protein content and quality of protein and then reducing the concentration of toxio antinutritional factors. Improving the content of amino acids such as albumin, glutamin, metheonine and high vitamins like thiamine, Riboflavin and Niacin along with minerals such as Ca, Mg and Fe. Reducing of protein and amylase inhibitors oligo saccharides polyphenols, phytolectine, cynogenic glucocide, mycotoxins. The heritability estimates are very low for these characters indicated polygenic in nature. Therefore, the success in the improvement is very limited.

Soybean :
The higher nutritive value of soybean is largely dependant on acid component of protein and content of antinutritional factors. Sebern and Lambert (1984) suggested the early generation selection for protein followed by selection for yield in later generation will be successful if non additive effects are important selection for protein content should be in later generation. All types of breeding methods such as pedigree – mass selection for low oil, recurrent selection are being adopted Wehrmann *et al* (1987). The studies revealed that the protein content controlled by two major genes.

Sunflower :

Sunflower seed has a hard weedy pericarp, the kernel constituting of the whole seed. The oil content of the seed ranges from 22 to 36 percent, the kernel contains 45-55 percent. The component of fatty acid of the oil are saturated acids 10% (Myristic, 0.38 Palmitic 4.27 and steric 5.46%) Oleic acid 35% and Linoleic acid 57% Regarding the fatty acid profile the oil contains lesser amount of saturated fatty acids, appreciably high amounts of essential fatty acids, linoleic. In addition that the oil contains vitamins A, D and E, sterols, squalene and other aliphatic hydrocarbons, terpene and methyl ketones. The Phosphatids (0.1 - 0.2%) present in the oil are lecithin (38.5%) and cephaline (61.5%). They occur in combination with protein and carbohydrates. Antinutrients such as haemoglutinin activity ranged from 50.6 to 132.8 units / mg of protein. The phenol content ranged from 2.6 to 3.8 per cent. The ration of linoleic to oleic acid content is affected by environment variation in oil content and quality depends on the shape and size of sunflower head. The oil from dehulled seeds could be stored for longer period. Oleic acid content showed significant correlation with linolic acid and linolenic acid and has positive correlation. Oil content is negatively correlated with seed yield per plant. Negative correlation between oil and protein content (Mendal and Single, 1993). It is suggested that the increase in oil level could probably be achieved through selection for thin hull, more seed weight, and high oil percentage in the kernel.High heritability value for oil content indicated that significant improvement could be made in increasing oil content through individual plant selection in early Generation. The improvement in oil yield and its desirable constitutions would be possible by restarting simple recurrent selection (Miller *et al,* 1977). Pustovoit suggested the important stage in sunflower improvement as head to row remnant seed method.

Safflower :

Carthamus tinctorius **:** The oil content and quality of oil can be influenced by environment (Patel and Jaisani, 1962). Generally the kernel contributed some 98 per cent of the oil content. The percentage of oil in hulls decreased with increase in seed weight, whereas the oil in the kernels increased. There was negative correlation between oil content and seed weight (El seed, 1996). The safflower oil has got high amount of unsaturated essential fatty acids. There is considerable difference in the characteristics of oil of the various species of *carthamus*. The correlation between spineless and oil content has been observed (Weins, 1971). The oil composition also varies in having a linoleic acid content averaging 48 per cent and an oleic acid 43 percent and these characters are governed by gene. OL/ol. In breeding programmes oil content and oil yield **per se** must always be considered.

Rape and Mustered oil :

In rape seed and mustard oil, the presence of erucic acid is an important characteristic feature. Genotypes in B.juncea. where the erucic acid content is 60 to 65% of the total fatty acids are available and considered as industrially important. The poly unsaturated fatty acids namely linaleic and linolenic acids are also present in significant amount (20 to 25%) and confer liquidity on the oil. Among saturated fatty acids, palmetic acid and steric acid are present in very low quantities totaling about 5%. They are found to be involved in increasing the thrombic tendency in blood platelets. The main path way of the fatty acid biosynthesisThe undesirable acid viz., erucic acid and linolenic acid are the end produced and reduction / elimination of these fatty acid is possible if the genetic block is achieved in the steps controlling the synthesis of

erucic acid from oleic acid; linolenic acid from linoleic acid. The oleic acid has negative correlation with linoleic and linolenic acid on the one hand and erucic acid and eicosenic acid on the other (Ahiya *et al* 1978). Because of the interdependence in the progenetic substrate, the zero-erucic acid is reflected in increase oleic acid, linoleic acid and linolenic acid contents. Genetic studies in rape seed has been found to be controlled by multiple alleles. Anand and Downey (1981) identified five genes in *B.napus*. They found to act in additive manner resulting in erucic acid leves of >1,10,15,30 and 35% respectively. Later occurrence of a single gene controlling high erucic acid content was reported by Chen *et al* (1988). Use of double haploid lines have been attempted for *Brassica* improvement (Lichter *et al* 1988). Repeated back crossing of double low segregants to superior variety is also advocated. Triple low types can be produced by hybridizing double low types with yellow seeded donors. Directional selection for high linolenic acid is found very effective (Laakso *et al* 1986) Reciprocal recurrent selection is also suggested for simultaneous improvement of the traits. (Ahuja and Banga, 1992.)

Castor :

The castor seeds differ from other oil containing seeds in respect of specific content. Such as toxic protein, ricin and the alkaloid ricinine. In castor oil there is greater quantity of trigly-cerides of ricinolic acid. The unsaturated fatty acid in castor oil (Olieic and linoleic) are synthesised in the seeds in much greater quantities. The oil and hull content is in polygenic inheritance.

Cotton :

Since fabric quality is mostly governed by that of yarn from which it is woven and the quality of the yarn inturn depends upon the properties of fibre from which it is spun. The quality of cotton is judged on the physical properties of the fibre. Fibre length and its distribution is an important character of the fibre. The staple length of cotton is highly associated with the strength fineness of the yarn and with its appearance. The mean length of fibre of world cotton varied form 12 to 63m.m. The fibre fineness ie weight per unit length of fibre is generally taken as a measure of fineness, it is closely related to the fibre maturitey i.e. depends upon perimeters and wall tickness of hthefibre. The fibre strength is very great, the range being 2.5 to 3.0 grams weight per unit length. The tensile strength of fibres varies form 50,000 to 1,25,0001b / squae inch. The long fine cottons tend to have greater tensile strength than the short and coarse cotton. The bundle strength of fibre depends upon its area of cross section, test length, type of test instrument, the rate of loading etc. also depends upon relative humidity of the atmosphere. Fibre maturity indicates the degree of thickenning of the cell wall relation to its diameter. The deposition of cellulose inside the fibre is not uniform in all fibres. Generally in medium and long staple cottons,have high fibre maturity gives a better spinning performance. The genetic variability is higher in *G.hirsutum* for fibre length, uniformity ratio and *G.barbadense* for fibre fineness heritability values upto 80 percent is observed in span length, bundle strength and elongation in percent in the *G.hirsutum*. High heritability combined with high genetic advance will be more useful than heritability alone in predicting and performance of the progenies of the selected lines (Johanson *et al* 1955). A combination of high heritability and high genetic advance observed for the fibre length and bundle strength indicated the importance of additive gene action (Parse 1957) would respond well for further improvement through pedigree breeding and simple selection procedures. The study of heterosis, hybrids reveals that low positive relative heterosis for2.5% span length, uniformity ratio, and elongation percent and heterosis for fibre fineness and

2.5% span length. The intra *hirsustum* hybrids showed relative and standard heterosis for uniformity ration and low positive heterobeltiosis for maturity coofficient.

Forage crops:
In forage crops apart from nutritive value of green fodders, physical quality parameters like stem thickness, length of leaf and width, softness of stem and leaves etc. are important from the point of view of palatability to cattle. The breeding strategies adopted to improve the fodder cereals depends on the crops. Temperature: Indirect methods of estimating amylose content and gelatinization temperature are available for the benefit of those in research stations where facilities for regular analysis are not available.
The elongation of kernels on cooking is a special feature of 'Basmati' rices and needs experimental measurements for breeding such types.
Protein content : The protein content of rice varieties ranges from 6 to 18 per cent. The application of nitrogenous fertilisers, irrigation, etc. influences this character. Variation is noticed even among the kernels of the same panicle. The inheritance of this character seems to be complex and difficult to study because of several factors influencing this trait. The amino acid balance of rice is, however, quite good. The lysine content of rice protein is 3.8 to 4.0 per cent. The distribution of protein in rice grains differs among genotypes (Siddiq 1985). Deep diffused network of protein is retained much better after polishing and hence is a desirable breeding objective.
Aroma : Presence of fragrance in rice kernels is liked in India and hence scentedtypes fetch a premium price irrespective of size and shape of kernels. Scented types are available in almost all States in India. The inheritance of this character has not been fully understood. Efforts have been made to breed scented types with partial success.

Seed production technology in self pollinated, cross pollinated and vegetatively propagated crops:

1. Nucleus seed:
The seed maintained by the particular breeder who evolved a particular variety. The nucleus seed will be 100% genetically pure confirming to the varietal character of a particular variety. The nucleus seed is utilised for raising the Breeder seed.

2. Breeder seed:
The breeder seed will be multiplied from the nucleus seed in the Research Stations by plant breeders. The Breeder seed will be utilised for raising the foundation seed by the State Dept. of Agriculture. Every year the Director of Agricultural will place the indent of Breeder seed to the University. Based on the request, the university will take up breeder seed production in the Research stations. The Breeder seed plot will be monitored by the monitoring team to verify the varietal characters and genetic purity of that particular crop. The monitoring team members will be a Plant Breeder, Dy. Directior of Agri. (Seed certification) and a nominee from National Seeds Corporation. The monitoring team will visit the seed production plot twice in a crop growth period *ie*. At the time of flowering and at the time of harvest.

3. Foundation seed

From Breeder seed, the foundation seed will be raised in state seed farms. This foundation seed production plot is to be certified by the seed certification dept. The foundation seed is utilised for raising certified seed production.

4. Certified seed production
Done either by the Agricultural Department or by individual farmers after paying a nominal fee. The seed production plot will be certified by the seed certification agency and after that the seed will be sold to farmers.

B. Steps involved in release of a variety
After identification of the best cultures from the segregating generation or any other source it has to undergo the following trials.

1. Row yield trial (RYT)
For every 10th row there will be a check entry and the trial will be non replicated.

2. Replicated row yield trails (RRYT)
From the row yield trial, the best cultures will be tested in RRYT along with appropriate check. The best entries from RRYT will be carried forward to preliminary yield trial.

3. Preliminary yield trial (PYT)
Replicated trial conducted with appropriate checks. PYT will be conducted normally for two seasons. While conducting, PYT, the best entries will be nominated to All India trials also. Screening for biotic and abiotic stresses will be done during PYT stage. The best entry will be carried to comparative yield trial. The entries entered into All India trial will be given project number. For eg. sorghum entry will be given SPV (Sorghum Project Variety). Rice - IET (Initial Evaluation Trial), etc.

4. Comparative Yield trial (CYT)
CYT is replicated one conducted with more than one check. The trial will be repeated for 3 seasons. The entry proved to be superior in all the 3 seasons will be proposed for multilocation trial. (MLT).

5. Multilocation trial (MLT)
The entries for MLT will be decided at Crop scientists meet held once in a year. Each station will propose its own entry. Based on discussion of merits and demerits of each culture, the entries will be nominated. The MLT will be conducted at Research Stations of TNAU spread over the State. The best entries will be proposed for Adaptive Research Trial (ART).

6. Adaptive Research Trial (ART)
ART will be conducted at farmers field by the Agricultural Department Staff. The entries for ART will be decided during Scientific Workers Conference (SWC) which will be held once in a year at TNAU. Both scientists of TNAU and Agri. Dept. Staff will participate. At SWC, the entries will be fixed and each Joint Director of Agriculture will fix number of trials for his division. The entries performing well in ART will be proposed for release as a variety. Each culture has to be tested atleast in a minimum of 50 centres spread all over the state. If a culture is

non season bound, it will be tested in all the three seasons. If it is not so, one or two seasons result is enough.

7. Variety Release Proposal

The scientist incharge of the culture will propose the culture for release as a variety. There is a proforma for variety release. This proforma will contain all the information about the culture viz., Parentage, parents morphology, cultures morphology, key characters of the culture for identification, agronomic practices, pest and disease resistance, quality characters and yield trial results. The variety release proposal will be discussed by Director of Research and Scientists. After approval the proposal will be presented before Variety Release Committee.

8. Variety release committee

It will be headed by Commissioner and Secretary, Agrl. Dept. members will be Director of Agriculture Joint Directors of Agriculture and TNAU scientists. Besides these, two leading farmers of the state will also be the members. After discussion, based on merit the VRC will approve it for release. Then the culture will be released for general cultivation.

9. Notification of the variety

For certified seed production, the variety is to be notified by the central variety release committee, Delhi. After release of the variety for notification purpose the information will be furnished in the prescribed proforma. At that time details about All India trial will also be furnished. After notification only, a variety can be multiplied under certified seed production.

Hybrid seed production technology in Maize, Rice, Sorghum, Pearl millet and Pigeonpea, etc.

Seed Production of Rice

The student should write the important varieties and hybrids that have been released along with their characters, date of release and station from where it is released.

Seed Production of Varieties:

Land requirement: The same crop should not be grown on the same piece of land for the last one season, unless it is the same variety and certified by seed certification agency for its purity. The land requirement should be followed for nursery and the main field.

Isolation Requirement: Paddy is highly self-pollinated crop, however, some crosspollinated does occur. The extent of natural cross-pollination varies from 0-6.8%. For pure seed production the seed fields must be isolated by atleast 3m for both foundation and certified seed production from other varieties and same varieties not confirming to varietal purity.

Source of seed: Obtain appropriate class of the seed from the source approved by seed certification agency.

Brief cultural practices: Paddy can be cultivated as direct sown, puddle seeding or by transplanting. For seed production it is desirable to grow paddy under transplanting system so as

to avoid the weed problem. The seed rate required is 30-40 kgs/ha. The spacing adopted is 10x15 cm for early duration varieties and 15x15 and 20x15 for medium and late duration varieties. Transplanting should be done when the seedlings are 3-4 weeks old. Follow all the recommended package of practices and take necessary prophylactic measures so as to raise a good crop.

Rouging: Rouging of offtypes should be done once prior to flowering then at flowering and maturity. Major rouging should be done before flowering. The offtypes should be identified based on morphological characters such as plant type, plant height, days to flowering, leaf color, flag leaf shape, flag leaf angle , shape of the panicle, color of glumes, color of apiculus etc. rogue out the wild rice plants, plants infested by stem borer and diseased plants such as false smut, paddy bunt etc.

Number of field inspection: the numbers of field inspections required are two and they should be done between flowering and harvesting. During field inspection verification should be done for isolation requirement, volunteer plants, offtypes and diseased plants.

Harvesting : The crop should be harvested when the grains are hard and yellow with a moisture percentage of 23-24 %. For combine harvesting the moisture percentage should be in the range of 16-18% . the crop is cut at the base with the sickle and the plants are left in the field for 2-3 days. Then they are threshed on clean threshing floor or tarpaulin. After winnowing and cleaning the seed should be dried to safe moisture limits of 13% before storage.

Seed Yield: The seed yields are in the range of 5.0 to 6.0 t/ha depending up on the variety and the management practices adopted.

Hybrid Seed Production

Prof. Yuan Long Ping is the father of hybrid rice in China. The successful development and use of hybrid rice technology in China during 1970's led the way for development and release of rice hybrids in India. In general the hybrid rice gives 1.0 ton more yield than the best variety available. At present more than 10 rice hybrids have been developed in the country from different states. However the first rice hybrid have been developed in the country by ANGRAU. Hybrid rice can be produced by three different methods

1. **Three line system**: In this method hybrid rice is produced by utilizing cytoplasmic genetic male sterile system. The source of male sterile cytoplasm used is wild abortive. In this method there are three different lines i.e. A-line or male sterile line, B-line or maintainer line and restorer line or R-line. For maintaining A-line it has to be crossed with B-line and for producing hybrid seed A-line has to be crossed with R-line.

2. **Two line system**: This method of hybrid rice seed production involves the use of photoperiod sensitive genetic male sterile system or temperature sensitive genetic male sterile system. In this method any normal line can be used as restorer line.

3. **By Using chemical emasculants** : The chemicals which kills or sterilise the male gamete with little no effect on the normal functioning of the female gamete can be used to emasculate female

parental line in hybrid seed production. In China chemical emasculants are commonly used in hybrid seed of rice. In India they are not used commercially for hybrid seed production, but they are used in academic studies. The chemical which can be used as potent gametocides are etheral, maleic hydrazide, etc.

Hybrid seed production (using three line system)

The hybrid rice seed is produced by utilizing cytoplasmic genetic male sterile system. The source of cytoplasm used is wild abortive. One of the drawbacks of wild abortive cytoplasm is incomplete panicle exertion from the flag leaves. Hybrid seed production involves two steps;

1. Maintenance of parental lines (A-line, B-line and R-line)
2. Commercial hybrid seed production (AxR).

Maintenance of parental lines is generally referred as foundation seed production and hybrid seed production as certified seed class. The A-line can be maintained by crossing with B-line in an isolated plot, while in hybrid seed production A-line is crosses with R-line or fertility restorer line. The B-line and the R-line can be maintained just like normal varieties by following the required isolation and field standards. As the maintenance of B-line and R-line is just like normal varieties it is not discussed in detail.

Maintenance of A-line or Hybrid seed Production:

Land requirement: The same crop should not be grown in the same piece of land in the previous one season. The land requirement should be followed for nursery as well for the main field.

Isolation requirement: The hybrid paddy fields should be isolated from the other paddy fields, including commercial hybrids and same hybrid not confirming to varietal purity requirements for certification by atleast 200 meters for seed classes A, B & R-line production and by 100 meters for hybrid seed production (AxR). For hybrid seed production (A x R), if space isolation is a problem we can go for time isolation or barrier isolation. For time isolation the difference between the flowering of seed plot and the contaminating plot should be atleast 4 weeks. When both space and time isolation is not possible we can go for barrier isolation. In barrier isolation a barrier crop which is of 6-8 feet height should be grown around the seed plot for 10 to 10 meters. The commonly used barrier crops are daincha, sugarcane, sorghum etc.

Brief cultural practices: The success in hybrid seed production depends on synchronization of flowering between male and female parent. For maintenance of A-line synchronization of flowering will not be a problem as both A and B-lines iso-genic and come to flowering at the same time, while in hybrid see d production synchronization will be a problem as A-line and R-line have different genetic constitution. Generally the A-line is sown once while the B-line or R-line is sown three times at an interval of five days. When both A and R-line are of same duration sowing of A-line should be adjusted with second sowing of R-line. If A and R lines are of different growth duration, the difference in duration should be adjusted with second sowing of R-line. (For example if A-line comes to flowering in 65 days and R-line in 72 days then the difference is 7 days. After second sowing of R-line adjust the sowing of A-line with a gap of 7 days I.e. if First sowing of R-line is done on 1st June, Second sowing on 5th June and third sowing on 10th June, then sowing of A-line should be done on 12th June)

Planting ratio : The row ratio of female and male parental varies from region to region depending on weather conditions and potentiality of parental lines. The commonly adopted planting ratios of male and female are 2:8, 2:6 or 3: 8. Factors influencing the row ratio are; There can be more than 8 A lines in relation to 2 R -lines, 1. If R-lines are taller than seed parent 2. Have good growth and vigour 3. Have large panicles and 4. Shed a large amount of residual pollen.
The Character of A-line should be
1. It should be shorter than pollen parent
2. Has long duration of floret opening and stigma receptivity
3. Should have wide angle of floret opening and
4. Should have a higher percentage of stigma exertion
Transplanting should be done when the seedlings are 25-28 days old. Before transplanting mix all the B or R-lines sown on three different dates. All the missing hills should be replaced within seven days. The spacing adopted for A-line is 15x15 cm and for B or R-line is 20x15 or 30x15 cm. All the recommended package of practices should be followed to raise a good crop.

Number of Field Inspections : A minimum of four field inspections should be conducted. The first field inspection should be conducted before flowering stage, second and third during flowering stag and fourth before harvesting. During the first field inspection verification should be done for volunteer plants, isolation requirement, errors in planting and the actual acreage sown. During the second and third field inspection verification should be done for isolation requirement, offtypes, diseased plants, pollen shedders and objectionable weed plants. Actual counts should be taken during second or third field inspection. Fourth or final field inspection should be done to verify for all the above factors and the offtypes can be identified based on panicle or seed characters.

Rouging: Roughing should be done in both male and female parental lines. Remove all the offtype and volunteer plants from both male and female parental line. During flowering period rouging should be done daily to remove the pollen shedders from female parental line. The male sterile plants have shriveled anthers and they do not shed pollen while the pollen shedders have yellow colored plumpy anthers, which shed large amount of residual pollen. The off type plants should be identified based on morphological characters like plant height, plant type, flag leaf shape, flag leaf angle and other characters. Remove all the plants, which are infected with stem borer, and diseased plants like paddy bunt.

Methods of increasing out-crossing rate : Paddy is highly self -pollinated crop and the extent of natural cross—pollination is very less. Hence to increase the outcrossing rate certain methods should be followed like Flag leaf clipping, spraying of GA3 and rope pulling.

a. **Flag leaf clipping**: Flag leaves are taller than panicles and are the main obstacles for pollen dispersal and cross-pollination. Hence the flag leaves should be removed so as to improve cross -pollination and seed set. The flag leaves should be clipped one or two days before heading so that it enhances uniform pollen movement and wide dispersal of pollen grains to give higher seed set. First cut the flag leaf of the main tiller at the flag leaf joint and use it as a guide in clipping the rest of the plants. The flag leaves should be cut to half or 2/3 of the blade from the tip. Do not clip the flag leaves in plants, which are infected with bacterial leaf blight or sheath blight. The

cut leaves can infect other plants or contaminating tools used for flag leaf clipping can spread infection. The infected plants may be clipped after completing the clipping of healthy plants.

b. **GA3 application**: Application of GA3 increases the internode length and the panicles will be fully exerted from the flag leaves. It increases the duration of floret opening and stigma receptivity. Helps in adjusting the plant height of both the parents. It also increases the growth rate of secondary and tertiary tillers so that they bear productive panicles. Spraying of GA3 should be done twice first when 15-20% of the plants started heading with 40% of the chemical and second at 50% flowering with 60% of the chemical. The dosage required is 50 grams with knapsack sprayer and 25 grams with ultra low volume sprayer. For first spray use 20 g GA3 in 500 litres of water and for second spray use 30 g in 500 litres of water.

c. **Rope Pulling** : Rope pulling should be done during the peak flowering time, which helps in shaking of the male plants and dispersal of pollen grains. Rope pulling should be done daily during peak flowering stage at 8.30 AM and it should be repeated 3-4 times a day at an interval of half an hour.

Harvesting and threshing : Harvest the male row first and remove them from the field so a to avoid mechanical mixtures. Then harvest the female rows. Precautions should be taken while harvesting not mix male and female plants. Threshing should be done on a clean threshing floor and the seed should be winnowed and dried to safe moisture limits before storage.

Seed Yield: Depending on the management practices adopted and the potentiality of the parental line the seed yield may be in the range f 0.5 to 1.5 t/ha.

Seed Production of Sorghum

Seed Production of open pollinated varieties

Land requirement: Land should be free from volunteer plants, Johnson grass, Sudan grass and other forage types. The same crop should not be grown on the same piece of land in the previous one season unless it is the same variety and certified by certification agency for its purity.

Isolation requirement: sorghum is a self-pollinated crop but cross-pollination up to 8-10 % may occur. In some of the varieties with loose or lax panicle types the extent of natural cross-pollination may go up to 50 %. Hence the seed fields must be isolated from other varieties of grain and dual-purpose sorghum and same variety not confirming to varietal purity by 200m for foundation seed class and 100 m for certified seed class. An isolation of 400 m is required from Johnson grass (*Sorghum halepense*) and other forage sorghums with high tillering and grassy panicles. Differential blooming for modifying isolation distance are not permitted (i.e. time isolation is not permitted)

Brief Cultural Practices: Obtain appropriate class of the seed from the source approved by seed certification agency. The seed rate required is 12-15 kg/ha and the spacing adopted is 45cm between the rows and 15cm between the plants. Other cultural practices are similar to raising a commercial crop. Necessary prophylactic measures should be taken so as to raise a good crop.

Rouging: remove all the offtypes and volunteer plants before they start shedding pollen. The rouged plants must be cut from the bottom or uprooted to prevent regrowth. Offtypes can be identified based on morphological characters like plant height, leaf shape, leaf colour, stem pigmentation, days to flowering etc. Rogue out other related plants like Johnson grass, Sudan grass, forage plants and plants affected by kernel smut and head smut from time to time.

Number of field Inspections: A minimum of three field inspection should be done. First inspection should be done during vegetative stage to determine isolation, volunteer plants and designated diseases etc. Second inspection shall be made during flowering to check isolation, offtypes and other relevant factors. Third inspection shall be made at maturity prior to harvest to verify designated diseases true nature of plants, head and seed.

Harvesting and threshing : The seed crop must be harvested when it is fully ripe. The harvested heads should be sorted out to remove the diseased or otherwise undesirable. The heads should be dried on the threshing floor or tarpaulin for a couple of days before threshing. Threshing can be done by threshers or manually. The seed should be thoroughly cleaned and dried to 10 % moisture before storage.

Seed Yield: Depending up on the potentiality of the variety and the management practices adopted, seed yield may be in the range of 35-40 q/ha.

Hybrid Seed Production

In sorghum hybrid seed is produced by utilizing cytoplasmic genetic male sterile system. The source of male sterile cytoplasm used is Combined kafir. Hybrid seed production involves two steps;

1. Maintenance of parental Lines (A-line, B-line and R -line)
2. Commercial hybrid seed production (AxR)

Maintenance of parental lines is generally referred as foundation seed production and hybrid seed production as certified seed class. The A-line can be maintained by crossing with B-line in an isolated plot, while in hybrid seed production A-line is crosses with R-line or fertility restorer line. The B-line and the R-line can be maintained just like normal varieties by following the required isolation and field standards. As the maintenance of B-line and R-line is just like normal varieties it is not discussed in detail.

Seed Production of B-line and R-line: The seed is produced in an isolated plot and it is similar to seed production of open pollinated varieties. However the isolation distance required and the fields standards are similar to that of maintenance of A-line.

Maintenance of A-line or Hybrid seed Production (AxR):

Land requirement: Land should be free from volunteer plants, Johnson grass, Sudan grass and other forage types. The same crop should not be grown on the same piece of land in the previous one season unless it is the same variety and certified by certification agency for its purity.

Isolation requirement: The isolation distance for maintenance of A-line (AxB) is 300 m from fields of other varieties of grain and dual purpose sorghum and same variety not confirming to varietal purity and 400 m from Johnson grass, Sudan grass and other forage types. For

commercial hybrid seed production (AxR) the isolation distance required is 200 m from fields of other varieties of grain and dual purpose sorghum, and same hybrid not confirming to varietal purity requirements of certification, 5 m from other hybrid seed production plot having the same male parent and 400 m from Johnson grass, Sudan grass and other forage types. Differential blooming dates for modification of isolation distance are not permitted.

Planting ratio : The planting ratio of female to male plants is 4:2 with two rows of male parent all around the field.

Brief cultural practices: The success in hybrid seed production depends on synchronization of flowering between male and female parent. For maintenance of A-line synchronization of flowerin g will not be a problem as both A and B-lines are isogenic lines and come to flowering at the same time, while in hybrid seed production synchronization will be a problem as A-line and R-line have different genetic constitution. If there is any difference between the male and female parent for days to flowering the sowing dates should be adjusted for proper synchronization of flowering. The seed rate required is 8.0 kgs/ha of A-line and 4.0 kgs/ha of B or R-line. Other cultural practices similar to commercial crop production should be adopted for raising a good crop.

Cultural manipulation for nicking: Proper synchronization of flowering between Aline and R-line is a common problem. In-spite of taking the precautions like adjusting the sowing dates some times synchronization may be a problem. If the difference between the male and female parent is less than a week it can be manipulated by cultural practices. The parent which is lagging should be sprayed with 1 per cent urea solution 2-3 times at an interval of 2-3 days or additional irrigation should be given to the Lagging parent. Blowing air by operating empty duster with the mouth directed horizontally to the male ears, will help to disseminate pollen.

Rouging: Before flowering remove all offtypes from both seed parent and pollen rows based on morphological characters. Some of the precautions to be taken while rouging are

1. Start rouging before offtypes, volunteers and pollen shedders in female rows start shedding pollen
2. Out crosses can be easily identified be cause of their greater height and more vigorous growth and should be removed
3. At flowering rouging should be done every day to remove pollen shedders from female parent rows. The sterile types have only stigma or a pale aborted anthers without pollen, while the fertile ones have yellow colored plumpy anthers which shed large amount of residual pollen.
4. Remove all plants out of their place (i.e. plants in between the lines), and male plants in female rows and vice versa. Special attention should be given at the ends where there is a chance of male seed falling in female rows.
5. Remove other sorghum related plants like Johnson grass, Sudan grass and other forage types from the seed plot and from within the isolation distance.
6. Remove the plants affected by kernel bunt and head smut.
7. Preharvest rouging may be done based on grain and ear characters.

Number of Field Inspections : A minimum of four field inspections should be conducted. The first field inspection should be conducted before flowering stage, second and third during flowering stag and fourth before harvesting. During the first field inspection verification should

be done for volunteer plants, isolation requirement, errors in planting and the actual acreage sown. During the second and third field inspection verification should be done for isolation requirement, offtypes, diseased plants, pollen shedders and objectionable weed plants. Actual counts should be taken during second or third field inspection. Fourth or final field inspection should be done to verify for all the above factors and the offtypes can be identified based on panicle or seed characters.

Harvesting and threshing: Harvest the male rows first and keep their heads separate to avoid mixture male and female seed. Then harvest the female parental line and thresh it separately. Precautions may to taken while harvesting and threshing to avoid mechanical mixtures.

Seed Yield: the seed yield may be in the range of 4-6 q/ha depending on the parent line and the cultural practices adopted.

Seed Production of Maize

Open Pollinated varieties (Synthetic's and Composites):

Land requirement: No specific land requirements are there for maize seed production, however the field should be free from volunteer plants and have good drainage facility.

Isolation distance: Maize is a highly cross pollinated crop, the refore for pure seed production the fields of maize should be isolated from other varieties of maize and same varieties not confirming to varietal purity by 400 m and 200 m foundation and certified seed production reciprocally.

Brief Cul tural Practices: obtain appropriate class of the seed from the source approved by seed certification agency. Seed rate required is 15 kgs/ha and the spacing adopted is 60-70 cm between the rows and 20 cm between the plants in a row. The recommended package of practices should be adopted for raising a good crop. No of Field inspections: A minimum of two field inspections shall be made in such a way that one is conducted before flowering and the other during flowering stage so as to check for isolation distance, offtypes, desig nated diseases and other relevant factors.

Rouging: Not much rouging is required in open pollinated varieties has they have broad genetic base and are phenotypically uniform for most of the characters. However rouging for offtypes such as very tall or dwarf should be completed before pollen shedding. Remove malformed and diseased plants affected by stalk rot from time to time. At harvest sorting should be done remove off-colored and off –textured ears.

Harvesting of maize ears: Maize ears can be harvested at high moisture content (30- 35 %) when artificial heated air drying facilities are available, otherwise harvest the crop when the seed moisture content is 15-16 %. After harvest sort out all off-type maize ears, particularly those showing different colour and texture and the diseased ears before placing them in bins for drying.

Shelling: After drying, the ears are once again examined and any offtypes or diseased ears are removed before shelling. The certification standards require bin inspection of maize ears before

shelling. Therefore shelling should be undertaken after taking the approval from seed certification agency.

Seed Yield: Depending upon the management practices adopted and the potentiality of the variety the yield may be in the range of 25-30 q/ha.

Hybrid seed production

In maize we are having single cross, double cross and three-way cross hybrids. Maintenance of parental lines/inbred lines and single cross seed production is considered as foundation seed class and commercial hybrid seed production or double cross seed production or three-way cross seed production as certified seed production.

Maintenance of Parental lines/ Inbred lines:

Land requirement: same as open [pollinated varieties.

Isolation requirement: 400 m of isolation is required from other maize varieties and hybrids with same kernel colour and texture as that of the seed parent and 600 m from other maize varieties and hybrids with different kernel colour and texture. In case where space isolation is a problem we can go for time isolation. Time isolation is provided 5% or more plants in the seed field should not be with receptive silks when more than 0.1% of plants in the contaminating field is shedding pollen.

Brief Cultural practices: Obtain appropriate class of the seed from the source approved by seed certification agency. The seed rate required is 15 kgs /ha and the recommended cultural practices should be followed as that for raising a commercial crop.

Number of field inspections : A minimum of four field inspections shall be made in such a way that first field inspection is done before flowering stage an the remaining three during flowering stage to verify isolation distance, offtypes and other relevant factors.

Rouging: the inbred lines are true breeding strains and rigorous rouging should be done to remove offtypes before they shed pollen. Remove tall and vigorous growing plants from the knee-high stage onwards. At preflowering stage rogue out offtype based on morphological characters such as leaf shape, tassel color and silk color. Final rouging should be done to remove disease -affected plants.

Harvesting & Shelling: Similar to open pollinated varieties. Seed Yield: depending upon the yield potentiality and the management practices adopted the yield may be around 5-6 Q/ha.

Single cross seed production:

The single cross seed is produced by crossing two specific inbred lines by following a planting ratio of 2 lines of male parent and 4 lines of female parent in alternate rowswith 4-6 male parents around the seed production plot. The female parent has to be detasselled before shedding pollen to ensure cross -pollination with male line. The seed harvested from female rows is the single cross hybrid seed.

Land requirement and isolation requirement: same as maintenance of inbred lines. Depending on the differences in duration adjust the sowing dates of male and female inbred line. Necessary precaution may be taken to avoid mixing of male and female lines. The male lines have to marked on both the ends by a label or tag or by sowing the seed of other crops like sannhemp or daincha.

Cultural Practices: The seed rate required is 10 kgs/ha for female parent and 5kgs/ha for male parent. After adjusting the sowing dates the recommended package of practices should be followed.

Number of field inspections : A minimum of four field inspections shall be made in such a way that first field inspection is done before flowering stage an the remaining three during flowering stage to verify isolation distance, offtypes and other relevant factors.
Shedding tassels in female parent any inspection 0.50 % During flowering when 5.0% or more of the plants In the seed parent have receptive silks Total pollen shedding tassels including tassels that 1.00 %

Detasselling : when Cms line is not used the seed parent has to be detasselled so that it will be fertilized by the pollen from the male parent. Removal of the tassel from the female parent before shedding pollen is called as detasselling. For detasselling hold the stalk by left hand and take a firm grip of the entire tassel in the right hand and pull it gently to detassel.

Precautions to taken while detasselling

1. Remove all tassels from seed parent before they shed pollen.
2. Detasselling should be done when the tassel is completely out of the flag leaf but before anthers shed pollen
3. Remove the entire tassel
4. Avoid immature detasselling as they cause injury to the top leaves.
5. Once detasselling starts in the field it must be repeated daily in all weather conditions at a fixed time. Detasselling should be done from the same side every day in case of large fields.
6. Precaution may be taken not to detassel in male rows.
7. Lodged plants in female rows must be detasselled as they are likely to pass unnoticed during detasselling.
8. After detasselling drop the tassel immediately on the ground and they should not be carried till the end of the row as they contaminate receptive silks.

Rouging: Rouging should be done both in male and female parental lines. Remove the offtypes from both male and female parental lines before they start shedding pollen. Shedding tassels should not be there in female rows. Offtypes can be identified based on morphological characters like plant height, leaf shape, tassel and silk color etc. remove all the plants affected with stalk rot and other diseases.

Harvesting and shelling : Harvest the male rows first and remove them from the field to avoid mechanical mixtures. Then harvest the female rows. After harvesting sorting should be done to

remove off-colored, off textured and diseased ear heads. Before shelling approval should be taken from the seed certification agency.

Seed Yield: average seed yield of a single cross varies from 4-6 Q/ha.

Double cross hybrid seed production / Commercial hybrid seed production

The double cross hybrid seed is produced by using high yielding single cross as the female parent. The planting ration adopted is 2line of male parent and 6 lines of female parent. The female single cross has to be detasselled before pollen shedding to ensure cross-pollination with male parent (single cross). Land requirement: Same as open pollinated variety Isolation requirement: 200 m From any maize with same kernel color and texture of seed parent 300 m From maize with different kernel color or texture of that of seed parent 5 m From other hybrid seed production plot having same male parent. Differential blooming dates are permitted for modifying isolation distance provided 5% or more plants of the seed parent should not have receptive silks when more than 0.5% pf plants in the contaminating field shed pollen. Or Distance less than 200 m may be modified by planting additional border rows of male parent if the kernel color and texture of the contaminating maize are same as that of seed parent.
For area upto 4 hectares and with decrease in isolation distance by 12.5 m an additional border row of male parent should be planted.
1. Border rows must be planted in continuation to the seed field at the same time and with same seed rate and spacing.
2. Seed fields having diagonal exposure to the contaminating field should be planted with border rows in both the directions of exposure.
3. Natural barriers like thick trees and buildings cannot be substitute the border rows.
4. when two seed fields with different pollinators are within the isolation distance both are to be provided with border rows.
5. Modification of isolation distance with boarder rows is not permitted if the contaminating field parent is of different kernel color or texture if it is popcorn or sweet corn

Seed Production of Bajra

Seed Production of Synthetics & Composites

Land requirement: Land to be used for seed production of bajra open pollinated varieties should be free from volunteer plants

Isolation requirement: Bajra is predominantly a cross pollinated crop with 80% cross pollination due to protogynous condition. Therefore for pure seed production the seed field should be isolated by 400 and 200 m for foundation and certified seed respectively from other varieties of bajra and from same variety not confirming to varietal purity requirements.

Brief Cultural Practices: Obtain appropriate class of see d from the source approved by seed certification agency. Bajra can be directly sown in the field or a nursery can be raised and transplanted after 20-25 days. The seed rate required is 3-4 kgs/ha. Transplanting is generally useful under following conditions.
1. There is shortage of seed and when assured yield is required.

2. When the main field is occupied by previous crop, we can save upto 1 month time.

Number of field Inspections: A minimum of three inspections shall be made as follows;
1. The first inspection shall be made before flowering preferably within 30 days after planting to determine isolation, volunteer plants, offtypes, downy mildew incidence and other relevant factors
2. The second inspection shall be made during 50 % flowering to check isolation, offtypes, downy mildew/green ear (*Sclerospora graminicola*) and other relevant factors.
3. The third inspection shall be made at maturity and prior to harvesting and in order to determine the incidence of downy mildew/green ear disease, ergot, grain smut and to verify the true nature of plant and other relevant factors.

Roughing: Rogue out offtypes and volunteer plants before they begin to shed pollen. The rogues must be cut from the base or uprooted. The offtypes can be identified based on morphological characters like leaf shape and color, hairiness, anthocyanin pigmentation on the stem and leaves, plant height etc. at harvest offtypes can be identified by panicle characters. Remove the plants affected by green ear, ergot and grain smut disease from time to time.

Harvesting: Bajra should be harvested when the grains are fully mature. After harvesting remove the ear heads infected with ergot and green ear disease before drying and threshing. Care should be taken during harvesting, threshing and drying to avoid mechanical mixtures.

Seed yield : Depending upon the variety and the management practices adopted the seed yield may vary from 20 –25 Q/ha.

Hybrid seed Production
The hybrid seed in bajra is produced by utilizing cytoplasmic genetic male sterile system. The cytoplasmic male sterile source used in bajra is Tift 23A identified by G.W.Burton. The hybrid seed production in bajra can be discussed under to heads
1. Maintenance of parental lines (A -line, B-Line and R-line)
2. Commercial hybrid seed Production (Crossing A X R)

Maintenance of A-line or male sterile line : For maintenance of A-line it has to be crossed with male fertile, non-pollen fertility restoring strain i.e. B-line in an isolated plot. The usual planting ratio adopted is 4 lines of A-line and 2 line of B-line with 4-6 borders of B -line around the field.

Isolation Requirement: Isolation required is 1000 m from other bajra fields. Time isolation is not permitted in bajra.

Cultural practices: obtain appropriate class of the seed from the source approved by seed certification agency. The seed rate required for drilling is 1.5 Kgs/ha of A-line and 0.75 kgs /ha of B-line, for transplanting the seed rate required is 600-650 gms of A-line and 200-300 gms of B-line. The spacing adopted is 70-90 cms between the row and 20-25 cm within the row. Follow the recommended package of practices as that of normal cultivation.

Number of field Inspections: A minimum of four field inspection shall be made as follows;

1. The first inspection shall be made before flowering preferably within 30 days after planting to determine isolation, volunteer plants, offtypes, planting ratio, planting errors, incidence of downy mildew and other relevant factors
2. The second and third inspection shall be made during flowering to check isolation, pollen shedders, offtypes, downy mildew/green ear (*Sclerospora graminicola*) and other relevant factors.
3. The fourth inspection shall be made at maturity and prior to harvesting and in order to determine the incidence of downy mildew/green ear disease, ergot, grain smut and to verify the true nature of plant and other relevant factors.

Roughing: Roughing should be done frequently to produce high quality seed. Following precautions should be taken while rouging.
1. Roughing should be started before flowering to avoid contamination with foreign pollen
2. Remove offtypes and volunteer from seed parent and pollen parent by uprooting to prevent re-growth.
3. Female parent rows should be roughed daily during flowering to remove pollen shedders
4. Remove plants in between the lines or male plants in female rows and vice-versa. Remove the plants affected with green ear, ergot and grain smut.
5. Remove offtypes and volunteers from within the isolation distance.
6. Before harvest rouging should be done based on seed characters.

Harvesting: Harvest the male rows first and keep them separate to avoid mechanical mixture. Then harvest the female rows and sort out the undesirable heads and reject them before drying and threshing.

Seed Yield: Depending on the potentiality of the inbred line and the management practices adopted the seed yield may be 3-4 Q/ha.

Maintenance of restorer line: It is produced in an isolated field just like normal varieties as it is male fertile, by following the standards given for maintenance of A-line.

Commercial Hybrid seed Production:
The hybrid seed is produced by crossing male sterile line (A-line) with the restore line in an isolated field. The planting ratio adopted is 4 lines of A-line and 2 -lines of R-line.

Isolation requirement: 200 m from fields of other varieties of bajra and 5 m from fields of other hybrid seed production plots having the same male parent.

Cultural practices: the spacing and seed rate are same as that of maintenance of male sterile line. If male and female parents of different durations then the sowing dates should be adjusted accordingly for proper synchronization of flowering between male and female parent. If the difference in flowering is 3- 4 days it can be adjusted by cultural practices. The parent, which is late, should be sprayed with 2.0 % urea solution, which enhances flowering.

Number of field Inspections: A minimum of four field inspection shall be made as follows;
1. The first inspection shall be made before flowering preferably within 30 days after planting to determine isolation, volunteer plants, offtypes, planting ratio, planting errors, incidence of downy mildew and other relevant factors
2. The second and third inspection shall be made during flowering to check isolation, pollen shedders, offtypes, downy mildew/green ear (*Sclerospora graminicola*) and other relevant factors.
3. The fourth inspection shall be made at maturity and prior to harvesting and in order to determine the incidence of downy mildew/green ear disease, ergot, grain smut and to verify the true nature of plant and other relevant factors.

Roughing: Roughing should be done frequently to produce high quality seed. Following precautions should be taken while rouging.
1. Roughing should be started before flowering to avoid contamination with foreign pollen
2. Remove offtypes and volunteer from seed parent and pollen parent by uprooting to prevent regrowth.
3. Female parent rows should be roughed daily during flowering to remove pollen shedders
4. Remove plants in between the lines or male plants in female rows and vice-versa. Remove the plants affected with green ear, ergot and grain smut.
5. Remove offtypes and volunteers from within the isolation distance.
6. Before harvesting rouging should be done based on seed characters.

Harvesting: Harvest the male rows first and keep them separate to avoid mechanical mixture. Then harvest the female rows and sort out the undesirable heads and reject them before drying and threshing.

Seed Yield: Depending on the potentiality of the inbred line and the management practices adopted the seed yield may be 3-4 Q/ha.

Seed Production of Sunflower

Seed Production of Open Pollinated varieties

Land requirement: Select the fields in which sunflower was not grown in the previous year unless it is the same variety and certified by the seed certification agency for its purity. In addition to that the seed field should have good drainage and the soil should be deep fertile and with neutral pH

Isolation requirement: Sunflower is partially self and cross pollinated crop. The extent of natural cross pollination varies from 17-62% according to insect activity. The fields must be isolated by atleast 400 meters for foundation seed class and 200 meters for certified seed class from fields of other varieties, same varieties not confirming to varietal requirement and wild sunflower.

Brief cultural practices: Obtain appropriate class of the seed from the source approved by seed certification agency. The seed rate required is 8-10 kgs/ha and the spacing adopted is 60x20 cm. Other cultural practices similar to commercial crop production should be adopted for raising a

good crop. Follow the recommended package of practices and take necessary prophylactic measures so as to raise a good crop.

Number of Field Inspection: A minimum of three field inspection should be done. First inspection should be made at he stage of 6-7 pairs of leaves are present to determine isolation, volunteer plants and designated diseases etc. Second inspection shall be made during flowering to check isolation, offtypes and other relevant factors. Third inspection shall be made at maturity prior to harvest to verify designated diseases true nature of plant, head and seed.
Rouging: Generally two to three rougings are necessary. First rouging should be done at pre-flowering stage and other rouging during flowering stage. Before flowering remove tall, very early and very late flowering plants, branched plants with multiple heads and diseased plants. At maturity remove offtypes, diseases plants and wild sunflower plants, plants affected by wilt, charcoal rot, blight etc. Sunflower continues to shed viable pollen even after removal from stalks. Therefore the heads should be thrown on the ground with face downward towards the soil.

Suppleme ntary pollination: supplementary pollination is done by gently rubbing the palm with a muslin cloth on the heads, so that all the flowers will be fertilized and increases seed setting.

Harvesting and threshing: Sunflower should be harvested when the back side of the head turns to lemon yellow in colour. The heads are to be removed form the plants and dried in sun for a couple of days. Then threshing is done by gently beating with sticks.

Seed yield: Depending up on the variety and management practices adopt ed the seed yield may be around 15 q/ha.

Hybrid Seed Production
In Sunflower hybrid seed is produced by using cytoplasmic genetic male sterile system. The source of cytoplasm used is Helianthus peteolaris. Hybrid seed production involves two steps
3. Maintenance of parental Lines (A-line, B-line and R -line)
4. Commercial hybrid seed production (AxR)
Maintenance of parental lines is generally referred as foundation seed production and hybrid seed production as certified seed class. The A-line can be maintained by crossing with B-line in an isolated plot, while in hybrid seed production A-line is crosses with R-line or fertility restorer line. The B-line and the R-line can be maintained just like normal varieties by following the required isolation and field standards. As the maintenance of B-line and R-line is just like normal varieties it is not discussed in detail.

Seed Production of B-line and R-line: The seed is produced in an isolated plot and it is similar to seed production of open pollinated varieties. However the isolation distance required and the fields standards are similar to that of maintenance of A -line.

Maintenance of A-line or Hybrid seed Production (AxR):
Land requirement: Select the fields in which sunflower was not grown in the previous year unless it is the same variety and certified by the seed certification agency for its purity. In addition to that the seed field should have good drainage and the soil should be deep fertile and with neutral pH.

Isolation requirement: The seed fields mus t be isolated from other sunflower fields, increase of same line seed fields not confirming to varietal purity requirements of certification and from wild sunflower species by 600 meters for maintenance of Aline and 400 meters for hybrid seed production or AxR.

Planting ratio: The proportion of female (A-line) and male line (B or R-line) should be 3:1 with two border rows of male parents on the sides of seed production plot.
Brief Cultural Practices: The success in hybrid seed production depends on synchronization of flowering between male and female parent. For maintenance of A-line synchronization of flowering will not be a problem as both A and B-lines are isogenic lines and come to flowering at the same time, while in hybrid seed production synchronization will be a problem as A-line and R-line have different genetic constitution. If there is any difference between the male and female parent for days to flowering the sowing dates should be adjusted for proper synchronization of flowering. The seed rate required is 7.5 kgs/ha of A-line and 2.5 kgs/ha of B or R-line. Other cultural practices similar to commercial crop production should be adopted for raising a good crop.

Roughing: Rouging should be done in both male and female parental line. Remove the volunteer plants and offtypes from both male and female parental line. During flowering period roughing should be done daily to remove the pollen shedders. Pollen shedders should be removed in the morning hours before the bee activity starts. Precautions to be taken while rouging.
1. Start rouging before offtypes, volunteers and pollen shedders in female rows start shedding pollen
2. Remove plants with pink or purple colored centre in the heads. As the cultivated forms have greenish yellow in the center.
3. Remove plants showing branching and multifloret types
4. Remove diseased plants and plants which are too early or too late in flowering
5. Before threshing remove the heads with white seeds or seeds with prominent white streaks.

Number of Field Inspections : A minimum of four field inspections should be conducted. The first field inspection should be conducted before flowering stage, second and third during flowering stag and fourth before harvesting. During the first field inspection verification should be done for volunteer plants, isolation requirement, errors in planting and the actual acreage sown. During the second and third field inspection verification should be done for isolation requirement, offtypes, diseased plants, pollen shedders and objectionable weed pla nts. Actual counts should be taken during second or third field inspection.

Supplementary Pollination :
a. Hand pollination: Rub the palm with muslin cloth on the male parental line and then on female parent so as to transfer the pollen from male to female parent during peak flowering time. This as to be repeated daily during the flowering period in the morning hours
b. Bee Hives: Bee hives may be kept at 200 feet distance at 3-4 places in the field to increase bee activity.

Harvesting and threshing : Harvest the male parent first and remove them from the field to avoid mechanical mixtures. Then harvest the female rows. Harvesting and threshing will same as that of open pollinated varieties.

Seed Yield: Depending on the inbred line and the management practices adopted seed yield may be in the range of 4-5 q/ha.

Seed Production Castor

Castor is most difficult crop for seed production as there is lot of variation in a variety when grown in different seasons for plant height, node number upto primary raceme and other characters. Due to this reason, they have given a range for node number in different classes of seed.

Land requirement: Land for seed production of castor should be free from volunteer plants.
Isolation requirement: Castor is cross-pollinated crop. Cross -pollination by wind varies from 5-36% according to the prevailing climatic conditions. For pure seed production the seed crop must be isolated from other variety fields and same variety not confirming to varietal purity by atleast 300m and 150 m for foundation and certified seed classes respectively.

Cultural practices: Obtain appropriate class of the seed from the source approved by seed certification agency. The seed rate required is 11-18 kgs/ha. The recommended package of practices for commercial cultivation should be followed for raising a good crop.

Number of field inspections : A minimum of two field inspections are to be made from the time the crop approaches flowering until it is ready for harvest. During field inspection verification should be done for isolation requirement, offtypes and other relevant factors.

Roughing: Remove the offtypes based on morphological characters like stem color, internode length, shape of the leaf, bloom type and remove them before flowering. After initiation of primary spike, examine the plants for number of nodes upto primary raceme, type of internode, proportion of male to female in the spike and remove all undesirable plants not confirming to standards. Any delay in roughing adversely effect the seed quality hence during flowering roughing may be done 3-5 times at an interval of 2-3 days. Remove the plants affected by diseases like phytophthora blight and cersospora leaf spot.

Harvesting: the crop is generally harvested in 3-4 pickings. The spikes should be harvested when the fruits start turning to light yellow and should be dried in sun until they are blacken and get dried.

Seed Yield: Depending upon the potentiality of the variety and the management practices adopted the seed yield ma be around 8-10 Q/ha.

Hybrid seed production:

In castor different types of sex phenotypes are observed like;
Monoecious plants : Plants bearing female and ma le flowers on upper and lower parts of the raceme respectively.

Pistillate/Female parent: Plants containing variable proportion of stable pistillate flowers.
Male parent: Monoecious inbred line used as pollen parent in hybrid seed production.
Bisexual flowers : Under certain environmental conditions the female parent (VP-1) produces 2-5 bisexual flowers per spike

Environmentally sensitive staminate flowers : Interspersed staminate flowers which develop all along the length of female raceme usually after the failure of first developed female flowers to set fruits. The intensity of interspersed staminate flowers is more conspicuous in male promoting environment. In hybrid seed production of castor environmentally sensitive genetic male sterility system is used. Castor is monoecious and under certain environment conditions it produces only female flowers. Presence of male and female flowers in the inflorescence is influenced by temperature and nutrient management. In general when the daily mean temperature is above 32oC favors production of male flowers and temperature below 32oC favors production of female flowers. Similarly good crop management with adequate fertilizer management produces more number of pistillate flowers.

Hybrid seed production in castor can be discussed under two heads
1. Maintenance of parental lines (Female and male parental line)
2. Hybrid seed production (Crossing of female and male parent)

Maintenance of female parental line :
The female parent should be grown in Kharif or Summer season when the daily mean temperatures are above 32oC to promote more number of male flowers. Under this male promoting environment selection should be made for pistillate lines and interspersed staminate flowered plants. There are two methods for maintenance of female parental line conventional method and renovated method.

Conventional method: In conventional method we have to maintain 75% of pistillate lines and 25% of monoecious lines. During flowering period observe the plants regularly and remove all the plants with more than three whorls of male flowers in primary raceme and retain only 25% monoecious plants with male flowers in 2-3 whorls. At flower initiation in primary raceme identify the female plants with pistillate inflorescence with well-defined characters and tag them with red tape. Examine all the monoecious plants and remove those with male flowers beyond three whorls from the base. Count the number of female and monoecious plants in each row and remove the monoecious plants over and above 25%. Examine the tagged plants regularly for reversion to monoecious condition in 2nd, 3rd and 4th order racemes. Remove the tag as and when a female plant reverts to monoecious condition upto 4^{th} sequential order branches. On maturity harvest the female plants bearing the tape and keep the picking wise seed in separate lots after proper drying, packing and labeling. To avoid any possibility of mixing, delay the harvest of monoecious plants and early reverts by 3-4 days.

Renovated method: In renovated method 100 % plants should be pistillate lines. When ever a plants turn to monoecious condition in 2nd , 3rd or 4th order racemes it should be removed. As all the plants are pistillate the first flush of female flowers do not get the pollen and they drop off and 50 - 55% of the plants will produce interspersed staminate flowers, these interspersed

staminate flowers supply the pollen required for self pollination and help in fertilization. Here in renovated all the plants are 100 % pistillate upto 4th order raceme. Remove all the plants, which are monoecious, and plants deviating from female parental line.

Isolation: The isolation required is 300m from other varieties and hybrids of castor.
Number of field inspection: A minimum of four inspections shall be made as follows;
1. The first inspection shall be made before flowering in order to determine isolation, volunteer plants, outcrosses, planting ratio, errors in planting, stem color, types of leaves and other relevant factors.
2. The second and third inspections shall be made during flow ering to check isolation, offytpes, nature of bloom, petiole, leaves, raceme, sex expressivity, number of nodes upto primary raceme and other relevant factors.
3. The fourth inspection shall be made prior to harvesting after the seed has attained maturity so that true nature of the plant can be verified.

Harvesting: Harvest the crop when the panicles are fully mature. In general harvesting is done in two or three pickings.

Maintenance of Male parent: It is similar to that of maintenance of varie ties but the isolation and field standards are to be maintained as that of foundation seed class.

Commercial hybrid seed production / certified seed production:
The planting ratio adopted is 3 lines of female parent and 1 line of male parent. Commercial hybrid seed production should be taken up during rabi season when the daily mean temperatures are less than 32oC. Adjust the sowing dates of male and female parent for proper synchronization of flowering.

Isolation: isolation required is 150 m from other var ieties and hybrids of castor
Number of field inspection: A minimum of four inspections shall be made as follows;
1. The first inspection shall be made before flowering in order to determine isolation, volunteer plants, outcrosses, planting ratio, errors in planting, stem color, types of leaves and other relevant factors.
2. The second and third inspections shall be made during flowering to check isolation, offytpes, nature of bloom, petiole, leaves, raceme, sex expressivity, number of nodes upto primary raceme and other relevant factors.
3. The fourth inspection shall be made prior to harvesting after the seed has attained maturity so that true nature of the plant can be verified.

Roughing:
1. Remove all offtypes from male and female parents.
2. Identify the monoecious plants in female rows before flower initiation as well as the deviants for node number upto primary raceme, uproot and destroy them.
3. Continue this process everyday till all plants in female rows commence flowering.
4. Rogue out male parent for variants depending on node number upto primary raceme.
5. Reversion in female rows to monoecism in 3rd or 4th order racemes should not be uprooted but nipped off.

Harvesting: Harvest the male rows first and remove them from the field. Then harvest the female rows picking wise. Care should be taken to avoid mechanical mixtures during harvesting, threshing and drying.

Seed Production of Red gram (Pigeon Pea)

Seed production of OPV:

Varieties: ICPL – 87 (Pragati): ICPL – 151 (Jagriti), Pusa – 33, JA – 4, JKM – 7, Asha (ICPL – 87119); LRG – 30, LRG – 38, LRG – 41

Land Requirements:

Land to be used for seed production of pigeon pea shall be free of volunteer plants. In addition the soil should be light, well drained and with a neutral ph.

Isolation requirements:

Red gram is partially self and cross pollinated. Although anthers burst before flowers open, there is considerable cross-fertilization by bees and other insects. Natural crossing to the extent of sixty five percent has also been recorde d. Therefore, for maintaining variety purity an isolation of 200 mts. for foundation seed class and 100 mts. for certified seed class is necessary from fields of other varieties and of the same variety not confirming to varietal purity requirements of certification.

Brief cultural practices:

Obtain appropriate class of seed from the source approved by seed certification agency. The seed rate required is 12-15 kg/ha and the spacing adopted is 60 x 25 cm to 75 x 30 cm. Other cultural practices are similar to raising a commercial crop. Necessary prophylactic measures should be taken so as to raise a good crop.

Roguing:

Rogue the off type plants and diseased plants affected by wilt, leaf spot and stem canker, yellow mosaic virus and sterility virus from see d field from time to time, as required.

Number a field inspections:

A minimum two and maximum four field inspections are standardized for certification of different seed production programmes. For red gram, a minimum of two field inspections are required i.e. first one before flowering and second inspection during flowering and fruiting to determine isolation, volunteer plants, off types and diseased plants etc.

Harvesting and threshing:

The crop is harvested soon after the seed is mature. Harvesting is normally done with sickle and the crop is left in the field to dry for about one week. Threshing is done by beating the plants with sticks. After threshing and cleaning the seed should be dried to 8 to 10 percent moisture before storage. Necessary precautions should be taken to avoid mechanical mixtures during these operations.

Seed yield

The average seed yield varies from 20 to 25 quintals per hectare.

Redgram Hybrid Seed Production:

Hybrids : ICPH – 8 : PPH – 4, COH – 1, COH – 2,: AKPH – 2022, AKPH – 4101. To produce hybrid seed in bulk, male sterile lines are planted in the ratio of six male sterile rows (Female): one pollinator row (Male). The hybrid seed plot is surrounded by four pollinator rows to provide sufficient pollen load. In genetic male sterility (GMS) system 50% plants appears male fertile in the female (MS) rows. Therefore, these fertile sibs needs to be uprooted immediately as the first bud appear on the plant. The male sterile sibs those remain are to be tagged in the female rows. Periodic picking of immature pods from the pollinator rows may prolong their flowering time. It is possible to produce several hybrids in one isolation block using a common male parent and several male sterile, if their flowering can be synchronized. Appropriate isolation distance of 200 m between two seed blocks should be maintained to avoid contamination.

Seed Production of Green gram and Black gram

Green gram Varieties: WGG-2, WGG-37, MGG-295, MGG-348, LGG-450, LGG- 460.

Black gram Varieties for Kharif and Rabi : T-9, LBG-623, LBG-20, WBG-26

For Rabi only: LBG-752, LBG-648, LBG-645, LBG-402 LBG-17

Land Requirements

Land to be used for seed production shall be free of volunteer plants. In addition the soil should be light, well drained and with a neutral ph.

Isolation requirements:

Green gram and Black gram are highly self-pollinated. Natural cross pollination to the extent of 0 to 5% has been recorded. Therefore, for maintaining variety purity an isolation of 10 m. for foundation seed class and 5 m. for certified seed class is necessary from fields of other varieties and of the same variety not confirming to varietal purity requirements of certification.

Brief cultural practices:

Obtain appropriate class of seed from the source approved by seed certification agency. The seed rate required is 15-20 kg/ha for kharif and 20-25 kg/ha for summer and the spacing adopted is 30 x 10 cm. Other cultural practices are similar to raising a commercial crop. Necessary prophylactic measures should be taken so as to raise a good crop.

Roguing:

Rogue the off type plants and diseased plants affected by leaf spot and stem canker, yellow mosaic virus and sterility virus from seed field from time to time, as required. Roguing should be done once before flowering and once after flowering based upon varietal morphological characters

Number a field inspections:

A minimum two field inspections are standardized for certification of different seed production programmes. For green gram and black gram, a minimum of two field inspections are required i.e. first one before flowering and second inspection during flowering and fruiting to determine isolation, volunteer plants, off types and diseased plants etc.

Harvesting and threshing:

The crop is harvested soon after the seed is mature. Threshing is done by beating the plants with sticks. After threshing and cleaning the seed should be dried to 8 to 10 percent moisture before storage. Necessary precautions should be taken to avoid mechanical mixtures during these operations.

Seed yield
The average seed yield varies from 10 to 15 quintals per hectare.

IDEOTYPE BREEDING

Crop ideotype refers to model plants or ideal plant type for a specific environment. In broad sense an ideotype is a biological model which is expected to perform or behave in a predictable manner within a defined environment. More specifically, crop ideotype is a plant model which is expected to yield greater quantity of grains, fibre, oil or other useful product when developed as a cultivar. The term ideotype was first proposed by Donald in 1968 working on wheat.

Ideotype Breeding:
Ideotype breeding can be defined as a method of crop improvement which is use to enhance genetic yield potential through genetic manipulation of individual plant character. Main features of ideotype breeding are

1. Emphasis on individual trait
In ideotype breeding, emphasis is given on individual morphological and physiological trait which enhances the yield. The value of each character is specified before initiating the breeding work.

2. Includes yield enhancing traits
Various plant characters to be included in the ideotype are identified through correlations analysis. Only those characters which exhibit positive association with yield are included in the model.

3. Exploits physiological variation
Genetic differences exist for vario us physiological characters such as photosynthetic efficiency, photo respiration, nutrient uptake, etc. Ideotype breeding makes use of genetically controlled physiological variation in increasing crop yields, besides various agronomic traits.

4. Slow progress
Ideotype breeding is a slow method of cultivar development, because incorporation of various desirable characters from different sources into a single genotype takes long time. Moreover, sometimes undesirable linkage affects the progress adversely.

5. Selection
In ideotype breeding selection is focused on individual plant character which enhance the yield

6. Designing of model

In ideotype breeding, the phenotype of new variety to be developed is specified in terms of morphological and physiological traits in advance.

7. Interdisciplinary approach
Ideotype breeding is in true sense an interdisciplinary approach, it involves scientist from the disciplines of genetics, breeding, physiology, pathology, entomology etc.

8. A continuous process
Ideotype breeding is a continuous process, because new ideotypes have to be developed to meet changing and increasing demands.

Differences between traditional and ideotype breeding

S.No.	*Traditional Breeding*	*Ideotype Breeding*
1	The main objective is defined before initiating the breeding work	The conceptual theoretical model is prepared before initiation of breeding work
2	Selection is focused on yield and some other characters	Selection is focused on individual plant characters.
3	It usually includes various morphological and economic characters	It includes various morphological, physiological and biochemical plant characters
4	Value of each character is not fixed in advance	Value of each trait is defined in advance
5	This is a simple and rapid method of cultivar development	This is a difficult and slow method of cultivar development
6	The phenotypic of a new variety is not specified in advance	Phenotype of new variety to be developed is specified in advance

Features of crop ideotypes
The crop ideotype consists of several morphological and physiological traits which contribute for enhanced yield or higher yield than currently prevalent crop cultivars. The morphological and physiological features of crop ideotype differ from crop to crop and sometimes within the crop also depending upon whether the ideotype is required for irrigated cultivation or rainfed cultivation. Ideal plant types or model plants have been discussed in several crops like wheat, rice, maize, barley, cotton and beans. The important features of ideotype from some crops are

Wheat
The term ideotype was coined by Donald in 1968 working on wheat. He proposed ideotype of wheat with following main features:
1. **A short strong stem.** It imparts lodging resistance and reduces the losses due to lodging.
2. **Erect leaves.** Such leaves provide better arrangement for proper light distribution resulting in high photosynthesis or CO_2 fixation.

3. **Few small leaves.** Leaves are the important sites of photosynthesis, respiration and transpiration. Few and small leaves reduce water loss due to transpiration.
4. **Larger ear.** It will produce more grains per ear.
5. **An erect ear.** It will get light from all sides resulting in proper grain development.
6. **Presence of awns.** Awns contribute towards photosynthesis.
7. A single culm.

RICE

The concept of plant type was introduced in rice breeding by Jennings in 1964, through the term ideotype was coined by Donald in 1968. He suggested that in rice an ideal or model plant type consists of 1. Semi dwarf stature
2. High tillering capacity and
3. Short, erect, thick and highly angled leaves
4. More panicles /m2,
5. High (55% ore more) harvest index.

Now emphasis is also given on physiological traits in the development of rice ideotype.

MAIZE

IN 1975, Mock and Pearce proposed ideal plant type of maize.
1. Stiff-vertically-oriented leaves above the ear.
2. Maximum photosynthetic efficiency.
3. Efficient translocation of photysynthate into grain.
4. Short interval between pollen shed and silk emergence.
5. Small tassel size.
6. Photoperiod insensitivity
7. Cold tolerance
8. Long Grain -filling period

BARLEY

Rasmusson (1987) reviewed the work on ideotype breeding and also suggested ideal plant type of six rowed barley.
1. Short stature
2. Long awns
3. High harvest index
4. High biomass.

Kernel weight and kernel number were found rewarding in increasing yield.

COTTON

Ideotype for irrigated cultivation
1. Short stature (90-120 cm)
2. Compact and sympodial plant habit making pyramidal shape
3. Determinate in fruiting habit with unimodal distribution of bolling
4. Short duration (150-165 days)
5. Responsive to high fertilizer dose
6. High degree of inter plant competitive ability

7. High degree of resistance to insect pests and diseases, and
8. High physiological efficiency.

Rainfed conditions (Singh and Narayanan 1993)
1. Earliness (150-165 days)
2. Fewer small and thick leaves
3. Compact and short stature, indeterminate habit
4. Sparse hairiness,
5. Medium to big boll size
6. Synchronous bolling
7. High response to nutrients
8. Resistance to insects and diseases.

FACTORS AFFECTING IDEOTYPES

There are several factors which affect development of ideal plant type. These are briefly discussed below:

1. Crop Species

Ideotype differs from crop to crop. The ideotype of monocots significantly differs from those of dicots. In monocots, tillering is more important whereas in dicots branching is one of the important features of ideotype.

2. Cultivation

The ideotype also differs with regard to crop cultivation. The features of irrigated crops differ from that of rainfed crop. The rainfed crop needs drought resistance, fewer and smaller leaves to reduce water loss through transpiration. In dicots, indeterminate types are required for rainfed conditions, because indeterminate type can produce another flush of flowers if the first flush in affected by drought conditions.

3. Socio -economic Condition of Farmers

Socio-economic condition of farmers also determines crop ideotype. For example, dwarf *Sorghum* is ideal for mechanical harvesting in USA, but it is not suitable for the farmers of Africa where the stalks are used for fuel or hut constructions.

4. Economic Use

The ideotype also differ according to the economic use of the crop, for example, dwarf types are useful in *Sorghum* and pearl millet when the crop is grown for grain purpose. But when these crops are grown for fodder purpose, tall stature is desirable one. Moreover, less leafy types are desirable for grain purpose and more leafy genotypes for fodder purpose. The larger leaves are also desirable in case of fodder crop.

STEPS IN IDEOTYPE BREEDING

Ideotype breeding consists of four important steps,

1. Development of Conceptual Model

The values of various morphological and physiological traits are specified to develop a conceptual theoretical model. For example, values for plant height, maturity duration, leaf size,

leaf number, angle of leaf, photosynthetic rate etc., are specified. Then efforts are made to achieve this model.

2. Selection of Base Material

Selection of base material is an important step after development of conceptual model of ideotype. Genotypes to be used in devising a model plant type should have broad genetic base and wider adaptability. Genotypes for plant stature, maturity duration, leaf size and angle and resistance are selected from the global gene pool of the concerned crop species. Genotypes resistant or tolerant to drought, soil salinity, alkalinity, diseases and insects are selected from the gene pool with the cooperation of physiologist, soil scientist, pathologist and entomologist.

3. Incorporation of Desirable Traits

The next important step in combining of various morphological and physiological traits from different selected **genotypes into single genotype** . Various breeding procedures, *viz* single cross, three way cross, multiple cross, backcross, composite crossing, intermating, mutation breeding, heterosis breeding etc., are used for the development of ideal plant types in majority of field crops.

4. Selection of Ideal Plant Type

Plants combining desirable morphological and physiological traits are selected in segregating populations and intermated to achieve the desired plant type. Morphological features are judged through visual observations and physiological parameters are recorded with the help of sophisticated instruments. Screening for resistance to drought, soil salinity, alkalinity, disease and insects is done under controlled conditions.

PRACTICAL ACHIEVEMENTS

Ideotype breeding has significantly contributed to enhanced yields in cereals (wheat and rice) and millets (*Sorghum* and pearl millet) through the use of dwarfing genes, resulting in green revolution. Semidwarf varieties of wheat and rice are highly responsive to water use and nitrogen application and have wide adaptation. The Norin 10 in wheat and Dee-geo-Woo-gen in rice are the sources of dwarfing genes. The genic cytoplasmic male sterile systems in *Sorghum* and pearl millet laid the foundation of green revolution in Asia (Swaminathan, 1972). Thus ideotype breeding has been more successful for yield improvement in cereals and millets than in other crops.