

Cereals

RICE *Oryza sativa* (2n=24)

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.

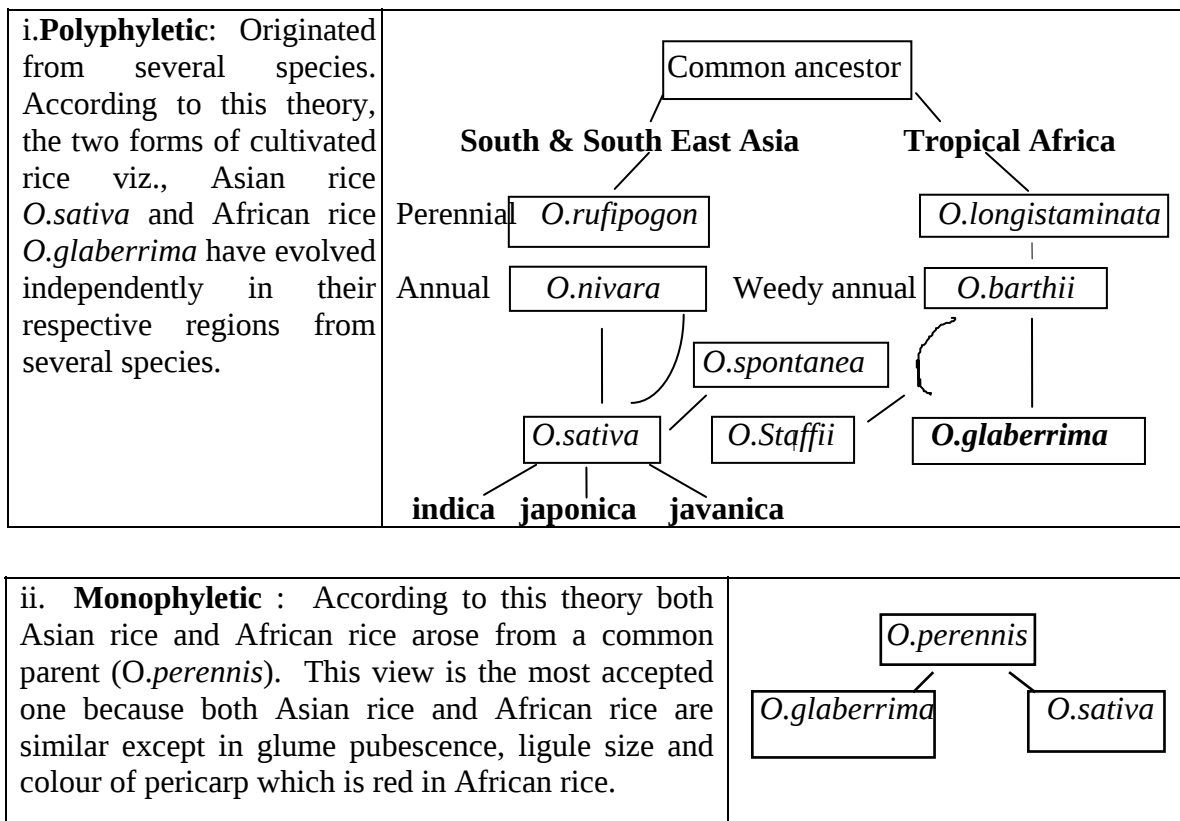
The three races in cultivated Asian rice are

- i) indica
- ii) Japonica (Sinica)
- iii) Javanica.

Origin of cultivated rice.

The views regarding the origin of rice can be grouped in to two classes viz.,

- a) Polyphyletic origin
- b) Monophyletic origin.



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
<i>O.sativa</i>	24	AA	Asia
<i>O.nivara</i>	24	AA	Asia
<i>O.meridionalis</i>	24	-	Australia
<i>O.longistaminata</i>	24	AA	Africa
<i>O.rufipogan</i>	24	AA	Asia
<i>O.glumaepatula</i>	24	-	America
<i>O. grandiglumis</i>	48	CCDD	America
<i>O.glaberrima</i>	24	AA	Africa
<i>O.barthii</i>	24	AA	Africa
<i>O.australiensis</i>	24	EE	Australia
<i>O.latifolia</i>	48	CCDD	America
<i>O.alata</i>	48	CCDD	America
<i>O.eichingeri</i>	24	CC	Africa
	48	BBCC	
<i>O.minuta</i>	48	BBCC	Asia
<i>O.punctata</i>	48	BBCC	Asia
<i>O.officinalis</i>	24	CC	Asia
<i>O.granulata</i>	24	-	Asia
<i>O.meyeriane</i>	24	-	Asia
<i>O.ridleyi</i>	48	-	Asian
<i>O.longiglumis</i>	48	-	New Guinea
<i>O.brachantha</i>	24	FF	Africa
<i>O.schlechter</i>	-	-	New Guinea

RICE

Related species of rice and their contributing characters in rice improvement.

Species	Genome	Useful traits
<i>O.alata</i>	CCDD	High biomass production
<i>O.australiensis</i>	EE	Drought tolerance, BPH resistance
<i>O.barthii</i>	AA	Drought avoidance, BLB resistance
<i>O.brachyantha</i>	FF	Yellow stem borer and leaf folder resistance
<i>O.eichengeri</i>	CC	BPH, GLH, WBPH resistance
<i>O.grandi glumis</i>	CCDD	High biomass production
<i>O.granulata</i>	unknown	Shade tolerance, adaptation to acrobic soils
<i>O.latifolia</i>	CCDD	High biomass production
<i>O.longistaminata</i>	AA	Drought tolerance
<i>O.meridionalis</i>	AA	Elongationability
<i>O.meyeriana</i>	Unknown	Shade tolerance, adaptation to aerobic soils
<i>O.minuta</i>	BBCC	BPH, GLH, WBPH, BLB and blast resistance
<i>O.nivara</i>	AA	Grassy stunt virus resistance
<i>O.officinatis</i>	CC,BB,CC	BPH, GLH, WBPH resistance BPH resistance
<i>O.prnetate</i>	BB, BBCC	BPH resistance
<i>O.ridleyi</i>	unknown	Shade tolerance, stemborer, blast and BLB resistance
<i>O.rufipogon</i>	AA	Source of CMS

Wild Species: There are twenty valid species in the genus *Oryza* of these two are cultivated i.e.

Oryza sativa

Oryza glaberrima

In the remaining 18 species nine are diploid ones.

Six - tetraploid ones

Two - mixed diploid

One - chromosome number not reported.

Some of the wild species utilised in breeding programme are

Oryza perennis - Co 31 GEB 24 x *O. perennis*

Oryza nivara - IR 34 One of the parents is *O. nivara* resistant to grassy stunt disease.

BREEDING OBJECTIVES

1. High yield potential
2. Adaptability and stability of yield
3. Early maturity.
4. Resistance to lodging and shattering
5. Resistant to cold temperature.
6. Resistant to salinity and alkalinity
7. Resistant to diseases.
8. Resistant to pests
9. Improved grain quality
 - a) Grain shape and size
 - b) Texture of Endosperm and quality of starch in Endosperm
 - c) Aroma & Cooking quality
 - d) Colour of kernel
 - f) Milling out turn
10. Breeding for alternate source of dwarfing gene.
11. Breeding varieties suited for direct seeding
12. Breeding varieties for dry lands
13. Breeding varieties for deep water conditions
14. Breeding varieties for export - scented rice
15. Breeding varieties to control wild rice
16. Breeding varieties to suit any other local conditions.

1. High yield potential

Grain yield of rice is a complex character. It is influenced by many morphological traits and physiological process. These along with interaction of environment decide the yield potential. It is necessary to assemble in the rice variety a desirable combination of genes for those plant characteristics, that will enable the rice plant to give higher yields.

To get higher yield we must have an ideal plant type. The ideal plant type is

- Short stature.
- Thick, Stiff culm
- Compact panicle that hold the plant erect.
- Short, narrow, erect leaves to effectively utilise solar radiation.
- high tillering

- Non / low photo sensitivity
- Nitrogen responsive
- Flag leaf angle should not be more than 40°.

2. Adaptability and stability of yield :

Wide adaptability across locations is desired since rice is grown over a large variety of agroclimatic zones which are varying. IRR1 varieties are having wide adaptability. Characteristics associated with wider adaptability are

- low sensitivity to temperature variations.
- low sensitivity to changes in light intensity.
- Resistant to wide spectrum of pests and diseases.

Across seasons refers to the consistency with which a variety produces satisfactory yield in an area where biotic and abiotic conditions may vary every season of a year. Tolerance to local fluctuations in biotic and abiotic stress is important.

3. Early maturity:

This character is desired to have multiple cropping. It is also helpful to overcome terminal drought and to escape from pest and diseases.

In rice the optimum early maturity will be around 105 days. When the duration is reduced still further, the yield is also reduced correspondingly.

CR 666, Akashi, Co 41 are varieties having less than 100 days duration.

4. Resistant to lodging and shattering.

This is also a complex character. Non lodging lines will have

- Short stature
- Thick strong culm
- Short internode
- Leaf sheath tightly encircling the culm.

Grain shattering is also a complex character. Wild rices are having this character. So while using wild rice as parents this should not be linked with desirable trait which is to be transmitted.

5. Resistance to cold temperature

More suited to cumbum valley and Gudalur taluk of Nilgiris. Japonica rice varieties are more cold tolerant

MDU 2 cold tolerant (Co 25 x IR 8)

6. Resistant to salinity and alkalinity :

Parts of Trichy and Dharmapuri districts of Tamil Nadu face this problem.

Old varieties : SR 26 B, Gettu, Dasal.

Latest Co 43 (Dasal x IR 20), ADT 35, TRY 1, TRY 2

7. Resistant to Diseases:

Blast, Helminthosporium, bacterial leaf blight, Tungro virus are some of the important diseases . Blast resistant varieties :

- IR 20, Medium duration
- Co 37 - short duration
- Co 25 - Long duration

Grassy stunt : *O. nivara*.
 Blast and BLB : *O. minuta* tetraploid.
 resistant Co 45 - resistant to RTV, Blast and BLB.
 PY 3 - RTV, BLB

8. Resistant to pests:

Brown plant hopper, Stem borer, Rice gall midge are important pests.

Stem borer donor : TKM 6

IR 20, (IR 262 x TKM 6)

PY 3 - Bharathidasan - Resistant to BPH

O.officinalis BPH Resistant

9. Improved grain quality

a) Grain shape size and texture

Rice cultivars can be classified based on the size, shape and texture of the grain.

According to FAO the trade grades are

Length :

Extra long	-	over 7 mm length
Long	-	6 to 7 mm
Medium	-	5 to 5.99 mm
Short	-	below 5mm.

Shape :

Based on Length / Breadth ratio.(L/B ratio).

Basmati, Ponni, Slender - over 3 L/B

IR 20 Medium - 2.0 to 3.0 L/B

Co 37 Bold - 2.0 to 2.39 L/B

Texture :

Two main types are recognised

1. Hard starchy grain with (translucent) vitreous fracture
2. Soft dextrinous grain with opaque fracture. Known as glutinous rice.

Hard starchy types are the major one consumed. They differ in their translucency, hardness and presence or absence of abdominal white depending on starch content. They remain dry and flaky when cooked. Soft dextrinous grain become sticky and clot on cooking and usually used for special dishes (puttu rice). These types are preferred by people using chop sticks for eating.

b) Aroma and Cooking quality:

Some varieties give aroma when it is cooked. Varieties like Basmati scented rice there will be elongation in the cooked rice also. The aroma is due to certain chemicals present in endosperm. An alkaloid PANDAMARILACTONE is the cause of fragrance. This alkaloid is present in the leaves of Pandanus also.

E.g. Basmati 370

Zeeraga Samba

ADT41

Kalabath
Seetha bogam

The cooking quality vary with the variety and grain type. Long grain varieties remain dry and flaky when cooked, while medium and short grain varieties are sticky and chewy. Preference for a particular variety differs with use. In evaluating rice varieties cooking tests are conducted for

- a) amylose content,
- b) Water absorption properties
- c) gelatinisation test.
- d) grain elongation ratio
- e) protein content
- f) par boiling quality
- g) milling out turn.

c) Nutritive value :

Protein in brown rice is about 8% while in polished rice it is about 7% Inheritance of protein content is complex. It depends on environment and nitrogen application. When protein content is increased there will be lowering of lysine content.

d) Colour of kernel :

The preference for particular kernel colour varies with region to region. In Kanyakumari and Kerala red rice is preferred. Depending on local needs the varieties are to be evolved.

TKM 9 - Red rice, (TKM 7 x IR 8)

e) Milling out turn

The unhusked rice grain is known as Rough rice or paddy. The miller converts it to brown rice by scouring off the outer bran layer. The value of rough rice depends largely on its milling quality which is determined by head rice and total rice that is obtained from rough rice.

Head rice : Whole grain and large broken pieces.

Total rice : includes all rice recovered after milling.

10. Breeding for alternate source of dwarfing gene

All the present day cultivars are result of breeding with dwarfing gene Dee - Gee - Woo - Gen there is danger in using the same source. If Dee - Gee - Woo - Gen becomes susceptible to a new pest or disease, the whole programme will collapse. So it is necessary to seek alternate sources of dwarfing gene. Efforts are underway to identify alternate source thro' conventional and non - conventional breeding techniques.

11. Breeding varieties suited for direct sown conditions.

This again a location specific problem. In cauvery delta region getting cauvery water becomes an uncertainty these days. To minimize water requirement direct sowing

of rice is recommended. The varieties for direct seeding must be quick growing and suppress weed growth.

12. Varieties suited for dry land conditions

In certain parts of Ramnad and Chengalpet rice is grown as dryland crop. Local land races like kurivikalayan and putturu rice are grown. To suit these needs varieties are to be evolved.

13. Deep water paddy:

Areas in tail end parts of cauvery delta need deep water paddy. It is again a location specific problem

TNR 1 and TNR 2.

14. Varieties suited for export

The scented rice Basmati 370 is exported to Arab countries. The limitation in this programme is Basmati 370 grown in all areas cannot be exported. The importing countries prefer the Basmati Rice grown in valleys of Himalayan Range only. The rice grown in those areas alone pass the chemical test. This must be due to effect of environment. Efforts are underway to identify export quality scented varieties grown in other parts of the country.

15. To breed varieties to control wild rice:

This again a location specific problem.. In states of Bihar, Maharashtra, Madhya Pradesh and Punjab the wild rice *O. sativa* var. *fatua* is often creating problems. So it is necessary to have marker genes in cultivated rice to isolate them from wild ones. Purple colour stem is a marker.

16. Breeding varieties to suit any other local problems.

E.g. - to identify varieties to cultivate in areas of turmeric cultivation where a short duration 70 days rice variety can be fit in between two turmeric crops

Satari - short duration (70 days).

RICE VARIETIES RELEASED USING DIFFERENT BREEDING TECHNIQUES

1. Introduction :

All the IRRI Rice varieties from IR 8 to IR 72. Other Examples are Basmati from Punjab, Ponni (mashuri) from Malaysia, CR 1009 (Ponmani) from Orissa.

2. Pure line selection :

Co 9. Short duration

Co 32. Thiruchengodu Samba - Medium duration

Co 19. Chengalpattu Sirumani - Long duration

3. Hybridization and Selection :

a) Pedigree method

i) Inter varietal:

Co 37 Vaigai TN 1 x Co 29 - Short duration.

Co 41 CuL 2410 x IR 22 - Short duration

Co 43 Dasal x IR 20 - Medium duration.

Co 44 ASD 5 x IR 20 - Medium duration, suitable for late planting.

Co 45 Rathu Heenathi x IR 3403 - 207 - 1 - Medium duration, Resistant to blast, BLB and RTV.

Ponmani (CR 1009) Pankaj x Jagannath - Long duration.

ii) Inter-racial

Japonica x indica cross ADT 27 (Norin 10 x GEB 24)

Ponni (Mashuri) (Taichung 65 x ME 80)

iii) Inter specific crosses

Co 31 (*O.perennis* x GEB 24) Drought resistance.

IR 34 Complex cross, one of the parent is *O.nivara*

b) Back Cross Method of breeding

Co 37 male sterile line.

Sabarmati and Jamuna.

4. Mutation breeding :

a) Spontaneous mutation

GEB 24 - From Athur Kichili Samba known as KONAMANI, fine grain and quality rice.

ADT 41 - Dwarf mutant of Basmati 370.

b) Induced mutation :

Jagannath rice from Orissa. Semi dwarf.

Parbhani - from Maharastra

Prabavathi -

Satari - Short duration, gamma irradiated

AU 1 - from Tamil Nadu.

5. Heterosis breeding

CORH 1 IR 62829 A / IR 10198 - 66-2 R

CORH 2 IR 58025 A / C 20 R

ADT RH 1 IR 58025 A / IR 66 R

IMPORTANT RICE VARIETIES SUITABLE FOR TAMIL NADU

Short duration

Name	Parentage	Duration (Days)
TKM 9	TKM 7 x IR 8	105
Co 37 (Vaigai)	TN 1 x Co 29	115
ADT 36	Triveni x IR 20	110
IET 1444	TN 1 x Co 29	115
PY 2	Kannagi x cu 12032	115
IR 50	IR 21153-14 x IR 28 Y	110
IR 36	Multiple cross derivative	120
TPS 1	IR 8 x Katti Samba.	115
PMK 1	Co25 x ADT 31	115
ASD 16	ADT 31 x Co 39	115
ASD 17	Multiple cross derivative	110
ADT 37	BG 280 - 1-2 x PTB 33	105
IR 64	Multiple cross derivative	115
ASD 18	ADT 31 x IR 50	110
ADT 41	Dwarf mutant of Basmati	115
ADT 39	IR 8 x IR 20	125
ADT 20	IR 18348 x R 25869 x IR 58	110
ADT 43	IR 60 x White Ponni	110
TKM-11	C 22 x BJ 1	120
Co 47	IR 50 x Co 43	110-115

Medium duration.

IR 20	IR 262 x TKM 6	135
Bhavani	Peta x BPI 76	135
Paiyur - 1	IR 1721 - 14 x IR 1330 - 33 - 2	150
Co 43	Dasal x IR 20	135
Co 44	ASD 5 x IR 20	135
Ponni, White Ponni	Taichung 65 x ME 80	140

MDU 2	Co 25 x IR 8	135
ADT 38	Multiple cross derivative	135
ADT 40	RPW 6.13 x Sona	145
Co 45	Rathu Heenathi x IR 3403 - 261 - 1	140
TKM 10	Co31 x C 22	135
TPS 3	RP 31-492 x LMN	140
PY 6 (Jawahar)	IR 8 x H4	135
Co 46	T 7 x IR 20	125
Long duration :		
Ponmani		
(CR 1009, Savithri)	Pankaj x Jagannath.	155-160
ADT44	Selection from OR 1128-7-S1	145-150
Rice Hybrids		
CoRH 1	IR 62829 A / IR 10198-62-2-R	
CoRH 2	IR 58025 A / C 20 R	
ADTRH 1	IR58025A / IR 66 R	

HYBRID RICE

The utilization of the dwarfing gene (d1) from the mutant variety Dee-Gee-Woo-Gen (DGWG) discovered in Taiwan in 1960s led to the development of Semidwarf, high tillering, nitrogen responsive, high yielding varieties of rice throughout the world. Consequently the yield level of rice in the tropics raised even 8-10 t/ha. Close observation of the yield performance of HYVS had revealed that the realised yield in such varieties are showing a plateauing trend (De Datta, 1990; Pingali *et al*; 1990). Among the various strategies proposed to break the yield plateau in rice productivity, exploitation of heterosis through the development of rice hybrids had been proved to be successful.

Heterosis in rice was reported by Jones in USA as early in 1926 and Ramaiah in 1933. But the research work on hybrid rice was initiated in 1964, in China by Yuan Long Ping (Father of hybrid Rice). The identification of 'Wild Abortive' or 'WA' type cytoplasmic male sterility in 1970 was a breakthrough in hybrid rice breeding. In 1971 China accepted Hybrid Rice Research as a national cooperative project and in the year 1976, hybrid rice became a reality in China, for the first time in world, by the release of commercial rice hybrids suited for sub-tropical and temperate zones. Since then many of the rice growing countries had accepted the strategical approach of exploitation of heterosis through the development of commercial rice hybrids. And as such rice hybrids were released in countries like Vietnam (for subtropical zone), Korea (for temperate zone); besides these countries, research on hybrid rice is progressing in countries like Philippines, Indonesia, Malaysia, Thailand, United States, Egypt, Colombia and Brazil.

Although research on the commercial utilization of heterosis in rice has made tremendous gains during the last 20 years, it is still in its infancy stage because the high yield potential of hybrid rice has not been fully tapped yet. And hence various approaches are adopted in major rice growing countries of the world to maximize the yield potential advancements of hybrid rice production.

Breeding techniques for developing hybrid rice involve the following:

a) Three-line method or CGMS system

This system now a days known as CMS system, involving three lines viz- cytoplasmic, genic male sterile line (A), maintainer line (B) and restorer line (R) is the most commonly used method in China and outside. Until 1985, more than 95% of the CMS lines used in the commercial indica rice hybrids, were of CMS-WA type which make the hybrid rice vulnerable to biotic and abiotic stresses. And hence attempts to identify new sources of male sterile cytoplasm led to the identification of CMS system like GA (Gambiaca), Di (Disi), DA (Dwarf wild rice), BTC (Chinsurah Boro II) and IP (Ido Paddy 6). Mechanism of male sterility maintenance and hybrid seed production in three-line system given in figure-1.

Many years experience had undoubtedly proved that the CGMS system involving sporophytic and gametophytic male sterility is an effective way of developing hybrid rices and will continue to play an important role in the next decade. However there are some constraints and problems in such a system. The most serious is that yields of existing hybrid rice varieties including newly developed ones, have stagnated (Yuan, 1994). They have already reached their yield plateau, and are unable to increase the yield

potential through this approach and hence new methods and materials were adopted. In this regard two-line hybrids are promising ones, to raise the yield ceiling in hybrid rice.

b) Two-line method of rice breeding

Two-line hybrids can be evolved through

- Mechanical means
- Application of gametocides
- Use of cytoplasmic male sterility (CMS)
- Use of genic male sterility (GMS)
- Use of environmentally induced genic male sterility (EGMS)

In rice EGMS system is commonly used. In EGMS systems two kinds of rice lines are made use of viz. PGMS (Photosensitive Genic Male Sterility) and TGMS (Thermosensitive Genic Male Sterility) which had been developed successfully in China. In this system male sterility is mainly controlled by one or two pairs of recessive nuclear genes and has no relation to cytoplasm. Developing hybrid rice varieties with these system has the following advantages over the classical CMS system, as given below.

- Maintainer lines are not needed.
- The choice of parents for developing heterotic hybrids is greatly broadened.
- No negative effect due to sterile cytoplasm
- Unitary cytoplasm situation of WA will be avoided.

In this system the exploitation of heterosis can be achieved by developing intervarietal and intersubspecific F_1 hybrids. In 1991, China had released hybrid combinations using this approach, and some of these combinations out yielded the best existing hybrids by 10-20% (Yuan, *et al*; 1994)

Detailed studies about physiological and ecological requirements of EGMS lines had been made in China and Japan. Work is progressing in India and International Rice Research Institute, in Philippines to identify best suited rice hybrids through this approach, for commercial exploitation. TGMS system is considered useful in tropical and subtropical regions where as PGMS system is useful in temperate regions.

Other possible approaches to develop two-line hybrid breeding system includes identification of a genic male sterility system which would revert to male fertility response to application of growth regulators and also the chemical induction of male sterility.

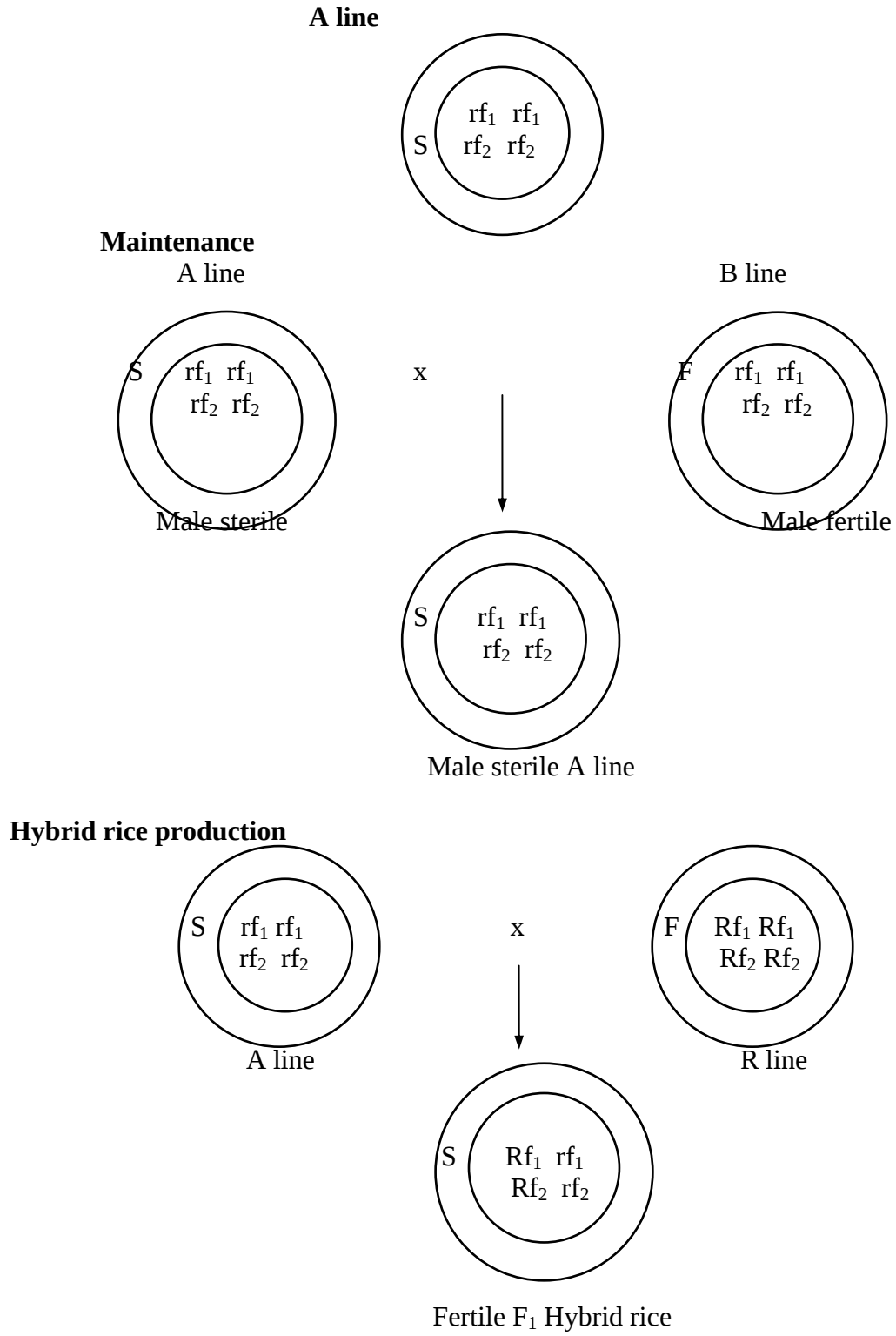
c) One-line method of rice breeding

Rice hybrids can be developed and popularised through the following concepts

- Vegetative propagation
- Micro propagation
- Anther culture hybrids
- Apomictic lines

Among the above for large scale cultivation, apomictic lines and anther cultured materials will be economical.

CGMS SYSTEM IN RICE



Hybrid rice breeding in Tamil Nadu :

Hybrid rice research in Tamil Nadu was started as early as in 1979 at Paddy Breeding Station, Coimbatore before the Chinese achievements were known to others. The first male sterile line identified from a cross between CO 40 / Jeeraga Samba was of Genetic male sterile line which was maintained upto 1984 through stubble planting until Chinese and IRRI, male sterile lines were introduced. New Cytoplasmic Genic Male Sterile Lines were introduced to India as intensification of hybrid rice research at IRRI and its NARS, IRRI took leadership in introducing the CGMS lines such as V20A, V41A, ZS97A, Er-jiu-Nan 1A and Yar-ai-Zhao 2A from Hunan Hybrid Rice Research Centre, China and IRRI developed lines such as IR 46827 A, IR 46828 A, IR 46839 A, IR 46831A and 48483 A. Of these introduced lines Chinese lines were found not suitable and IRRI lines remained unstable for their sterility in Tamil Nadu. However, intensive research on hybrid rice was started during 1989 by ICAR with financial help of UNDP and FAO. This ICAR/ UNDP/FAO collaboration led to the establishment of a network for hybrid rice research among the 10 leading rice research centres of India. Paddy Breeding Station, Tamil Nadu Agricultural University is one among them. Intensification of hybrid rice research in TNAU resulted in the identification of a superior hybrid combination of IR 62829 A / IR 10198-66-2R named as TNRH 1. This hybrid has a duration of 115 days and out yields all the ruling short duration varieties. The variety release committee of TNAU recommended this hybrid for general cultivation in November 1993 and Tamil Nadu State Variety Release Committee endorsed the recommendation by releasing it as CORH 1 January 1994 and named it as MGR. TNAU has released three hybrids.

Future strategies :

Wide hybridization : Wide hybridization work in rice started as early as in 1934 to incorporate agronomically important genes available in wild species to cultivated varieties. A variety CO 31 was developed by crossing GEB 24 and *O.perennis*. Though there was a slow down in this approach during mid period between 1940 and 1996, the work on wide hybridization has been intensified with financial support from Department of Biotechnology. The major objective of this programme is to produce male sterile lines with diverse cytoplasmic bases and derivatives with good restoration capacity.

Tissue Culture : Work on rice tissue culture was initiated in 1978 with a major objective of synthesizing dihaploids through anther culture. The programme was successful and resulted in a promising culture from a cross combination of IR 50/ARC 6650. Attempts were made to find out the genotypic responses to tissue culture using wild species of rice and cultivated varieties. In vitro screening for salt tolerance was carried out. Most of these studies were carried out by the post graduate students of this Directorate. A dihaploid line from TNRH 10 rice hybrid is in the evaluation stage. The work is being further strengthened at the Centre for Plant Breeding and Genetics.

Two line breeding for hybrid rice : For synthesizing rice hybrids, attempts to use temperature sensitive genetic male sterility (TGMS) and photoperiod sensitive genetic male sterility (PGMS) are made. To exploit this potential, a separate Hybrid Rice

Research Station has been established with financial support of Tamil Nadu Agricultural Development Programme (TNADP) at Gudalur in Nilgiris along with Coimbatore main centre. Hybrid rice research for salt affected areas of Tamil Nadu has also been programmed and Indian Council of Agricultural Research has already sanctioned a scheme on this line and work is in progress at Agricultural College and Research Institute, Trichy.

Exploring apomixis : Apomixis is an alternative to dihaploids being explored to fix the heterosis in rice. Serious attempts are being made at IRRI. Our maiden attempt in this line helped us to develop protocols and establish our scientists and post graduate students to work in this new area of rice research. Besides this, attempts are being made to exploit potential of cytological techniques and molecular approaches to understand the phenomenon of apomixis.

Molecular marker analysis : Molecular marker analysis is a new and useful tool for the rice breeders. The construction of molecular marker map of rice paved the way for mapping the rice genes to specific locations of rice chromosomes. A marker aided selection laboratory established at present will be utilized for mapping the genes controlling resistance to WBPH, BPH, quality traits and TGMS. A programme to map the favourable Quantitative Trait Loci (QTLs) available in wild species responsible for yield and their components and transfer them to cultivated varieties is in progress. Finger printing of rice varieties will be another area of interest to catalogue all the accessions of rice, considering the wealth of germplasm available at Paddy Breeding Station, Coimbatore.

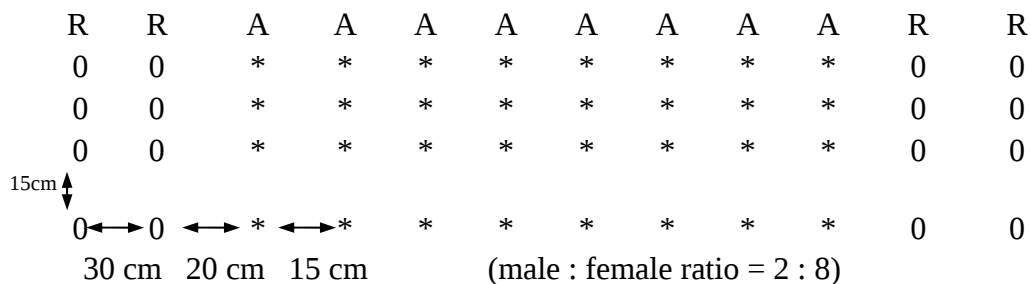
Hybrid Rice Seed Production

Hybrid vigour in rice has been first reported by Jones (1926). This has led to speculation regarding the production of hybrid rice by utilising cytoplasmic male sterility. Most japonica rice has normal cytoplasm, but indica varieties with sterile cytoplasm and fertility restoring system have been identified. But difficulties have been encountered in obtaining sufficient seed set by cross pollination to make hybrid rice seed production economically feasible. After the implementation of UNDP/FAO project entitled "Development and use of hybrid rice technology in India" - the hybrid rice production in India has become a success story.

Hybrid rice seeds were produced using (cytoplasmic genic male sterility) three line system. The two genes Rf_1 and Rf_2 are the genes for fertility restoration.

The process of hybrid rice production involves continuous supply of agronomically improved cytoplasmic male sterile line (A), maintainer line (B) and fertility restorer (R) line in system. Maintainer and restorer lines are maintained by selfing, while CMS line and F_1 seeds are produced with efforts to enhance cross pollination in field. F and S refer to fertile and sterile cytoplasm. Rf and rf are fertility restoring and non restoring gene respectively.

Row ratio and spacing of A and R lines in the main field



Technique of hybrid rice seed production

The following points are to be taken in to account for a successful hybrid rice production.

- 1) **Choice of field** : Fertile soil, protected irrigation and drainage system, sufficient sunshine. No serious disease and insect problem.
- 2) **Isolation** : To ensure purity of hybrid seed and avoid pollination by unwanted pollen isolation is a must.
 - a) Space isolation : No other rice varieties should be grown except pollen parent with a range of 100m distance.
 - b) Time isolation : a time of over 20 days is practiced (The heading stage of other variety over a 100m range should be 20 days earlier or later over the MS line).
 - c) Barrier isolators : Topographic features like wood lot, tall crops to a distance of 30m/artificial obstacles of (plastic sheet) above 2m height.

3) Optimum time for heading and flowering

Favourable climatic condition for normal flowering are

- (i) Mean temperature 24-28°C
- (ii) Relative humidity 70-80%
- (iii) Day and night temperature difference 8-10°C.
- (iv) Sufficient sunshine
- (v) Sufficient breeze.

4) Synchronization of flowering

As the seed set on MS line depends on cross pollination it is most important to synchronize the heading date of the male and female parents. In addition, in order to extend the pollen supply time, the male parent is usually seeded twice or thrice at an interval of 5-7 days.

5) Row ratio, row direction and planting pattern

Row ratio refers to the ratio of number of rows of the male parent to that of the female parent in the hybrid seed production field. The layout of row ratio depends on

- (i) The growth duration of the R line
- (ii) Growth vigor of the R line
- (iii) Amount of pollen shed and
- (iv) Plant height of the R line.

The principles include

- * R line should have enough pollen to provide
- * the row direction should be nearly perpendicular to the direction of winds prevailing at heading stage to facilitate cross pollination.

Practically, a row ratio of 2:8 is currently widely used in indica hybrid seed production.

Generally, the R line is transplanted with two to three seedlings per hill and separated by a spacing of 15cm from plant to plant, 30cm from one row of restorer to another and 20cm from CMS line. The MS line is transplanted with one to two seedlings per hill with a spacing of 15x15 cm.

A good population structure to get more seed yield is given below :

a) Seedling/hill b) Hills/sq.m c) effective tillers/sq.m

A line = 1-2 A line = 30 A line = 300

R line = 2-3 R line = 5 R line = 120

6) Prediction and adjustment of heading date

Even if the seeding interval between both parents is accurately determined, the synchronization of their flowering might not still be attained because of variation in temperature and difference in field management. Hence it is necessary to predict their heading date in order to take measures as early as possible to make necessary adjustments by examining the primordial initiation of panicle.

Adjustment of flowering date can be made by applying quick releasing nitrogen fertilizer on the earlier developing parent and the later developing parent should be sprayed with 2% solution DAP. By this measure a difference of 4 to 5 days may be adjusted.

7) Leaf clipping, gibberellin application and supplementary pollination

These techniques are very effective for increasing the outcrossing rate.

a) Leaf clipping : The leaves taller than the panicles are the main obstacles to cross pollination and, therefore, should be cut back. Generally leaf clipping is undertaken 1-2 days before the initial heading stage, and more than 2/3 rd of the blades of flag leaves are cut back from the top.

b) Application of gibberellin (GA₃) GA₃ can adjust physiological and biochemical metabolism of rice plant and helps in hybrid seed production by stimulating the elongation of young cells. In most of the CMS lines, about 20-30% of spikelets of a panicle are inside the flag leaf sheath (exsertion is only 70%). GA₃ affects exsertion of panicle completely out of flag leaf sheath. In India recommended dose of GA₃ is 50g/ha using knapsack sprayer and 25g/ha with ultra low volume sprayer.

Advantage of GA₃ application

- * enhances panicle and stigma exsertion
- * speed up growth of late tillers and increase effective tillers
- * flag leaf angle is increased
- * reduces unfilled grains
- * enhances seed setting and seed yield

Spraying stage : 5% of panicle emergence

Spraying time : 8-10AM is the best time.

c) Supplementary pollination : Shaking the R lines panicles by rope-pulling or rod driving during anthesis can enhance the crossing rate. This is carried out during peak anthesis (10-12 AM).

8) Rogueing

To get 98% purity of CMS lines and R lines, in addition to strict isolation, a thorough rogueing is also necessary.

9) Harvesting and processing

- the male parent harvested first
- care should be taken to avoid admixture of male and female lines.
- female line should be threshed separately in a well cleaned threshing floor
- seed field dried in shade to 12% moisture content
- packed in suitable, cleaned gunny bags after grading

Hybrid Rice CORH - 1 (MGR Rice) : Released in 1994

Short duration, medium fine grain (Parentage : IR 62829A x IR10198-66-2R)

Breeding method : Three line Breeding

Season : May-June (Kar-Kuruvai)

Duration : 110-115 days

Yield : 6380 kg/ha

Area of adaptation : Coimbatore, Madurai, Chengalput, Salem, Nagapattinam, Periyar Districts.

SEED PRODUCTION TECHNIQUES FOR CORH 2 HYBRID RICE

Parentage : IR 58025 A x C 20 R

Selection of Field :

Previous crop should not be of rice. If previous crop is rice, irrigate the field and there by the dropped seeds will germinate which can be puddled in. If the pervious crop is having dormancy means, we must be careful to see that the dropped seeds are all germinated and puddled in.

Isolation distance :

100 meters. If time isolation is to be followed, there should not be any rice crop near by within 100 meters, in the process of flowering while the crop in seed production plot is in flowering. There must be a difference of 30 days in flowering for the near by crop.

Season : April - May and Dec - January month of sowing.

Seed rate : A line : 20 kg / ha
R line : 10 kg / ha.

Nursery :

Apply 2kg DAP to the nursery. Adopt 1kg / cent of nursery for both A line and R line while raising the R line 5 kg seeds can be raised on the same date when A line is raised. The rest 5 kg can be sown five days after first sowing.

Manuring of main field : 10 tonne FYM / ha

	N	P	K
Basal dressing	50 kg/ha	60kg/ha	20kg/ha
Tillering stage	50kg/ha	-	20kg/ha
Boot leaf stage	50kg/ha	-	20kg/ha

Planting date : A line - 25 - 30 days after sowing
R line - 20-25 days after sowing

Planting Ratio : 8 rows of A line
2 rows of R line

Spacing : A line : 10cm between rows
15 cm within rows
Single seedling / hill
B line : 30 cm between rows
15 cm within rows.
Two seedlings / hill.

The space between A line and R line is 20 cm

Plant protection :

Follow the plant protection measures advised for rice. Avoid spraying or dusting during anthesis and pollination i.e. early morning period.

Rogueing and removal of pollen shedders :

From the beginning rogueing is to be done in both A line and R line. Pollen shedders are to be removed along with tillers. In A line seed set may not exceed 40%. If plants having a setting of 70 to 80% means they are rogues and they have to be removed before harvest.

Special techniques :

- i. Pulling of ropes across the plot
- ii. Shaking the R lines with bamboo poles.

Harvest :

Harvest the R line first. Then harvest the hybrid. Thresh it properly dry it with 12% moisture and bag it.

WHEAT - *Triticum* sp. ($x=7$)
(Gothumai/ Kottampam/Gothi/Godi/Genhu)

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.

Chromosome number:

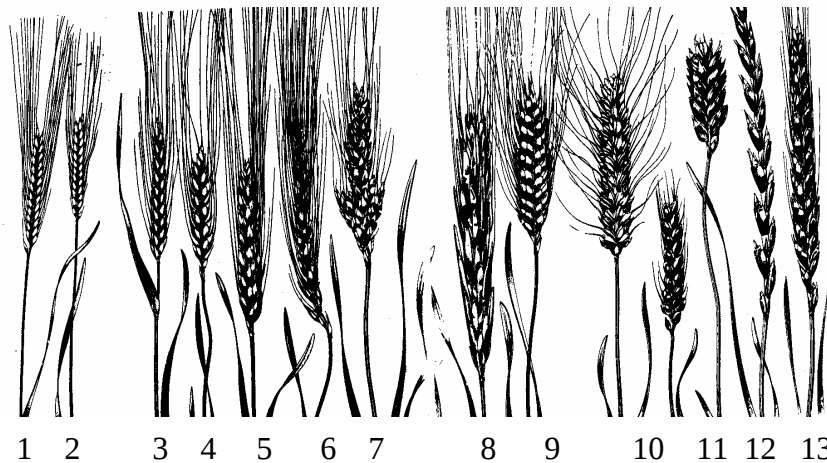
Diploid	:	$2n = 14$
Tetraploid	:	$2n = 28$
Hexaploid	:	$2n = 42$

Place of origin:

Diploid	:	Asia minor
Tetraploid	:	Abyssinia, North Africas
Hexaploid	:	Central Asia

Classification :

Ploidy level	Species	Common name	Genome
Diploid	<i>T.boeoticum</i> (<i>T.aegilopoides</i>)	Wild einkorn	AA
($2n=14$) 2 species	<i>T.monococum</i>	Einkorn	AA
	<i>T.dicoccoides</i>	Wild Emmer	AA BB
Tetraploid	<i>T.dicoccum</i>	Emmer	AA BB
($2n=28$) 7 species	<i>T.durum</i>	Macaroni wheat	AABB
	<i>T.persicum</i>	Persian wheat	AABB
	<i>T.turgidum</i>	Rivet wheat	AABB
	<i>T.polonicum</i>	Polish wheat	
	<i>T.timopheevi</i>	-	
Hexaploid	<i>T.aestivum</i>	Common or bread wheat	AABBDD
($2n= 42$) 5 species	<i>T.compactum</i>	Club wheat	AABBDD
	<i>T.sphaerococcum</i>	Dwarf wheat	AABBDD
	<i>T.spelta</i>	Spelt wheat	AABBDD
	<i>T.macha</i>	Macha wheat	AABBDD

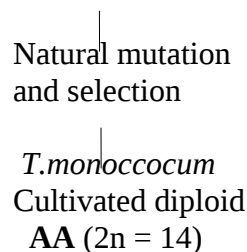


Fourteen species of wheat according to Vavilov (Fig.1):

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. compactum*
13. *T. spelta*
14. *T. macha.*

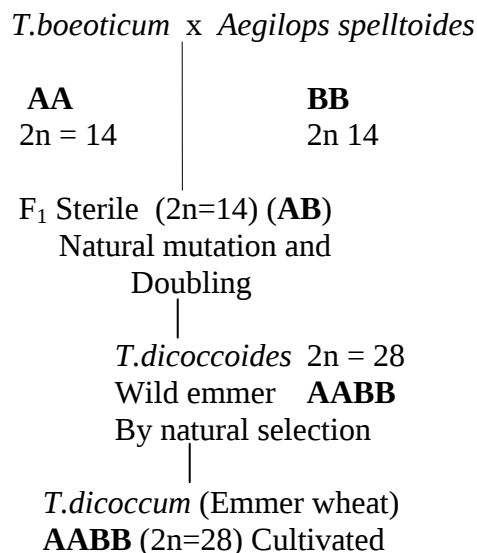
Origin of diploid wheat:

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

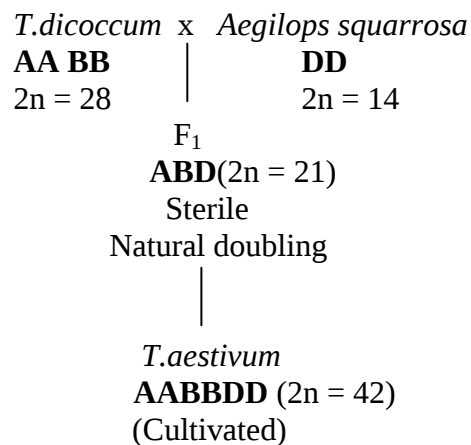


T. boeoticum is probably the ancestor for all the cultivated wheats:

Origin of Tetraploid wheats:



Origin of hexaploid wheats (Fig.2):

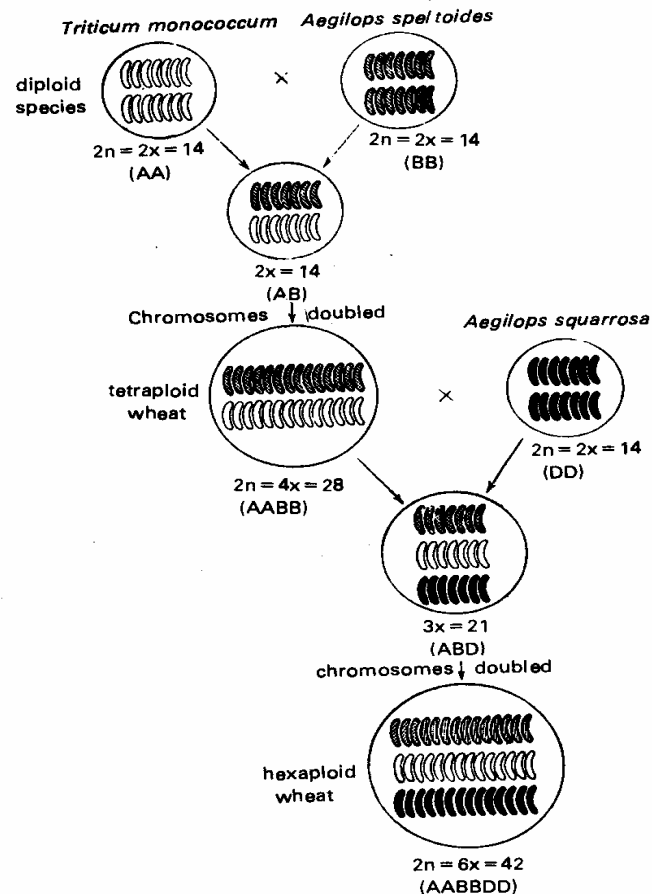


Related Species of *Triticum*:

1. *T. boeoticum*: forms with one to two seeded spikelets occur. The brittle ears shatter at maturity into individual spikelets armed with awns which provide an effective means of seed dispersal. 2. *T. monococcum*: Primitive diploid form domesticated, evolved from

T.boeoticum by mutation and selection.. 3.*Aegilops speltoides*: ($2n=14$;B genome). It is naturally cross-pollinating. It is the recognized donor of the B genome. 4.*T.dicoccoides*:It is an amphidiploid form resulting from the hybridization of *T.boeoticum* and *Ae. speltoides*. 5.*T.dicoccum*: The spikes are dense, bearded and laterally compressed, the spikelets are two grained and the grains are retained within the glumes after threshing (speltoid). It is the oldest of the cultivated wheat. 6.*T.durum*: Free thrashing wheat with naked grains, important of the tetraploid wheats. Grains contain high gluten. 7.*Ae. squarrosa*: ($2n=14$; D genome) It is the source of D genome in the cultivated hexaploid wheat, high adaptability. 8. *T.spelta*: Hexaploid species, considered an amphidiploid from hybridization between *T.dicoccoides* and *Ae.squarrosa*.

Fig.2. The evolution of hexaploid bread wheat from its wild relatives.



The most important of all the hexaploid wheat is the common bread wheat, *T.aestivum* grown in all parts of the tropics and sub tropics. This hexaploid wheat from which most modern wheats have been developed. It exhibits an extremely wide range of morphological and physiological variation and ecological adaptation.

Breeding objectives

1. High yield

High yield depends on

- a) The number of heads / unit area
- b) The number of grains / head.
- c) The average weight of grain

While breeding for high yielding varieties all the above three components must be looked into. Omitting any one of them may not yield results. Further while breeding for high yield it is necessary to combine into a variety a favourable combination of genes influencing all yield process.

2. Breeding non- lodging varieties:

This is achieved after the identification of dwarfing gene in Japanese variety Norin 10. Most of our dwarf wheats are two gene dwarfs. E.g. Sonara 63, sonara 64, kalyan sona. Emphasis is now on triple gene dwarfs.

3. Breeding for disease resistance

Rust is the major disease. Both stem rust and leaf rust are important ones. There are different races of rust. So while breeding for rust resistance horizontal resistance is to be looked into. Back cross method of breeding and development of multi lines are the methods.

4. Breeding for insect resistance

Hesisan fly is the major pest. Resistance in most varieties is thro' Antibiosis.

5. Breeding for quality.

Different wheat varieties vary greatly in their chemical composition which is considerably influenced by environment. The varieties of hard wheat or bread wheat which have higher gluten content. The soft wheat contain lesser gluten content which is suitable for cake making, pastries. The durum wheats are unsuited for either cakes or bread but they are suitable for making macaroni.

So depending upon the use the quality breeding objective is to be fixed.

Methods of breeding :

1. Introduction :

Semi dwarf wheat from Mexico, Sonara 63, Sonara 64, Mayo 64, Lerma Roja 64

2. Pure line selection :

Earlier varieties like P₄, P₆, P₁₂ evolved at pusa institute are result of pure line selection from local population.

3. Hybridisation and selection

a) Inter varietal:

A number of successful derivatives were developed at IARI New Delhi and Punjab.

NP 809 - New pusa multiple cross derivative.

However all these varieties were lodging and poor yielder when compared to other countries. Hence the wheat hybridization programme was changed by Dr. M.S. Swaminathan during 1963. **Borlaug** was invited to our country and he suggested for introduction of semi dwarf varieties from Mexico. As a result four commercial spring wheat varieties viz., Sonara 63, Sonara 64 Mayo 64 and Lerma Roja 64 were introduced. However they had red kernel hard wheats. These were utilised in our breeding programme and amber colour wheat varieties like Kalyan Sona, Safed Lerma, Sharbati Sonara were released, these are double gene dwarfs.

b) Inter specific crosses

To get Hessian fly resistance. So also for rust resistance.

c) Back cross method of breeding

Rust resistance in Chinese spring from Thatcher.

4. Hybrid wheat :

At Kansas Agri. Expt. Station USA male sterile lines were identified by crossing *T. timophevi* x *T. aestivum* Bison variety

By repeated back crossing a male sterile line resembling Bison was evolved. At present USA and Canada are doing work on this.

5. Mutation breeding

Dr. M. S. Swaminathan did extensive work on this with gamma rays.

Sharbati, Sonara with increased protein content was evolved.

6. Development of multilines

Borlaug developed multilines against rust. MLKS 15 was developed at IARI.

Multi line is a mixture of pure lines which are phenotypically similar but genotypically dissimilar. Each line is produced by separate back cross method of breeding. Each line having resistance against a particular race of a disease.

MAIZE

***Zea mays* (2n = 20)**

Place of origin : Mexico.

Origin of cultivated maize

The genus *Zea* was previously considered as monotypic. Later on *teosinte* has been included *Euchlaena mexicana* has been changed as *Zea mexicana*

Another wild relative is *Tripsacum* (gamma grass). All the three are inter crossable.

Three views about origin

1. From *Teosinte* it arose. *Teosinte* is having cob and tassel and easily crossable. This theory was not accepted based on cytological studies.
2. Maize arose from pod corn *Zea mays* var. *tunicata* thro' natural mutation. This view is the most accepted one. But origin of pod corn is not known.
3. All the three came from common ancestor but this common ancestor lost during evolution.

Ideal plant type in maize

- Plant with up right leaves which will increase photosynthesis.
- Extended grain filling period to have uniform well matured grains.
- Cob with increased row no. > 15.
- Multi cob plant

Breeding objectives :

1. Yield :

Complex character controlled by polygenes. Attention is to be paid to have ideal plant type. Varietal hybridization as a maize breeding method did not gain popularity. The main reason for this is difficulty in getting superior segregants.

2. Breeding for pest and disease resistance :

Shoot fly, Stem borer, *Heliothis* are major pests. Mexican varieties are resistant.

Downy mildews, leaf blight and *helminthosporium* are major diseases. Co1, CoH 2 are resistant. Taiwan lines are resistant to downy mildew.

3. Breeding for high protein :

Composed of two fractions. a) Protein in endosperm known as *Zein* which is nutritionally not balanced since it is lesser in lysine and tryptophan. 80% protein found in endosperm.

b) Protein in germ (embryo) 20% balanced one. By increasing the embryo size we can increase protein content.

4. Breeding for increased oil content.

12-15% in germ. By increasing the embryo size we can increase oil content.

5. Alternate sources of cytoplasm

CMS - T. susceptible to helminthosporium

C and S Resistant.

6. High yielding baby corn.

Z.m. var. *sachharata*, Sweet corn. The green cobs can be eaten as salad. The cobs can be harvested 45 days after sowing. CoBc 1 is latest variety of baby corn.

Breeding methods:

1. Introduction :

Initially the varieties were all introduced one.

Sikkim primitive 1

Sikkim primitive 2.

Mexican line were first introduced during 16th century by portuguese

2. Mass Selection : Prior to 1945 mass selection was the only method used for maize improvement.

KT 1 - U. P.

RAS 1 - Rajasthan.

By adopting mass selection technique it is possible to get yield increase by 19% per cycle.

3. Ear to Row Selection :

First proposed by Hopkins for improving oil and protein content of maize. This method involves selection of a number of phenotypically desirable ears out of a population grown in isolation. The selected cobs are harvested on single plant basis and keeping part of the seeds & remaining sown in rows. Based on the best performing rows during next season the reserve seeds are sown.

This method is suitable for characters having high heritability like oil content and protein content. But it was not helpful to get increased yield.

4.Modified Ear to Row method :

Proposed by Lonquist.

I. Best ear heads from population selected (100 No.) and harvested on single plant basis. And threshed individually.

II. The single heads harvested are raised in progeny rows in more than one location representing different environment with local checks.

III. In the main station the progeny rows are used as crossing block. Pollen from best plants are collected, mixed and used for crossing the rows.
Select best five plants from each rows and harvest them separately record the yield.
On the basis of performance of over all locations only top 20% progenies are selected. These 20% will include the five plants selected.

IV. The seeds from 5 plants selected are sown in progeny rows and cycle is repeated.

5. Hybridization and Selection

Not popular since isolation of superior recombinants was not made.

6. Heterosis breeding :

Instead of using CGMS lines, detasseling the female inbred line is followed in India. Since use of CGMS line is costlier compared to detasseling it is not followed.

Crossing the inbreds of indigenous x exotic origin resulted in release of best hybrids.

Indian x Indian - 24 to 43% yield increase.

Indian x U.S. dent 58 %

Indian dent x Caribbean Flint 47 to 54 %

1. Single cross hybrid - CoH 1, CoH 2.
2. Three way cross hybrids - Ganga -5
3. Double cross hybrids - CoH 3
4. Double top crop hybrid - White kernel hybrids - Ganga safed 2, Histarch, Ganga 4.

7. Population Improvement :

Recurrent selection technique was initiated by Dhawan in 1963. The initial synthesis of composites were done from high yielding inter varietal crosses which exhibited minimum inbreeding depression.

Kisan, Jawahar, Vikram, Sona, Vijay, Amber.

Co 1 K. 1

Future thrust

1. Development of broad based, genetically diverse gene pool of populations.
2. Evaluation of the performance of these base populations thro' recurrent selection procedure.
3. Development of superior inbreds.
4. Development of superior hybrids.

SORGHUM

Sorghum bicolor (2n = 20)

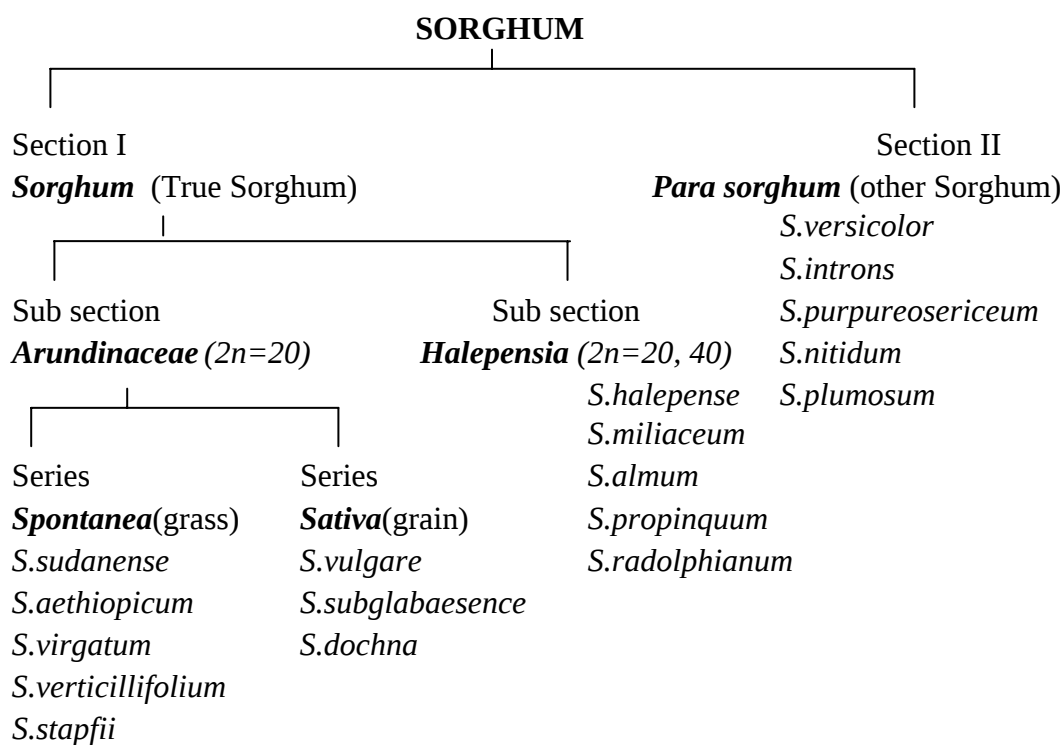
Origin : Africa

Progenitor of sorghum

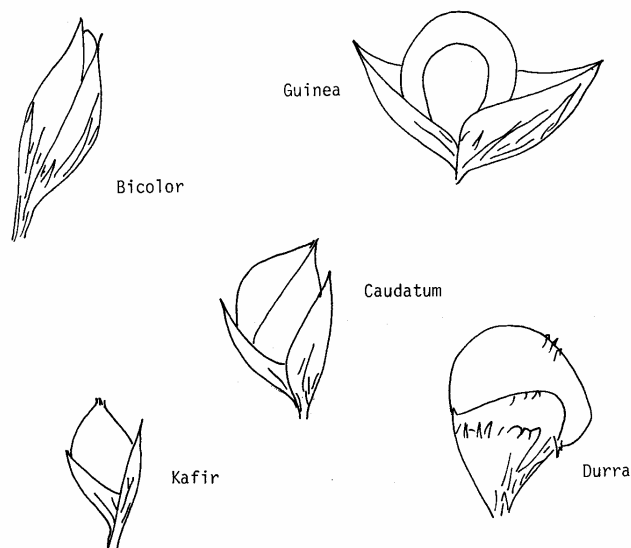
1. *S.arundinaceum*
2. *S.verticilliflorum*
3. *S.sudanense*
4. *S.aethiopicum*

Classification :

Right from 16th century there were number of classification for the genus sorghum. The famous among them is **Snowden's** classification (1936) later refined by Garber (1950) and by Dogget (1970).



The latest classification was done by **Harlan** and **De Wet** (1972).



1. *Bicolor* (B): Grain elongate, glumes clasp the grain which may be completely covered or $\frac{1}{4}$ exposed.
2. *Guinea* (G): Grains flattened dorso-ventrally.
3. *Caudatum* (C): grains asymmetrical, glumes $\frac{1}{2}$ the length of the grain.
4. *Kaffir* (K): Grains symmetrical (spherical), glumes clasp in varying length.
5. *Durra* (D): Grains rounded obovate, wedge shaped at the base and broadest slightly above the middle; glumes very wide.

Fig.1. Five basic races of sorghum based on coverage of glumes

According to them, the cultivated sorghum *Sorghum bicolor* is divided in to five basic races based the coverage of glume on the grain (Fig 1).

Hybrid races :

This consists of all combinations of the basic races.

1. Guinea	bicolor	(GB)	6. Guinea	kaffir	(GK)
2. Caudatum	bicolor	(CB)	7. Guinea	durra	(GD)
3. Kaffir	bicolor	(KB)	8. Kaffir	caudatum	(KC)
4. Durra	bicolor	(DB)	9. Kaffir	durra	(KD)
5. Guinea	caudatum	(GC)	10. Durra	caudatum	(DC)

Wild *Sorghum* sp. of Tamil Nadu:

S. halapense : Both $2n = 20$ and $2n = 40$ forms are available utilized for forage sorghum improvement.

S. sudanense : Utilized for improvement of forage sorghum.

S. nitidum : Found in Kodai Hills. Processes shoot fly resistance and dormancy.

S. staffii : Found in Southern districts, used for inducing dormancy.

Cultivated sorghum

Grouped in to two a) Tall, tropical late maturing adapted to short day length photo sensitive, longer internodes. E.g. Land races.

Land races of sorghum

1. Peria manjal cholam -
2. China manjal cholam -
3. Sen cholam
4. Talaivirichan cholam
5. Vellai cholam
6. Irungu cholam
7. Makkattai

b) Temperate, dwarf plant adapted to longer day length, photo in sensitive, shorter internodes, long panicles, high yielding varieties.

Breeding objectives

1. High yield : Productivity genes are present in *durra*, *roxburghi*, *Caudatum* and Zera - Zera.

Direct components : Panicle length and breadth panicle weight, number of primary branches, number of seeds / panicle and 100 seed weight.

Indirect components : Plant height, leaf area index endosperm texture.

2. Short duration - to fit in multiple cropping programme. Co22 is the shortest duration having a duration of 70 days. The drawback in this variety is it is dwarf and farmers who are in need of cattle feed may not cultivate this. 105 - 100 days is optimum. This can be grown in two seasons instead of a long duration land race. E.g. Co25 - Co 26. Tropical lines having dominant maturity gene Ma and temperate lines having recessive ma gene.

3. Breeding drought resistant varieties with low HCN content in the early stages of growth :

75% of sorghum is grown under rainfed condition. It is highly essential to breed varieties, which can withstand initial as well as terminal drought. Further in dry land varieties there will be high HCN content in the stem during early vegetative phase. This limits the use of varieties as cattle feed. To overcome this it is essential to breed varieties with low HCN content. Low HCN content exhibits partial dominance reaction. More than one gene involved in controlling this trait.

4. Breeding non - lodging sorghum

This is essential for southern districts, The hybrid sorghum kovilpatti tall (90 days duration) grown during N.E monsoon has a tendency to snap at nodes and lodge at maturity. This leads to considerable loss. To replace this the new hybrid COH3 having duration of 105 days was introduced. But it was not suitable because it could not withstand terminal drought. Dwarf character is conditioned by genes DW₁ to DW₄.

5. Resistance to pests

Shoot fly, stemborer, midge and earhead bug are the important pests of sorghum. Sources like *S. nitidum*, *S. virgatum* are available against pests. Some of the land races like local irungu cholam are resistant against shoot fly. Efforts are under way to evolve resistant varieties.

Resistance may be - Non preference for oviposition because of presence of trichomes.

Antibiosis - Silica content in the plant body

Recovery resistance by producing side tillers.

6. Resistance to diseases :

Sorghum downy mildew, helminthosporium blight, grain mould are the important diseases. The inheritance is complex and poly genic.

7. Breeding for sweet sorghum

Because of self sufficiency in rice, use of sorghum as human food is fast dwindling. So to find out alternate uses for sorghum, breeding sweet sorghum is one strategy. From the stem juice, ethanol can be produced which is a renewable source of energy. Brazil stands first in this. There are two types of sorghums.

a) **Syrup varieties** - Syrup for table purpose can be produced from this. This is also suitable for ethanol production.

b) **Sugar varieties** : contains more of sugars and less of combustible organics. Not suitable for ethanol production compared to syrup varieties.

Normal sorghum contains 12 %, TSS (Brix) where as sweet sorghums contain around 18% TSS. The juice will be extracted and sterilised. After sterilisation the juice is treated with yeast. After 48hrs, distillation is done to extract alcohol. Around 45% alcohol is recovered.

8. To breed red grain varieties suitable for biscuit making

Madurai - Tirumangalam area biscuit is made from Sencholan

Salem - boiled red grain used for consumption.

The variety Paiyur 2 is a red grain variety.

9. Breed varieties with nutritional quality :

Normal protein = 7-8 % with 1.9 to 2.5% lysine, 9.3 to 11.6% leucines

Increase in protein upto 12% is possible, but the problem is disability.

Two high lysine Ethiopian lines IS 11167 and IS11758 with 15% protein. The hl gene is monogenic recessive and seeds are shrivelled and red in colour.

10. To satisfy local needs

Small pearly white grain is used for preparing 'Kali' which has high keeping quality. *S. roxburghi* (Talai virichan cholam) is suitable and is grown in many districts. The varieties Co19 and Paiyur 2 are examples.

11. To isolate alternate sources of cytoplasmic genic male sterile lines.

The existing CMS lines are having A₁ cytoplasm as base. There are other sources viz., A₂, A₃, A₄ and A₅. But all of them are in grassy sorghum and susceptible to

foliar diseases. This we have to improve. There are local ones like Maldandi 35 GA, G.I.A. but they are season bound and long duration.

Breeding techniques :

Sorghum is often cross pollinated crop. So to maintain varietal purity isolation distance of 400 meters is necessary. Compared to other often pollinated crop like red gram, maintenance of inbreds is easy in sorghum. By putting brown paper and selfing the genetic purity can be maintained.

1. Introduction : Varieties of milo and kafir sorghum introduced from USA are used in conversion programme to convert the local long duration photo sensitive varieties to short duration, non-photo sensitive lines.

2. Selection : Old varieties like Co1, Co2, Co4 are all selection made from local land races.

3. Hybridization and selection

a) Inter varietal

(IS 4283 x Co 21) x CS 3541, Three way cross derivative Co 25

(MS 8271 x IS 3691) - Single cross derivative Co26

b) Inter specific

Co 27 Sorghum. (Co11 x *S.halapense*)

4. Heterosis breeding :

Use of CMS lines.

CSH 5 2077 A x CS 3541

CoH 4 296 A x TNS 30

5. Mutation breeding :

X ray mutant from CSV 5 (148)

Co21 (699 Tall)

Co 19 is a natural mutant from Co 2

6. Back cross method :

Co 20 peria manjal cholam.

(Bongan hilo x Co1 Peria manjal cholam). Co20 Peria manjal cholam. Striga resistance was evolved by back crossing. By following backcross method of breeding sorghum conversion programme was initiated. The long duration photosensitive germplasm was converted in to photo insensitive short duration sorghums. This was done at USA Similar programme was done at ICRISAT also.

7. Population improvement :

With the use of cytoplasmic genetic male sterility as well as genic male sterility we can go for population improvement. The local land races can be used as pollinators and by half sib family selection, we can isolate lines. We can follow recurrent selection idea to develop superior inbreds.

8. Use of Apomictic lines :

Some apomictic lines have been identified which can be utilised in breeding programme and by vegetative propagation we can fix up heterosis. E.g. R473 from Hyderabad.

Future thrust

1. Characterisation of released varieties and hybrids.
2. Differentiation of A₁, A₂, A₃ and A₄ cytoosteriles thro' molecular markers
3. Diversification of male sterile lines.
4. Use of Apomictic lines to develop hybrids.

Sorghum varieties suitable for Tamil Nadu.

Variety	Parentage	Duration
K5	Reselection from IS 3541	95
K7	K3 x M 35-1	110
Co19 (Talaivirichan cholam)	mutant from Co 2	145
Co 25	Three way cross derivative	105
Co 26	MS 8271 x IB 3691	110
Co 27	Co 11 x <i>S.halapense</i>	60
Co21	mutant of CSV 5	105
K 8	IS 12611 x SPV 105	85
K 9	M 36200 x Tenkasi vellai	120
K 10	K 7 x SPV 102	115
K 11	K 7 x A 6552	115
Paiyur-1	Co19 x Co24	145
BSR - 1	multiple cross derivative	110
Paiyur 2 (Sencholam)	PLS from IS 15845	95
Hybrids :		
CoH 2 (Kovil Patti Tall)	2219 A x IS 3541	90
CoH 3	2077 A x Co 21	110
CoH 4	296 A x TN 30	110
CSH 5	2077 A x CS 3541	100

FINGER MILLET

RAGI - *Eleusine coracana* Gaertn. ($2n = 36$)

(*Finger millet* / *Kezhvaragu* / *Keppai* / *Mutthair* / *Thamida* / *Nacheni* / *Mandal*)

Finger millet is an important staple food in parts of East and Central Africa, and India, particularly in Karnataka. It is used for malting and brewing.

Place of Origin : India

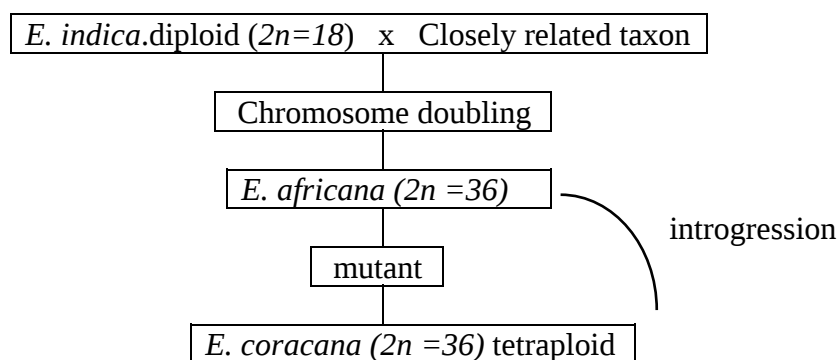
Classification : The genus *Eleusine* consists of eleven species. Of these six are diploids and five are tetraploids.

Eleusine indica is a diploid with $2n = 18$.

Eleusine coracana and *E.africana* are tetraploids ($2n = 36$)

Origin of cultivated species:

E. indica is considered as one of the parent for the tetraploid *E.africana*. *E.coracana* were mutants selected from of *E. africana*.



Hybridisation and introgression between *E.coracana* and *E.africana* continued and still continues in the highlands of Tropical Africa

Characters of *Eleusine*:

Inflorescence is contracted into a number of digitate spikes of spikelet.

Spikelet consists of more than two florets subtended by two glumes.

Cultivated types of Ragi :

There are two cultivated types of ragi.

1.Indian ragi, *E. coracana* and 2.African ragi , *E. africana*.

African ragi : It has long fingers, bold grain, stiff straw, photo sensitive and uneven grain maturity phase.

Indian ragi : Short fingers, small grains, photo insensitive.

RAGI (Finger millet)
***Eleusine Coracana* (2n = 36)**

Origin :

According to Krishnaswamy(1952) the cultivated species of *E.coracana* arose as a allotetraploid from its wild relative *E.indica*. Asia and Africa are supposed to be place of origin. The African types are having bolder grain.

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*

Breeding objectives :

1. Evolution of 80 days duration ragi suitable for irrigated conditions.
2. Breeding short duration drought resistant varieties suitable for rainsfed conditions
3. Breeding for high protein white ragi varieties suitable for malt making.
4. Blast resistant varieties.
5. Breeding varieties for sodic soils and tannery effluent affected soils.

Breeding techniques

1. By introduction

Indaf 5 Ragi from karnataka.

2. By selection

Pure line selection. Earlier varieties were all evolved by pure line selection.

Co7

Co11

Co12

Paiyur 1

TRY I

3. Hybridization and selection

The African types are with long fingers, bold grain with stiff straw. Further they are photosensitive and have un even grain maturity. Because of this character they are

not recommended for cultivation in India. The Indian types are with short fingers, small grains and photo insensitive. The African types are utilised in hybridization programme, to develop extra long fingered varieties coupled with disease and drought resistance. The Indian African cross derivatives are known as Indaf varieties which are interspecific.

Other state varieties

E.g. Indaf 5 cauvery x IE 929

Indaf 9

Tamil Nadu varieties

Co6 white ragi IS 1540 x EC 2985

Co9 white ragi

Co13 (Co7 x TAH 107)

4. Heterosis breeding :

Artificial induction of male sterility through use of gametocide, GA3, 2-4-D are being attempted.

5. Mutation breeding : T20 - mutant from AKP - 7.

PEARL MILLET
***Pennisetum glaucum* (2n = 14)**
(Cumbu, Bajra, Bulrush millet)

Origin : West Africa.

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.

Origin and putative parents.

Stapf included 32 species in penicillaria. Of these 32 species found in Africa, six annuals are considered wild and probable ancestors of the cultivated one. They are

1. *Pennisetum perottettii*
2. *P. molle*
3. *P. violaceum*
4. *P. versicolor*
5. *P. adonense*
6. *P. gymnothrix*

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

Wild species utilised in breeding :

The other species in this section is *P. purpureum* a rhizomatous perennial having chromosome number $2n = 28$

cumbu napier hybrid = BN1

Tetraploid x Diploid - Triploid.

P. squamulatum ($2n = 46$) - Drought and cold resistant having apomictic line crossed with *P. glaucum* to evolve superior cold resistant fodder.

P. orientale : used for transferring apomixis.

P. setaceum *P. violaceum* : To transfer male sterile genes to *P. glaucum*

Inter generic crosses :

Buffel grass *Cenchrus ciliaris* or *Pennisetum ciliare* utilised to cross with cumbu for fodder improvement

Breeding objectives :

1. Breeding for high grain yield

To get high yields the following plant characters are necessary

- a) more number of tillers
- b) well filled, compact, long panicle.
- c) heavy grains.
- d) Uniformity of ripening.

Under irrigated conditions photo insensitivity and early maturity are essential for multiple and relay cropping.

2. Breeding for improved grain quality.

It can be achieved by incorporating yellow endosperm to improve vitamin A content or white endosperm to improve protein content.

3. Breeding for drought tolerance :

This can be achieved thro' evolving lines having shorter duration so that they can escape drought, lines with more adventitious roots, lines with high leaf water potential and high chlorophyll stability index are to be evolved.

4. Breeding for disease resistance

Downy mildew is the major disease. Ergot and smut comes next. Of late, rust at late stage is also becoming a major problem.

Lines having Local Bellary cytoplasm (732 A) are observed to be downy mildew resistant.

5. Breeding for alternate source of cytoplasm in male sterile lines.

Original Tift 23 A evolved at Tifton, Georgia is highly susceptible to downy mildew. Because of this the HB series went out of cultivation. The indigenous 732 A obtained from Bellary is resistant. Similarly L 111A of Ludhiana is also tolerant. A₁, A₂, A₃ and A₄ are there 732 A belongs to A₄ cytoplasm.

6. Breeding for sweet cumbu to have high forage value :

The forage cumbu must have following characters.

- a) high sugar content in the stem juice
- b) Increased leaf number with more breadth.
- c) Digestibility.

In this connection, short day plants with photo sensitiveness is preferred because they remain in vegetative phase for longer periods. It is ideal to breed dwarf varieties with reduced stem height

Wild species utilised.

P. purpureum

P. squamulatum

p. orientale

p. ciliare

Methods of breeding

1. Introduction : Hybrid bajra from Punjab.

Tift 23 A from USA

2. Selection : Pure line selection : Co 2, Co 3,

Mass selection the earlier released variety Co5 is result of mass selection. The variety Co6 is selection from Nigerian accession MS 7625 selected for high tillering, long panicle, dense seed setting and bold seeds along with downy mildew resistance.

3. Hybridisation and selection

Interspecific hybridisation.

Pennisetum glaucum x *P. purpureum*



Cumbu napier hybrids.

4. Heterosis breeding : Hybrid bajra

In earlier days before the identification of male sterile lines utilising the protogynous nature hybrids were released. The hybrids were produced by sowing both parents in the ratio of 1:1.

X₁, X₂, X₃ are examples for this. In this case two hybrids are obtained.

After the discovery of cytoplasmic genic male sterile line Tift 23A by Burton in Tifton, Georgia led to development of hybrids. Earlier hybrids of India viz., HB1, HB2 to HB5 were produced utilising Tift 23 A. But due to susceptibility to downy mildew they went out of cultivation. Even before the discovery of CGMS lines by Burton it was discovered by Madhava Menon and his coworkers at Coimbatore. Unfortunately due to failure of publishing it was not recognised.

To over come the problem of downy mildew male sterile lines L 111A and 732 A were isolated and at present used in breeding programme.

X5 L111A x PT 1921

X6 732 A x PT 3095.

X 7 L111 A x PT 1890

NHB 3 - 5071 A x J 104

There are number of CMS lines developed by private agencies like Nath seeds, Mahyco, Mahendra.

5. Population improvement :

ICRISAT entry WCC 75 is an example for population improvement. This was developed from world composite by recurrent selection method. It was developed from derivatives of numerous crosses between diverse sources of germplasm and Nigerian early maturing land races known as 'Gero' millets. Another example is ICMV 155 of ICRISAT.

At TNAU Composite Co7 was released during 1987.

6. Synthetic varieties :

Synthetics are produced by crossing in isolation a number of lines tested for their GCA. E.g. ICMS 7703.

It is a result of crossing between 7 inbred lines of India x African crosses

7. Mutation breeding

At IARI Tift 23 A was gamma irradiated and 5071 A resistant to downy mildew was evolved. With this the hybrid NHB 3 was evolved (5071 A x J 104)

Future thrust :

1. Collection of un exploited land races and exotics, building up of germ plasm and utilising them.
2. Development of early maturing restorers with good combining ability.
3. Genetic and cytoplasmic diversification of male sterile lines.
4. Devising methodologies for wide hybridization and use of genetic engineering to evolve disease resistant varieties.

Bajra varieties suitable for Tamil Nadu

Variety	Parentage	Duration
Composites		
K 3	Composite	85
Co 7	Composite	90
WCC 75	Composite	95
Hybrids		
X 6	732 A x PT 3090	90
X 7	L111A x PT 1890	90
NHB 3	5071 A x J 104	90

TENAI (Fox tail millet)
Setaria italica ($2n = 18$)

A. Floral biology

Inflorescence is a spike, terminal, drooping. The spikelets are oval or elliptical in shape with two to three bristles. The spikelets contain two flowers partially protected by two membranous glumes. Lower floret with L_1 and P_1 , sterile; upper floret with L_2 , P_2 , stamens three, styles two, fruit a caryopsis.

B. Anthesis and pollination

Flowering proceeds from the top downwards in the main panicle and similarly from the tip down wards in each of the panicle branches. The stigmatic branches are the first to emerge. The anthers after emergence start dehiscing by longitudinal slits from the top to bottom the process taking about three minutes. Five to ten minutes after the emergence of the first anther, the other two are pushed out. After pollination the lodicules shrink and the glumes begin to close. The time taken for an earhead to complete its flowering varies from ten to fifteen days. From the third to sixth day to emergence a large number of flowers open. There are two times of flowering during a day, one between 10 p.m. and 12 midnight and other between 6 a.m. and 8 a.m. Self pollination is rule.

VARGU (Kodo millet)
Paspalum scrobiculatum (2n = 40).

A. Anthesis and pollination

The spikelets are highly cleistogamous. Only 10-15% of spikelets open under Coimbatore condition. Spikelets at the middle of spikes open first, gradually spread to either ends. Spikelets open after midnight i.e. from 2.30 AM to 3.00AM and continue till sunrise.

KUDIRAVALI (Barn yard millet)
Echlinochloa colona (2n = 34, 48, 54, 72)

The spikelets are more or less crowded on the spike like branches of the panicle. The anthers are purple in colour. Order of flowering is from tip to the bottom of panicle. The total flowering period extends from 19-22 days. Anthesis - 5 AM to 10 AM. Self pollination is the general rule.

Varieties : Pureline selection - **RAU 3**

PANI VARAGU (Proso millet)
Panicum miliaceum

Inflorescence is a drooping panicle. The spikelets contain two flower partially enclosed by the glumes. The flowers open between 10AM to 12 noon. The spikelets open and close within 7 minutes. The anthesis begins from tip of the panicle and proceeds down wards. Flowering completes within 7 to 10days. Self pollination is the rule.

Varieties : Pure line selection - **BR 7**

Emasculation and crossing technique in small millets

Hand emasculation is tedious because of small sized florets. To overcome this the **Russian method** is followed. The principle in this method is to induce artificial flower opening by increasing the temperature 1-2⁰ C and immersing the panicle in normal cold water prevent anther dehiscence but flowers will open.

Method

- i) Select the panicle which first commenced flowering
- ii) Remove the already opened florets
- iii) Rub the selected panicle in between hands to increase the temperature by 1 to 2⁰C for two minutes.
- iv) Immerse the panicle in cold water
- v) The flowers will open but anthers will not dehisce

- vi) Take out panicle from water and remove unopened flower
- vii) From opened florets remove anthers

Pollination:

1. Collect the panicle from male parent which are in the process of flowering. Shake the panicle on the emasculated florets. Tie the male panicle to the emasculated female panicle. Cover it with butter paper bag which was immersed in water. The water in butter paper bag will maintain humidity.

Minor Millet varieties :

Tennai

Co 4	Selection from Gujarat local	70 days.
Co 5	Co1 x A113/2	90 days.

Panivaragu

Co 4	Pureline selection	75 days.
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Kudiraivali

Co 1	Pureline selection	75 days.
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Somai

Co 2	Selection from Ananthapur local	85 days.
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Poriyu 2

Pure line selection	80 days
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Varagu

K ₁	Pure line selection	100 days.
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PULSES

The pulse crops in general give lower yields than the cereals. Pulses are rich in protein and it takes more energy weight for weight to synthesise protein than carbohydrates. When you compare the energy requirement of various metabolic pathways, one gram of glucose can give rise to 0.8g of carbohydrate but on an average only about 0.5 g protein and even less of oil.

Further maintenance of nitrogen fixation in roots require prolonged use of photosynthate and thus may reduce the energy available for storage in seeds. Other reasons for low yield are

1. Raised in submarginal lands.
2. Indeterminate growth habit.
3. Irregular flowering
4. Photosensitiveness.

The protein from pulses are incomplete. Legumes are good source of lysine, tryptophan and threonine but are low in sulphur containing amino acids *methionine*, *cystine* and *cystene* which are adequate in cereals. So a mixture of cereals and pulses are recommended for food. Many grain legumes contain toxic inhibitors which are removed while cooking.

RED GRAM

Arhar, Tur

Pigeon pea

Cajanus cajan (2n = 22)

Place of origin : Africa / Asia

Wild Species : *Cajanus kerstingii*

Related crossable genera : Rhynchosia

Putative parent :

The view is that cultivated *cajanus* arose from *Atylosia*. *Atylosia lineata* may be the progenitor of *cajanus*. In Western ghats *A.lineata* and *A.sericea* are known to local people as 'barn tur' (wild tur) so also in West Bengal and orissa *A.scaraboides* and *A.cajanifolia* are known as wild tur. The genus *Atylosia* has now been included in *Cajanus*.

Two botanically distinct varieties were described. *Cajanus cajan* var. *bicolor* (Arhar) perennial, late maturing, large bushy plant bearing purple streaked yellow flower. The pods are dark purple mostly cultivated in North India. *Cajanus cajan* var. *flavus* (Tur) short duration early maturing. Color of standard petal yellow. Pods green, glabrous cultivated in South India.

But the above classification is no longer valid because there are number of intermediate forms and it is hard to differentiate the varieties because of often cross pollination nature of the crop.

Breeding objectives :

1. Evolution of long duration high yielding variety suitable for rainfed to replace the local land races :

SA1 - Released during 1940

Co6 - result of mutation breeding

2. To evolve short duration (105 days) varieties suitable for irrigated / mixed crop with ground nut.

ICPL 87 - ICRISAT

Vamban 1 - 110 days.

3. Breeding for bold grain type with desirable seed coat color

HY 3C long duration variety with dull white seed coat and bold grains.

4. Breeding for vegetable type

Hosur area - Green pods with bold seeds are used as substitute for green peas. Perennial types like Attapadi local are used. BSRI is a perennial red gram whose green pods are used as vegetable.

5. Breeding for resistance to pests.

Heliothis is the major pest, Terminal cluster types are highly susceptible. All our varieties are highly susceptible.

6. **Breeding for disease resistance :**

Sterility mosaic, root rot, blight are important diseases. Wild species *Cajanus scaraboides*, *C. lineata* are having resistance.

7. **Breeding for high protein content and quality**

Mean protein content 23%. The wild species have 27% to 29%

Red seed coat contains more polyphenol (Tannin) than white seed coat. So preference is towards white seed coat. Red grain contains lesser amount of sulphur containing amino acid. When we increase protein content there will be lesser amount of these amino acids. So care is to be taken to increase them.

8. **Breeding high yielding perennial redgram suitable for bund cropping**

BSR 1, Attapadi selections

Breeding methods :

1. **Introduction :**

E.g. Prabhat short duration variety from IARI, ICPL 87 from ICRISAT.

2. **Pure line selection**

Earlier breeding work was based on the assumption that Redgram is a self pollinated crop. However it was later found to be often cross pollinated crop. SAI is a pure line selection from Tirupathur local.

3. **Hybridization and selection :**

Inter varietal : VBN 1 (Prabath x NY 34) (T.12 x 102)

Inter generic : *C. cajanus* x *Cajanus lineata*

C. cajanus x *C. scaraboides* are being attempted

4. **Mass selection :**

5. **Population improvement :**

Using male sterile line and recurrent selection methods.

Two populations are used, one is seed parent and the other is pollen parent. The seed parent must have one or two easily identifiable recessive character and the pollen parent more dominant genes. The seed and pollen parents are sown in alternate rows so as to maximize natural cross pollination.

The F_1 's and selfed ones are identified in, S_0 generation. The identified F_1 s are space planted in the next generation S_1 . In S_2 generation they are yield tested in 3 environments and best ones are either recycled or taken to conventional breeding programme.

6. **Mutation breeding**

Co2 - Chemical mutagenesis EMS.

Co5 - Mutant of Co 1 gamma rays.

Co6 - Mutant of SA 1 gamma rays.

7. Heterosis breeding

Ms T 21 x ICPL 87109 CoRH 1

Ms Co 5 x ICPL 83027 CoRH 2

Red gram Ideal plant type - long duration :

The genotype that have steady rate of growth and have a moderate harvest index.

High seed weight

Long pods

Increased number of pod bearing branches.

Short duration :

Dwarf in nature with erect branches having high dry matter production

High seed wt.

Long pods.

Increased no of seeds / Pod

Less flower drop.

RED GRAM VARIETIES FOR TAMIL NADU

Varieties

Varieties	Parentage	Duration
SA 1	Pureline selection from Thirupattur local	160-180
Co 3	Mutant of Co1	90-95
Co 4	Pure line selection from gene pool	90-95
Co5	Mutant of Co 1	100-110
Co6	Mutant of SA 1	160-180
Vamban 1	(Prabath x NY 34) (T12 x 102)	95-100
APK 1	PLS from ICPL 87101	95-105
VBN2	ICPL 341 x BSR local	170-185

Hybrids

CoRH 1	Ms T 21 x ICPL 87109	110
CoRH 2	Ms Co 5 x ICPL 83027	110

Hybrid Seed Production of CoRH. 1 Pigeonpea

In the exploitation of hybrid vigour for commercial cultivation, efficient production of hybrid seed is essential for which a full knowledge of the various steps involved in hybrid seed production is necessary to achieve the twin objectives of maximizing the hybrid seed production and improvement in quality of hybrid seed.

For hybrid seed production, a ratio of 4:1 of male sterile pollen parent is adopted. Sufficient isolation distance i.e., more than 200 metres for the hybrid seed production plot is needed. There should not be any pigeonpea crop within a radius of 200 metres from the seed production plot. Since the male sterility is maintained in heterozygous state following the test cross principle, there would be fertile and sterile plants in the ratio 1:1 in the male sterile population. It is therefore imperative to remove the male fertile plants in the male sterile population before flower opening. The roguing should be done thoroughly to avoid contamination by the pollen from any left out fertile plants.

Steps involved in hybrid seed production

1. Selection of site

- (i) Fertile field with an irrigation source
- (ii) Previous crop should not be pigeonpea
- (iii) Isolation distance of 200m from any other variety of pigeonpea.

2. Fertilizer

- (i) Farm yard manure @ 20 cart loads per hectare
- (ii) 25 Kg N + 50 Kg of P as basal application

3. Sowing

- (i) The female and male parents are sown in the ratio of 4:1 with two border rows of pollinator parent.
- (ii) The pollen parent (ICPL 87109) should be sown one week after sowing the female parent (MS T.21).
- (iii) Row spacing of 45 cm.
- (iv) Plant to plant spacing should be 15 cm.
- (v) Dibble 2-3 seeds per hill for the female parent
- (vi) Seed rate (per hectare) for 4:1 ratio 40 Kg of female parent, 5 kg of male parent.
- (vii) Sowing should be done during first fortnight of June or first fortnight of December.
- (viii) The whole plot should be bordered with sunflower to increase the bee activity to effect cross pollination.

4. Irrigation

- (i) First irrigation after sowing and a life irrigation 2-3 days after sowing.
- (ii) irrigate the plot at 7-10 days interval depending upon the moisture in the field

5. Rogueing

- (a) Male sterile line or female parent :

- (i) Remove the off type plants
- (ii) Remove the male fertile plants by examining the colour of the anthers (yellow) at the time of first flower formation, one-day before flower opening.
- (iii) Rogueing should be completed in 7-10 days time
- (iv) Remove the late flowering plants also.

(b) Male fertile line or pollen parent :

- (i) Rogue out off types.
- (ii) Remove the immature pods set in the plants from time to time to induce continuous flowering and to ensure pollen availability for a longer period.

6. Harvesting

Collect the pods from the female parent i.e., male sterile parent. This will give the hybrid seeds.

Production and maintenance of male sterile line

Genetic male sterility is utilized in hybrid seed production. In case of pigeonpea, the male sterile line will segregate in 1:1 ratio of fertile to sterile. For the maintenance of the male sterile population (to be raised under isolation), the male sterile plants have to be identified and tagged and the fertile plants have to be retained without tagging. The male sterile lines will be pollinated naturally by the pollen from the male fertile plants in the population through insect pollinators. After maturity, the seeds from the tagged male sterile plants are collected and will be used for producing male sterile lines again or for producing hybrid seeds.

The main difference between the hybrid seed production and the male sterile line maintenance is, during hybrid seed production the male fertile plants from the male sterile population are to be rogued off, while they are retained during male sterile line maintenance.

BLACK GRAM (URAD, ULUNDU)

Vigna mungo (2n = 22, 24)

Origin : India

Putative parents

V. trinerivus / *V. sublobata* or *V.mungo* var. *sylvestris*.

Breeding objectives

1. **Evolving medium duration high yielding varieties for dry land cultivation.**
Co5 black gram. Suitable for dry land cultivation.
2. **Evolving short duration high yielding varieties suitable for irrigated conditions.**
This can be used as mixed crop in cotton, turmeric Short duration varieties are Co2, Vamban 1, 2 and 3.
3. **Evolving short duration varieties suitable for rice follow condition**
ADT 3.
4. **Breeding varieties resistant to diseases**
YMV is a serious disease. Leaf crinkle virus, powdery mildew.
VBN 1, Karaikal, BDN 1, VBN 2, VBN 3 - resistant to YMV
5. **Pest** : White fly vector for YMV and leaf crinkle, leaf eating caterpillar
6. **Breeding for better quality**
24% protein. There are lines having 27% protein. These can be utilised Quality of black gram is determined by
 - a) Protein content
 - b) Methionine content 1.17%
 - c) cooking quality - Time
 - d) % of hard seeds.
 - e) Dhall recovery 70%

Breeding methods

1. Introduction :

E.g. T.9 from U.P.

2. Pure line selection :

Co3 - Alangudi local

Co5 - musiri local

3. Hybridization and selection

a) Intervarietal

KM 2 (Derivative from T9 x L.64)

TMV 1 - Derivative from Midhiulundu x KM1

ADT 4 - 29 x AD 2 x 6114

VBN 3 - LBG 402 x LBG 17.

b) Inter specific :

Vigna mungo x *V.mungo* var.*sylvestris* - Pant nagar. YMV resistant lines obtained. But pod shatters. More number of Back crosses suggested.

Vigna mungo x *V.radiata* for increasing pod length, digestibility. Sterility is the main problem. Few plants obtained revert back to parental form.

4) Mutation breeding

Variety Co4 - derived from Co1 by EMS treatment

5) Embryo rescue - Attempted in inter specific crosses.

Ideal plant type

For irrigated and Rice fallows

Determinate type, short duration, high dry matter producing with 30cm plant ht.

Photo insensitive.

For rainfed condition.

Semi determinate with pod setting from base of the main stem; higher pod length and more number of seeds / pod.

BLACK GRAM VARIETIES FOR TAMIL NADU

VARIETIES

Varieties	Parentage	Duration
Co 4	Mutant of Co 1	70
Co 5	Pure line selection from Mustri Local	70-75
KM 2	Derivative from T 9 x L. 64	60-65
VBN 1	KM 1 x H 76-1	60-65
T 9	Pure line selection	65-70
ADT 2	Derivative from Thirunelveli Local x ADT 1	70-75
ADT 3	Pure line selection from Thriunelveli Local	70-75
TMV 1	Derivative from Midhiulundu x KM 1	65-70
ADT 4	29/ ADT 2 / Plant 6114	60-65
ADT 5	Pure line selection Kanpur variety	62
VBN 2	Reselection from T 9	70
VBN 3	LBG 402 X LBG 17	70

GREEN GRAM (MUNG BEAN)

vigna radiata (2n = 22)

It is esteemed as the most wholesome among the pulses, free from the heaviness and tendency to cause flatulence, which is associated with other pulses.

Place of origin : India

Wild relative : *Vigna radiata* var. *sublobata*

Breeding objective :

1. High yield, medium duration dry land varieties

Co1 long duration, indeterminate plant habit.

2. High yielding, short duration irrigated varieties :

Lines having rapid growth rate or dry matter increase associated with high harvest index. They must give high biological yield and productive racemes. Co2

3. Breeding for rice fallows

ADT 2, ADT 3

4. Breeding for disease resistance

YMV

Leaf crinkle virus

Tarai local Lm 214 - resistant

5. Breeding for quality

a) Mung bean has highest digestibility among grain legumes from 83 to 90%.

Varieties having bold seeds to use as sprouts is the aim.

b) Transfer of high methionine content from black gram to green gram.

c) High dhall recovery - 80% and more

d) Less hard seed.

Breeding Methods :

1. **Introduction** - Pusa baisaki

2. **Pure line selection** - Co1

3. **Hybridisation and selection**

Inter Varietal : ADT 1, ADT 2, Co 5, VBN 1

Inter specific - To transfer high methionine content from black gram to green gram.

Green gram x *V.umbellata* rice bean to transfer resistance to bean fly
crossing with *V.radiata* var. *sublobata* resistance to bruchids

5. **Mutation breeding**

Co4 - mutant of Co1

6. Embryo culture :

Green gram x Black gram

Ideal plant type

1. 60 - 65 duration with determinate habit for irrigated conditions
2. 80 days duration with indeterminate type for dry land condition

Plants with more pods and seeds, increased branches podding from base of main stem with synchronised maturity non - shattering habit.

GREEN GRAM VARIETIES FOR TAMILNADU

VARIETIES

Varieties	Parentage	Duration
Paiyur 1	Pure line Selection from DPT 703	85-90
ADT 2	AB-33 x ADT 1	70-75
ADT 3	Hybrid derivative H 70-16 / Rajemdran / G 65	66
Co 4	Mutant of Co 1	85
KM 2	Hybrid derivative of No. 127 x S.9	65-70
VBN 1	Hybrid derivative of S.8 x PIMS 3	65
Co 5	Hybrid derivative of KM 2 x MG 50.10 (G)	70-75
K1	Co 4 x ML 65	70
Co6	WGG 37 x Co 5	65

HORSE GRAM

Macrotylenia uniflorum (2n = 24)

Place of origin : Hindusthan centre

Putative parent : Not known

Breeding objectives :

1. Increased yield :
Co1 Mudukalathur local
2. Non - Photo sensitive, short duration varieties
3. Varieties with low trypsin inhibitors

Methods of breeding :

1. Introduction

HPK varieties from Himachal Pradesh.

2. Pure line selection

Co1 from Mudukalathur local.

Paiyur 1 from Mettur local.

3. Hybridization and selection

- a) Intervarietal
- b) Interspecific

Dolichos lab lab x *M. biflorum*
Crossable.

4. Mutation breeding

SOY BEAN

Glycine max (2n = 40)

Place of origin : China.

Probable ancestors : *Glycine usuriensis*

Slender, viny plant with small seeds grows wild in Japan, Manchuria and Korea. It is considered to be the progenitor for *G.max*. Another view is that *G.max* arose from natural hybridization between *G.usuriensis* and *G.tomentella* which grows wild in China. A fourth species *Glycine gracilis* is intermediate between *G.max* and *G. usuriensis*. Cultivated types of *G.gracilis* are found in Manchuria. All the above species are crossable with each other. Many other species in *Glycine* have been identified but the exact classification of most of them is still in doubt.

Breeding objectives :

1. Breeding for short duration high yielding varieties

The yield of soy bean plant is determined by size, number of seeds per pod and number of pods / plant. The number of pods / plant is determined by no. of nodes / plant, number of pods / node. Each of the above components of yield are polygenic in inheritance and so it is complex.

The duration is also determined by multiple genes. Maturity is correlated with height of the plant. Early varieties will be short in stature.

2. Breeding varieties suitable for rice fallows

Short plants 65 -70 days duration. Suitable for inter cropping also in banana and sugarcane.

3. Breeding for quality

- a) Seed color and quality
- b) Oil content and quality
- c) Protein content

a) Seed coat color :

May be yellow, green, black, brown or combination of all the above colours. For oil extraction yellow color is preferred because of high oil content whereas black seeded varieties are low in oil content but high in protein content. Seed coat color other than yellow will give unattractive oil cake which is not preferred.

b) Oil content and quality :

Oil content greatly determined by environment :

Yellow seed coat varieties are rich in oil. Complex character determined by poly genes.

c) Protein content and quality :

Ranges from 35 to 50% protein content is negatively correlated with oil content so white breeding for high protein content a compromise is to be made.

4. Breeding for vegetable type

AVRDC, Taiwan has evolved vegetable types

5. Breeding for forage type of soy bean

6. Breeding for non-shattering type

E.g. Lee, Co2

7. Breeding for YMV resistant lines

Co 2

Breeding Methods:

1. Introduction :

Ec 39821 from Taiwan - released as Co1

2. Pure line selection

Co1

3. Hybridization and selection

Clark, Co 2 (AS 335 x UGM 21) YMV tolerance

4. Mutation breeding.

VARIETIES OF TAMIL NADU

Co 1 - Pure line selection from EC 39821

Co 2 - (AS 335 x UGM 21)

ADT 1 - Selection from HILL

COWPEA

Vigna unguiculata (2n = 22)

Place of origin : India

Putative parent : Wild sub species *V. unguiculata* SSP. *dekindtiana* or SSP. *menensis*

Classification :

According to Faris 1965 three subspecies are recognised.

1. *Vigna unguiculata* subsp. *unguiculata* (Syn V.u. subsp. *catjang*) - grain cowpea : Primitive of all cowpea types. Pods 8 to 13cm long. Neither flabby nor inflated. Pods remain erect at maturity.
2. *V. unguiculata* subsp. *sinensis* - Grain type cowpea. Pod length 20 to 30 cm. Pods are not inflated. Pods fibrous when green. The stature of pods are pendent when matured. Seed size medium 6-9 mm. Seeds are closely packed in the pod.
3. *V. unguiculata* subsp. *sesquipedalis* - Yard long bean - vegetable cowpea: Pod size may be 30 to 100 cm, pendent. No fibre content is seen in pods. Seeds are sparsely arranged, kidney shaped and usually double coloured. Pods inflated when green, shriveled on drying.

Distinguishing feature :

- * Kidney shaped seed
- * White hilum surrounded by brown or black ring.
- * Pubescent throughout plant body.

Breeding objectives.

1. Breeding for medium duration high yielding varieties for dry land conditions

- Co1 old variety resistance to YMV. Indeterminate Plant habit.
- Co4 - 85 days duration. Seed colour mottled
- C 152 - 85 days, buff color seed.

2. Breeding for short duration varieties suited for irrigated and mixed cropping conditions.

- Pusa do fasli - Short duration variety
- Co6 - 70 days durations.

3. Breeding for vegetable cowpea

- Co 2 - (C 521 x C 419), VBN 2 Selection from IT 81-D-1228-1 mottled seed.

4. Breeding for disease resistance

- Aphid borne mosaic virus
- Co6 - (Ms 9804 x C 152)
- Cercospora leaf spot
- Fusarium wilt
- YMV - Co1 resistant.

5. Breeding for pest resistance

Leaf hopper - Antibiosis and tolerance

Aphids - Antibiosis and tolerance

Pod borer - Antibiosis

6. Breeding for Forage cowpea.

Var. Co5 from Co 1 by gamma irradiation

Breeding Methods :

1. Introduction

Iron cowpea

Russian giant.

2. **Selection** : PLS cowpea Co1 is PLS from C 57 a local collection from Shirgali

3. Hybridisation and selection

a) Intervarietal

Co6 (Ms 9804 x C 152

Co2 (C 521 x C 419)

b) Interspecific

V.u x *V.vexillata* - (having tuberous roots which is edible)

V.u x *V.umbellata*.

4. Mutation breeding

Co5 Forage cowpea

5. Embryo rescue technique

For inter-specific crosses.

Ideal plant type

Short duration : Determinate plant with high harvest index The branching must be erect. Flower drop to be minimum. Bushy plants are ideal

Long duration types.

Indeterminate plant habit with steady growth rate.

COWPEA VARIETIES FOR TAMIL NADU

VARIETIES

Varieties	Parentage	Duration (days)
Co2	Hybrid derivative (C 521 x C 419)	90
Co 3	Pureline from C 152 Vegetable type	80
Co 4	Selection from Russian Giant	85
KM 1	Hybrid derivative (JC 5 x Dofasli)	60-65
Paiyur 1	Selection from VM 16	90
Co 6	MS 9804 x C152	65-70
Co 5	Mutant of Co 1 Forage Cowpea	100

LAB LAB (2n=22, 24)
Lab lab purpureus var. *typicus*
 Garden bean
 ‘Pandal avarai’

Lab lab purpureus var. *lignosus*
 Field bean
 Mochai.

Origin : India

Distribution : India, Central America, China and Africa.

In India mostly cultivated, in southern states of Tamil Nadu, Karnataka, Andhra Pradesh.

Var typicus :

Perennial. Twining herb. Cultivated as an annual. The pods are long, tapering. The long axis of seeds parallel to the suture. With out oilglands and ‘Mochai’ smell. Entire pod is edible as vegetable.

Var. lignosus

Semi erect bushy, perennial usually grown as annual. The pods are relatively shorter, oblong and fibrous 4 to 6 almost round seeded. Seeds vertical to the suture. Plants give ‘mochai’ odour.

	Avarai	Mochai
Habit	Perennial Twining herb requires support for normal performance	Semi erect bushy perennial, cultivated as annual
Plant part	No ‘Mochai’ odour	‘Mochai’ odour present
Pod	Whole pod as vegetable. matured green seeds vegetable	Green seeds alone as vegetable pericarp tough, parchment like.
Seed arrangement	Parallel to the length of suture	Vertical
Photosensitivity	Photosensitive	Photosensitive

Breeding objectives:

To evolve non season bound vegetable type, short duration varieties.

In Mochai there is one non season bound, short duration - Thenkasi local DL 3196. By crossing this with Panthal avarai, short duration, non season bound varieties were evolved. Example Co 11, Co 12, Co 13.

Varieties : Mochai
 Co 1 Pure line selection
 Co 2 Pure line selection
 Avarai (Bushy type) of MS 98678.
 Co 9 Natural mutant of Co 6
 Co 11, Co 12, Co 13

OILSEEDS
GROUND NUT (MONKEY NUT, PEANUT)
Arachis hypogaea (2n = 40)
Allo tetraploid
Genomic constitution AABB

Place of origin : Brazil

Putative parents and origin of cultivated ground nut.

The cultivated ground nut is a Allotetraploid having A and B genomes. The genus *Arachis* is sub divided into 7 sections. The cultivated ground nut comes under section *Arachis*. This section includes 12 species of which *hypogaea* is the only cultivated species having 2n = 40. The other one is *A. monticola*. The rest ten species are diploids.

One view is that cultivated ground nut arose from cross *A. cardinasi* x *A. batizocoi*. But this view is not accepted by Prasad (1996). According to studies involving RFLP, PCR, isozyme have led to the conclusion.

- a) *A. hypogaea* had an allopolyploid origin.
- b) A large amount of genomic differentiation between the diploid A and B genomes occurred.
- c) Definite identification of progenitors of *A. hypogaea* has not been completed.
- d) *A. duranensis* may be the female parent
- e) *A. batizocoi* would have contributed the smallest chromosome.

Groundnut an unpredictable Crop

Ground nut is popularly known as unpredictable legume. Since the pods are borne below ground positively geotropic we cannot predict its performance before harvest as in the case of other crops. Further Ground nut is highly influenced by environment.

If there is no favorable environment yield alone will not be affected but also the quality characters. **Less boron** means low shelling % and more of immature seeds **moisture stress** leads to lower yield as well as reduction in well developed kernels. Oil percentage is also influenced by environment. **Excess moisture** leads to more vegetative growth and reduction in yield. Compared to any other crop here. G x E interaction is more pronounced.

Besides abiotic stress, biotic stress also play a major role Rust and leaf spot in diseases, red hairy caterpillar and leaf minor in pests cause major havoc.

Seed multiplication ratio is 1:5. This is also one of the bottlenecks in the spread of improved varieties.

Classification :

The genus *Arachis* is subdivided into the following seven sections. (Gregory and Gregory, 1973)

Arachis

Erectoides

Rhizomatasae

Extranervosae

Triseminate

Ambinervosae

Caulorhizae.

1. <i>Arachis</i>	2n
<i>Arachis villosa</i>	20
<i>A. batizocoi</i>	20
<i>A. cardinassi</i>	20
<i>A. chacoense</i>	20
<i>A. monticola</i>	40
<i>A. hypogaea</i>	40

2. <i>Erectoides</i>	
<i>A. tuberosa</i>	20
<i>A. paraguayensis</i>	20

3. <i>Rhizomatasae</i>	
<i>A. glabarata</i>	40
<i>A. hagenbeckii</i>	40

4. <i>Extra nervosae</i>	
<i>A. villosulicarpa</i>	20
<i>A. marginata</i>	20

5. <i>Triseminate</i>	
<i>A. pusilla</i>	2n = 20

6. <i>Ambinervosae</i>	
none, named	

7. <i>Caulorhizae</i>	
<i>A. repens</i>	2n = 20

In hybridization programme intersectional hybridization is not successful but intra sectional hybridization is successful keeping wild species as female is more successful.

According to Smart 1961 *A. hypogaea* has been sub divided into two sub species

Viz. *A. hypogaea* subsp. *hypogaea*

A. hypogaea subsp. *fastigiata*

According to this *hypogaea* the first two nodes bear vegetative branches then next two branches bear inflorescence

fastigiata : Inflorescence are borne on second and subsequent nodes of primary branches.

Karpavickas (1968) recognised two other botanical varieties in each of the sub species.

A.hypogaea subsp *hypogaea*

var. *hypogaeae*. *Virginia* type spreading

var *hirsuta* *hirsuta* type semi spreading.

A. hypogaea sub. sp. *fastigata*

Var. *fastigata* (Valencia type)

subsp var *vulgaris* Spanish bunch.

In India the cultivated types are grouped into

i) bunch type Valencia

Spanish bunch

ii) semi spreading - *Virginia* bunch

iii) spreading - *Virginia* runner.

Breeding objectives :

Majority of area in Tamil Nadu is cultivated with bunch type and semi spreading is confined to certain pockets only. So the objectives are for bunch type.

1. Breeding high yielding bunch ground nut with dormancy suitable for dry land conditions

The dry land bunch type sown during June - July often caught up in early N.E. monsoon rains which results in germination of varieties. So it is necessary to breed varieties having dormancy. Semi spreading varieties are dormant TMV 7 slightly dormant varieties, BSR.1, ALR 2 dormant for 15 days.

2. Breeding varieties for quality

a) **High shelling percentage** > 75%

Thin shelled varieties have high shelling percentage.

b) **High oil content** > 50%

TMV 10 the semi spreading variety is having 52% oil. Oil content is highly influenced by environment.

ALR.2 52% oil

c) **High sound mature kernel (SMK)**

Which is also influenced by environment. Increased boron application results in high shelling percentage and high SMK %

d) **Table purpose varieties**

Hand picked kernel for export market. Valencia types are suitable for this.

3. Breeding disease resistance varieties.

Rust and leaf spot are causing major damage. If the onset of rust is in initial stage it results in total failure. Late leaf spot hinders harvest of crop due to foliage loss.

Tomato spotted wilt virus or Bud necrosis of late gaining importance. NCAC 17090 - resistant

4. Breeding for pest resistant varieties

Red hairy caterpillar, leaf miner are major pests.

5. Breeding short duration (85 days) varieties suitable for irrigated conditions

Chico

VR1 3 - (R33-1 x Ah selection 1) 90 days.

Breeding Methods:

1. Introduction:

All the ground nut lines are introduced ones. Ground nut was introduced in to Tamil Nadu by East India Company

2. Selection:

a) Pure line selection

TMV 2 - Selection from local Gudiyatham bunch.

b) Mass selection

JL 24 from Taiwan variety.

3. Hybridization and Selection

a) Inter varietal

Bunch x Bunch - VRI 2 (Co2 x JL 24)

SSP x Bunch - VRI 3 (R 33-1 x Ah selection)

b) Inter specific

For transfer of disease resistance.

Arachis sp :

A.hypogaea x *A.batzocoi*

2n = 40 2n = 20 (Resistant)

↓
Triploid sterile

↓ doubled

Hexaploid

↓

Reduced to tetraploid.

A. chacoense

2n = 20

A.monticola - for thin shelled conditions

Extranervosa sp.

A.villoulcarpa for increased number of pods.

5. Mutation breeding

Gregory in USA extensively adopted and released varieties.

Co2 EMS from POL 1

TMV 10 Natural mutant from Argentina local.

TG 1 to TG 6 (Vikaram) from BARC Trombay.
GNLM - Gujarat Narrow Leaf Mutant.

6. Embryo rescue technique :

A.pusilla x *A.hypogaea* crosses. But not much successful. Cotyledon culture is a success.

7. Transgenic plants

Transgenic plants for disease resistance. Transfer of a particular gene from wild species thro' use of medium of carrier (plasmid) micro projectile bombardment direct transfer.

Transfer of disease resistance gene from wild species through plasmid is a success.

Ground nut varieties for Tamil Nadu

Varieties	Parentage	Duration
Bunch		
Co 1	Ah 6279 x TMV 3	105
Co 2	Mutant from POL 1	105
ALR 2	Selection from ICGV 86011	105
TMV 2	Selection from Gudiyatham bunch	105
TMV 7	Selection from Tennessee white	105
TMV 12	Selection from Uganada variety	105
POL 2	Pollachi Red x Ah 2105	105
JL 24	Selection from Taiwan variety	105
VRI 1	TMV 7 x FSB 7-2	105
VRI 2	JL 24 x Co2	105
VRI 3	J 11 x Robout 33-1	95
VRI 4	VG 5 x NCAC 17090	110
BSR 1	Selection from ICGV 86143	110
Co3	VRI 2 (VG 55 x JL 24)	105
ALR 3	(R33-1 x KG 68) x (NCA 17090 x ALR 1)	105
Semi spreading		
TMV 10	Natural mutant from Argentina	130
TMV 8	Selection from Manapparai local	135
Spreading		
TMV 3	Selection from west African variety 'Bassi'	140.

GINGELLY (TIL, ELLU)

Sesamum indicum $2n = 26$

Centre of origin : Africa

Related species : So far 36 species were recorded in the genus *sesamum* 20 of them occur in Africa.

Wild species utilised in breeding programme

S.alatum $2n = 26$

Resistant to phyllody *S.alatum* x *S.indicum* *alatum* is having dormancy.

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.

S.laciniatum $2n = 32$

Tolerant to phyllody, drought and jassid resistant.

Fertile auto allopolyploid produced by crossing *S.indicum* x *S.laciniatum*

↓
Sterile, Double.

S.prostratum occurs in S.India ($2n = 26$)

Tolerant to drought.

Breeding objectives

1. **Breeding high yielding varieties tolerant to drought.**

2. **Breeding white seeded varieties**

Finest quality of oil is obtained from white seeded lines.

3. **Development of mono stemmed varieties.**

By this more population per unit area and yield can be increased. Monostemmed varieties are low yielders.

4. **Development of multicapsule / axil and multicarpellary varieties.**

5. **Rice fallow varieties :**

Shorter in duration.

6. **Non- shattering varieties**

African lines.

7. **Resistant to disease**

Powdery mildew;

Phyllody - transfer from wild species.

Breeding Methods :

1. **Introduction** : African lines.

2. **Pure line selection.**

TMV4 - Sattur local

TMV5 - Srivaikundam local

TMV6 - Andhra local.

SVPR1 - Western Ghat white seed variety

3. Hybridization and selection.

a) Inter varietal

Co1 (TMV 3 x SI 1878) x SI 1878, TMV 3 (S.A local x Malabar local), Paiyur-1

b) Inter specific : Male sterile lines evolved by crossing with *S.malabaricum*.

4. Population improvement

5. Poly ploidy breeding

6. Heterosis breeding

Epipetalous nature makes emasculation and crossing easier

Use of CMS lines is also being attempted.

7. Embryo rescue technique.

SESAMUM VARIETIES FOR TAMIL NADU

Variety	Parentage	Duration
Co 1	(TMV 3 x SI 1878) x SI 1878	90
TMV 3	South Arcot local x Malabar local	80
TMV 4	Pure line selection	80
TMV 5	PLS from Srivaikundam local	80
TMV 6	Selection from Andhra local	85
SVPR 1	Selection from Western Ghat white	80
Paiyur 1	SI 2511 x SI 2314	90
VRI 1	Selection from Tripathur local	75

MUSTARD and RAPE SEED

Brassica sp (2n = 16, 18, 20, 22, 36, 38 and 48)

Brassicaceae or *cruciferae*

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

Vegetable type : Cabbage, Cauliflower, turnip

Oil seed type - Rape seed and mustard.

Taxonomy :

Harberd (1972) examined 85 species of **Brassica** and grouped species of the genus into cytodesmes. These cytodesmes are composed of different species with the same chromosome number and which are cross fertile and other having species with different chromosome number and cross infertile. According to him most important agricultural species are four diploids, three allopolyploids, each belong to a separate cytodesme.

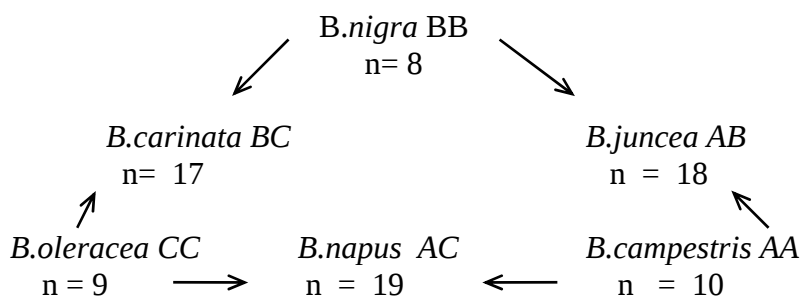
Four diploids are :

1. *B.nigra* - Black mustard
2. *B.oleracea* - Cabbage
3. *B.campestris* - Rape seed.
4. *B.tournefortii* - Wild turnip

Three allopolyploids

1. *B.napus* - Rape seed of Europe
2. *B.juncea* - Indian mustard
3. *B.carinata* - sthiplam mustard (veg / oil seed)

The genetical relationship between the oilseed brassicas are diagrammatically represented as follows.



B.napus will cross readily with *B.campestris* but with extreme difficulty in case of *B.oleracea*.

Rape seed

Botanical name	2n	Economic characters
1. <i>Brassica campestris</i>	20	Indian Rape Seed. Self sterile in nature. Important oil seed crop of North India. 3 Cultivated types. <i>B.campestris</i> var. Brown sarson <i>B.campestris</i> var. Yellow sarson

2. <i>B.napus</i>	38	<i>B.campestris</i> var. toria European Rape Seed. Self fertile.
Mustard		
1. <i>B.nigra</i>	16	Black mustard : Native of Eurasia. 28% fixed oil. Used as medicine pungent due to glucoside sinigrin.
2. <i>B.alba</i>	24	White mustard : Young seedling used as Salad, yellowish seed 30 % oil.
3. <i>B.juncea</i>	36	Indian mustard. RAI 35% oil. Leaves used as herb contains sinigrin.

MUSTARD

Breeding objectives :

1. **Seed yield** : Yield is the end product of many biological processes which are under control of complex polygenic systems. An ideal plant type is having increased branch number, pods per plant, seeds per pod and seed size. Further yield increase could result from increase in biomass and harvest index. Increased biomass can result from reduced photo respiration and increased light saturated rate of photosynthesis.

2 **Early maturity** : For use in various multiple cropping sequence.

3. Resistance to abiotic factors

Frost resistance is needed to prevent yield losses. Winter hardiness is very important.

4. Resistance to biotic stress

Powdery mildew

Black leg

Sclerotinia rot, alternaria blight

mustard aphid - so far no resistance source identified.

5. Herbicide resistance : (Atrazine simabine)

A few sources of resistance is available.

6. Shattering resistance

B.napus - highly shattering

B. juncea - tolerant. Introgressive breeding done.

7. Increased oil content and quality

High oil content 45% yellow seed varieties > oil.

For industrial purpose > Erucic acid.

Development of low erucic acid cultivars for edible purpose.

Reduced linolenic acid content is also desirable.

8. Meal quality

Meal having less Glucosinolate content.

Breeding methods :

1. Introduction - Regina from Sweeden

2. Simple selection

E.G. Seeta, Krishna, Kranti.

3. Hybridization and selection

Intervarietal

- a) Bulk method
- b) Pedigree method
- c) single seed descent

Inter specific

4. Back cross method

5. Population improvement

R S, mass selection

6. Heterosis breeding

CMS lines

7. Mutation breeding

E.G. Regina, RLM 198

8. Tissue culture technique for production of homozygous diploids

Saline resistance screening. Induction of mutation in haploids.

9. Embryo rescue technique for inter specific crosses.

CASTOR

Ricinus communis (2n = 20)

Place of origin : Ethiopia

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. macro carpus*
3. *R. micro carpus*

But this is not accepted by Botanists.

There are sub species which are considered to be ecological extreme varieties i.e. poly morphic 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 *cambogenisis*

Breeding objectives :

1. Long duration varieties for dry lands

S.A.1, Co1 perennial - Tall - Normal internodal, high node number.

Intermediate - Normal internode, low node no (13 or 10)

2. Short duration high yielding varieties suitable for irrigated mixed cropping conditions

TMV 5

3. Breeding non shattering spineless varieties

Baker variety of USA Non - Shattering.

4. Breeding for insect resistance

Semi looper, jassid. Hopper burn - serious in dry land varieties.

Triple bloom - TMV 5. - Triple bloom condition gives resistance.

5. Breeding varieties with low ricinin content.

Breeding Methods:

1. Introduction.

Hospet varieties.

Russian lines.

2. Selection

a) **Pureline selection** - Co 1 from Anaimalai local

b) **Mass selection**

TMV 3 - from South Arcot local.

3. Hybridization and selection

TMV 5 (SA2 x S 248/2)

TMV 6. (VP 1 x RC 962)

4. Population improvement

By using recurrent selection technique.

5. Mutation breeding Aruna castor

SA2 Natural Mutant from TMV 1.

6. Heterosis breeding

GAUCH - 1

100 % pistillate lines.

Geneic male sterility

Temperature plays a major role.

GCH 4

TMVCH 1 (LRES 17 x TMV 5)

SUN FLOWER

Helianthus annuus

Place of origin : North America.

Classification : The genus comprises nearly 67 species - all native to America. Of these two are cultivated.

a) *H. annuus* - diploid $2n = 34$

Oil seed crop.

b) *H. tuberosus* - Hexaploid $2n = 102$.

Jerusalem artichoke - cultivated for tuber.

Wild species : *H. hirsutus*, *H. rigidus* moderately resistant to *Alternaria*.

Putative parent : Weed sunflower gave rise to cultivated one. The weed sunflower was modified by introgression with *H. petiolaris*.

Cultivars of sunflower :

a) **Giant types :** 6 - 14 feet tall. Late maturing, Large heads 12 - 30" in diameter, seeds large, white or grey or with black stripes. Oil content is very low. E.g. Mammoth Russian.

b) **Semi dwarf varieties :**

Medium tall - 4 ½ to 6 feet, Early maturing. Heads 7 - 9" in diameter. Seeds smaller, black, grey or striped. High oil content 35%. E.g. Jupiter, Pole star.

c) **Dwarf types**

2 to 4½ feet tall. Early maturing. Head size 5½ - 6½ " diameter. Small seeds, high oil content 37%.

E.g. Sunrise, Morden, Co1, Co2

Breeding objectives

1. **To develop short duration varieties suitable for dry land and irrigated conditions.**

Dryland successful in black soils only. In red soil under rainfed it is not successful.

2. **Breeding varieties with high oil content :**

Ranges 38 to 48%. Complex character yield and oil content are negatively correlated. To increase oil content the shell must be thin.

3. **Breeding for self fertile lines.**

Protoandry and self incompatibility mechanism operates in sunflower. Hence hand pollination is necessary. To avoid this self fertile lines can be evolved.

4. **Breeding for disease resistance.**

Maharashtra hybrid susceptible to powdery mildew. Hence ban is there. Powdery mildew, rust, charcoal rot, *Alternaria*. Wild species like *H. hirsuta* are moderately resistance to *Alternaria*.

5. Resistant to pests

Heliothis , Grass hopper Jassids.

Breeding Methods:

1. **Introduction** : Morden from Canada.

2. **Mass selection:**

Ec 68414 from Russia. Co1 mass selection from Morden. Useful for characters which are highly heritable. E.g. Plant height, disease resistance.

3. Hybridization and selection

a) **Intervarietal** : E.g. Co2 Derivative of multiple cross
Co4 - (Dwarf x Surya)

b) **Interspecific** :

Wild species of North American origin and best Soviet varieties were crossed and number of varieties were evolved.

E.g. Progress.

Novelty

Jubilee 60-

They are resistant to *Verticillium* wilt also

4. Mutation

Co3 (Mutant from Co2 thro' gamma rays)

5. Head to row and remnant seed method

Developed by Pustovoit in Russia. By this method oil content is increased. In this method the following are the steps:

- From open pollinated type a large no (10,000 to 12,000) plants are selected based on Head size.
- The selected lines are analysed for oil content and high oil content lines are isolated (1000 plants).
- Part of the seed reserved and the part is sown in progeny rows along with check to estimate yield.
- Second season testing is also done. The best lines are identified.
- The remnant seed of elite plants which give high yield were raised in isolation and multiplied for crossing *interse* next season.
- The multiplied lines also tested for oil content and high yielding high oil content lines were raised in isolation and crossed *interse*.

6. Population improvement

By mass selection, recurrent selection and use of male sterile lines population can be improved and utilised for breeding.

7. Heterosis breeding :

Development of inbred lines and crossing them to harness heterosis was first done as early as 1920 in Russia. During 1970 cytoplasmic geneic male sterility was identified in wild types and obsolete cultivars. Now this system is being extensively used for production of hybrids.

First hybrid

BSH 1 CMS 234 A x RHA 274

BSH 2

BSH 8.

A number of CGMS lines were bred by Government as well as private seed growers and are utilised now.

Male sterility can also be induced by GA 100 ppm.

Steps

1. Development of inbreds.
2. Evaluation of inbreds for combining ability.
3. Conversion of inbreds into CGMS lines and R lines.
4. Production of hybrids.

Varietal renovation

In sun flower the varieties released are renovated annually to produce super elite (Breeder seed) and Elite Seed (Foundation seed).

SAFFLOWER
Carthamus tinctorius (2n = 24)

Place of origin : Africa

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

Classification of safflower :

Safflower can be grouped in to two broad categories.

1. The outer involucral bracts spinose, lanceolate mainly cultivated for oil. Flowers yellow in colour.
2. Involucral bracts moderately spined or spineless which are cultivated mostly for the dye than the spiny types. Flowers orange in colour.

Breeding objectives :

1. Breeding for high oil content :

Normal oil content is 32% of which 72% is linoleic acid, the factor which reduces blood cholesterol. Oil content is negatively correlated with yield. Wild species of *C.oxycanthus* having 28% oil were utilised in hybridization programme to increase yield and oil content but success was not achieved.

2. Breeding for non-spiny varieties with high oil content.

A very limited success was achieved Co1 safflower is an example for this.

3. Breeding varieties having thin shell

Thin shelled varieties have high oil content.

4. Breeding varieties for dry land conditions.

Under dry land conditions the spiny nature will be more pronounced. How ever dry land varieties with less pronounced spines were evolved. E.g. K.l.

5. Breeding varieties resistant to pest and diseases :

Pests like *Prodenia* and *Heliothis* are important pests. The wild species *C.oxycanthus* is moderately resistant to pests. This is being utilised in breeding programme.

NIGER
Guizotia abyssinica ($2n = 30$)

It is a cross pollinated crop oil content is 35 to 45 %. The inflorescence is a head or capitulum and heterogametes and florets are similar to that of sun flower.

The breeding objectives and methods are similar to that of sunflower.

FIBRE CROPS

COTTON (*Gossypium* sp.)

Diploid cotton : ($2n = 26$)

G.arboreum - Karunganni cotton

G.herbaceum - Uppam cotton

Tetraploid cotton : ($2n = 52$)

G.hirsutum - American cotton

G.barbadense = Egyptain cotton, sea island cotton.

A. Floral biology

Simple, solitary, terminal extra axillary, petals yellow to cream in colour, hermaphrodite, bracteoles called as epicalyx, three in number, free and deeply serrated and persistent at the base of the flower. Nectary gland is present on each bracteole. Calyx five united, cup shaped, corolla five, polypetalous, a purple spot is present on the inner side of the claw of the petal (petal spot) in some species. Androecium forming a staminal column (monadelphous), bearing numerous anthers. Ovary superior penta carpellary, style slender, passes thro' staminal column with three to five lobed stigma, ovules many in axile placentation.

B. Anthesis and pollination

There is much variation in case of flower opening. Asiatic cottons open between 8 and 10 AM. American cottons open much earlier. Temperature affects the flower opening. After flower opening the cream yellow colour corolla turns pink within a day and later changes to red. The receptivity of the stigma is 8 to 10 AM.

C. Selfing

Cotton is an example for often cross pollinated crop. Selfing is done by sealing the flower bud by using thread, paper clips, wet clay or mud and other devices to prevent entry of insects responsible for cross pollination.

D. Emasculation and crossing

Emasculation is done by removing the staminal column by giving a cut with thumb nail. Emasculation is done in the evening usually a day before flower opening. Immediately after emasculation the flower is covered with colour butter paper bag for easy identification next day morning. Pollen from the male flower is dusted on the emasculated flower by rubbing the staminal column of the male parent. Immediately after pollination the flower is covered with white butter paper bag and proper labelling is also done. This method is known as Doak's method.

E. Agencies dealing with Cotton Research

1. National Agency : CICR - Central Institute of Cotton Research, Nagpur
2. State level : CICR - Regional Station, Coimbatore. All India, Coordinated cotton improvement project
3. TNAU : Cotton Breeding Station, Coimbatore, RRS, Kovilpatti CRS, Srivilliputhur.

F. Varieties released

1. **Introduction** : **Cambodia cotton** in South India, **MCU- 1**

2. **Selection** : **K1** cotton reselection from SRT -1

3. Hybridization and selection

a) Inter varietal : **MCU 5** - Multiple cross derivative

MCU 6 - Multiple cross derivative

MCU 8 - Single cross hybrid derivative.

MCU 9 - (MCU 5 x MCU 8)

MCU 11 - (MCU 5 x Egyptian *hirsutum*)

b) Interspecific hybridization : Acala 1517 lines of *G.hirsutum* resistant to wilt and best fibre quality are due to natural crossing with *G.barbadense*. Evaluation of tetraploid cotton is due to interspecific crossing and natural doubling.

Old world diploid linted cotton (A genome) x *G.raimondii* (Dgenome)

↓
F₁ sterile

↓
Doubling

↓
G.barbadense
(AD genome)

Old world diploid linted cotton (A genome) x *G. thurberi* (D genome)

↓
F₁ sterile

↓
(Doubling)

↓
G.hirsutum
(AD genome)

4. Heterosis breeding

Both intraspecific and interspecific hybrids are evolved in cotton.

a) Intraspecific : *G.hirsutum* x *G.hirsutum* Shankar (H4) cotton of Surat (Gujarat 67 x American nectariless)

b) Interspecific hybrids : Varalakshmi (Laxmi x SB 289E)
(*hirsutum*) x (*barbadense*)
CBS 156 (Acala glandless x SB 10856)
DCH 32 (DS 26 x SB 425) (Jayalakshmi)
TCHB 213 (TCH 1218 x TCB 209)

G. Hybrid Seed production

1. DOAK's method of hybrid seed production

In this method, manual emasculation of flowers is done one day before anthesis, and pollination next day morning. For convenience, the parental varieties are grown in same fields in the ratio of 4:1 (Emasculation and pollination is done as described earlier).

2. Use of male sterile line

Cytoplasmic, genic male sterility was developed by Vesta G. Meyer an American scientist. She obtained CMS lines by transferring *hirsutum* genome to the cytoplasm of wild species *G.harknessi*. Restorer lines were also developed in *hirsutum* and *barbadense* back ground. Genic male sterility was also observed in cotton but utilisation is difficult due to segregation of sterile line in 50:50 ratio of sterile and fertile and maintenance of sterile line is laborious.

Another type of male sterility is transformation of staminal column into a petaloid condition. This was obtained when *G.arboreum* genome is transformed to cytoplasm of *G.anamalum*

3. Practical difficulties in use of CMS lines for hybrid seed production

- Lack of simply inherited restorer gene that maintains fertility over a wide range of environment.
- lack of development of good combiners possessing male sterile cytoplasm and restorer factor.
- Lack of dependable and economic method of controlling pollination by insect pollen vectors.

4. Mutation breeding

MCU 7- Xray irradiated mutant of L 1143

MCU 10 - Gamma irradiated mutant of MCU 4

5. Population improvement followed in USA

- Recurrent selection : Pima S₁ Pima S₄ of *G.barbadense*
- Synthetic variety : Deltapine 15 developed at konyvllwer USA.
- Composite : Pima 17 of *G.barbadense*.

H. Special breeding techniques in cotton

a) Bulk progeny method (Texas method)

In commercial cotton varieties with a broad genetic base is desirable so that they have the adaptability to the requirement of varied and widely different environmental conditions. Texas method provides such plasticity.

- Open pollinated seeds of selected F₂ single plants are grown in replicated randomized block design along with standard check variety. Best progeny are marked and harvested on single plant basis. Yield and fibre quality will be assessed and best ones will be selected and seeds will be bulked for testing in F₄.
- Again the F₄ bulks are also tested in replicated randomised block design the process done in F₃ is repeated.
- The F₅ and F₆ progenies are tested in MLT and later released as variety.

b) Mass pedigree selection technique of Harland

This system was used by Harland for the improvement of Peruvian cotton variety with spectacular success.

First season : Examine a large number of selected single plant from a heterogenous commercial crop and fix up specification or norms for making selection.

Second season :

- Grow progeny rows of single plants in replication

- (ii) Examine bulk samples from these progeny rows and eliminate rows failing to confirm to the norms fixed during first season. This is known as bulk norm test
- (iii) Examine the single plants in the selected progeny rows and eliminate the plants failing to confirm to the norms. This is called 'single plant norm test'.

Third season

Repeat the bulk norms test as done in second season and select the best lines.

Fourth season

Mix the seeds of selected lines and raise the multiplication plot and distribute them.

COTTON
TCHB 213 SEED PRODUCTION GUIDELINES

Parentage : TCH 1218 x TCB 209
 (*G.hirsutum*) (*G.barbadense*)

For the seed production in an area of one acre, the female parent TCH 1218 is to be raised in 80 cents and the male parent TCB 209 in 20 cents.

Spacing

For female parent 4' x 2'

Male parent 3' x 2'

Synchronisation

Sowing of male parent should be advanced by 15 days. The male parent should be sown 5 meters away from the female.

Seed rate

Female parent : 800 g

Male parent : 200 g

Season

August. Dibble the seeds of male parent at 2 seeds/hill on 1st August and female parent on 15th August.

Emasculation and pollination

Emasculate and pollinate as far as possible in the buds appearing during the first six to eight weeks of reproductive phase to ensure good setting and development of bolls.

Restrict emasculation to each day evening from 3 to 6pm and pollination next morning between 9 AM to 1 PM.

Cover the male buds in the previous day evening with butter paper bag for their use in the next day.

Emasculated buds may be protected with butter paper bag. Tie a thread to the pedicel of the bud immediately after pollination.

Close the crossing programme after 9th week from commencement of crossing and flowers appearing subsequently are removed to facilitate proper development of crossed bolls.

Nip the top and side shoots to arrest further vertical and horizontal growth respectively.

Normally one flower from the male parent will cover 5 to 10 flowers of the female parent for crossing.

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.

Capsularis strains are characterised by a single flush of flowering at the end of single vegetative period. Based on maturity, the varieties in *Capsularis* are divided in to
Early - Flowering in July
Medium - August
Late - September.

Breeding objectives

1. Breeding for high yielding short duration jute varieties.

Early varieties are generally low yielders whereas late varieties are high yielders. So to combine high yield with earliness is one of the main objectives. Yield is positively correlated with plant height, basal diameter of stem, fibre-stick ratio. Higher photo synthetic capacity with increased lamina length, breadth, petiole length and leaf angle at 40° also contribute to yield.

2. Breeding for quality fibre

In jute quality is negatively, correlated with yield. The quality characters are

- a) Fibre length.
- b) Fibre strength
- c) Fibre colour
- d) Lustre
- e) Percentage and quality of retting
- d) Proportion of faults such as roots, specks, knots.

Environment plays a major role in quality. Alternate and fluctuating bright sunshine, humidity and temperature and rainfall at minimal level are favourable for improved quality.

Further retting in clear and slow running water gives good quality fibre. The tall and thick plants in general gives inferior fibre than that in short and thick plant.

3. Breeding for pest and disease resistant varieties

In pests, stem borer and aphids cause greater damage and in diseases *Macrophomena* is major. Though resistance sources are available in other related species, the crossability barrier prevents transfer.

4. Breeding varieties for high seed yield :

Since jute is cut for fibre at 50% flowering stage, it is essential to reserve some plants for production of seeds. The fibre obtained from seed crop will be poor in quality. Hence it is necessary to breed varieties specially for high seed production with out losing quality characters.

5. Breeding for *olitorius* varieties having non-shattering habit coupled with non-pre flowering habit.

JRO 524

JRO 7885

Sudan green x JRO 632

Breeding Methods:

1. Germplasm building and Utilisation

Central Jute Technological Research Institute, Calcutta is maintaining the Jute collections. This shows wide range of variability thus offering a great scope for improvement by selection and hybridisation.

2. Introduction : Introduced short duration varieties are Jap green, Jap red, Jaichung sudan green.

3. Hybridization and selection

a) **Inter vareital:** Multiple crossing and selection are followed both in *olitorius* and *capsularis* improvement.

In *olitorius* improved varieties are JRO 524, JRO 7885.

In *capsularis* JRL 412, JRL 919

Since yield and quality are negatively correlated a balance must be struck in breeding for improved varieties.

b) **Inter specific cross:**

So far not successful. Attempts were made by straight cross mixed pollen method, Stigmatic paste method, self anther paste method, stigma cut method polyploidy breeding. But none of them proved successful. Difference in embryo endosperm growth is the reason

4. Mutation breeding : Using x rays useful jute mutants were obtained at Calcutta JRC 7447 and Rupali two varieties.

MESTA, KENAF
BIMLI JUTE
Hibiscus cannabinus
H.sabarriffa Var.*altissima*
Malvaceae
In Thailand **Siami jute** or **Roselle in India.**

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 *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.sabadariffa 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.

Breeding objectives :

1. Breeding of high yielding short duration mesta varieties

(Similar to Jute)

2. Breeding for quality fibre

(Similar to Jute)

3. Breeding for pest and disease resistant varieties.

BREEDING FORAGE CROPS

Procedures in breeding forage crops are based upon the same genetic principles utilised in the breeding of other crops. Yet, forage breeding presents certain difficulties which must be recognised and understood by the breeder. The difficulties arise from the diversity in pollination of the different species, irregularities in fertilization and seed setting, the perennial nature of most forage species, and differences in the evaluation and maintenance of new strains. Examples are :

- (a) Most important forage species are cross pollinated. The heterozygosity in cross-pollinated species makes it difficult to propagate and maintain the identity of lines.
- (b) Self incompatibility is common in many forage species, limiting the extent to which they may be inbred.
- (c) Many forage species have small floral parts, making artificial hybridization tedious.
- (d) Some grasses reproduce largely by apomixis (seed setting without union of sperm and egg) presenting problems in crossing and obtaining gene recombination.
- (e) Many forages are poor seed producers, or produce seed of low viability
- (f) Many forages produce weak seedlings and stands are not easily established.
- (g) Isolation and clean land on which new strains may be increased without contamination are not always available.
- (h) The initial evaluation of selected plants or lines in the breeding nursery is generally based on the performance of spaced plants or rows, which may not accurately represent the performance of the strain in a thickly seeded stand as grown by the farmer.
- (i) Forage species are often seeded in mixtures with other species which complicates the evaluation of individual strains.
- (j) Strains may perform differently with different systems of grazing management
- (k) Most forages are long-lived perennials and many years are required to evaluate persistence and productiveness of new strains.
- (l) Many forage species are polyploids, which increases their genetic complexity.

Varieties released

- | | |
|---|---|
| 1. Cumbu napier hybrid grass | : NB 21 from Ludhiana
BN 2 from West Bengal
CO 1 (PT 2787 x <i>P. purpureum</i> ; Merkeri)
CO 2 (PT 8369 A x <i>P. purpureum</i>)
CO 3 (PT 1697 x <i>P. purpureum</i>) |
| 2. Cenchrus (<i>Cenchrus glaucus</i>) | : CO 1 (Selection from Kangaysm Local ; FS 391) |
| 3. Fodder sorghum | : CO 27 (CO 11 x <i>S. halepense</i>) - inter specific
hybrid derivative. |
| 4. Maize | : African Tall (Composite) |
| 5. Cumbu | : CO 8 (732 A x Giant Bajra) (Composite) |
| 6. Lucerne | : CO 1 (Mass selection from Coimbatore local) |
| 7. Cowpea | : CO 5 (Gamma ray mutant from CO1) |
| 8. Velimasal | : CO 1 (Introduction from Thailand in 1967) |
| 9. Lucaena | : CO 1 (Hawaian Giant) selection from K.28 |

10. Deenanath	: CO 1 (Gamma ray mutant from Pusa 3)
11. Guinea grass	: CO 1 (Clonal selection from Coimbatore local)
12. Muyal masal	: <i>Stytosanthes scabra</i> - Introduction from Australia cv. Fitzoroi.

Breeding

The two main groups of forage crops are grasses and legumes. For grasses the following characteristics are important and should receive attention in any breeding programme.

1. Yield of digestible nutrients and their distribution.
2. Persistence - Perennially
3. Ease of reproduction.
4. Ease of management.
5. Palatability

1. Yield of digestible nutrients and their distribution : Yield in terms of both quantity and quality is more important. Quantity depends upon genotype as well as environment the quality characters include protein, fat, fibre, carbohydrate, minerals and vitamins. This depends on nature of the species, stage of growth when it is cut for grazing.

2. Persistence : The persistence of the herbage is also influenced by the vigour and growth habit of the species, and its tolerance to drought and temperature variations. Persistence is lacking in grasses due to disease, pests, drought, excessive grazing. Persistence can be increased by agronomic methods than by breeding. However this character is also to be borne in mind while taking up breeding programmes.

3. Ease of reproduction : High foliage yield often associated with poor seed set. So a compromise is to be arrived while taking up breeding programme.

4. Ease of management : The forage grass must have high seedling vigour so that it can be established easily. Since grasses are grown as mixtures there cannot be separate management practice for them. It has to grow along with other crops.

5. Palatability : It is not linked with nutritive value. But palatability decides the intake of forage/fodder. Leafiness and succulents are more important.

Based on the above the objectives of forage crop improvement may be :

1. Ability to grow well and quickly both independently and in association with legumes.
2. Resistance to pests and diseases, drought and frost.
3. Suitable growth habit - Short types or grasses for grazing. Tall types for hay making.
4. Prolific seeding and non seeding types, ease of vegetative reproduction.
5. Elimination of undesirable characters such as HCN in sorghum and Sudan grass, coumarin in sweet clover, steamininess in grass or dry, pithy culms, presence of awns and leaf shedding.

Breeding procedures

Forage crops, based on their mode of pollination can be divided into following groups.

1. Largely cross pollinated : Eg. *Pennisetum*, *S.halapense*, *Cynadon*, Lucerne.
2. Largely self pollinated : Eg. Sudan grass, *Vicia*
3. Largely apomictics : Eg. *Panicum maximum*, *Paspalum dilatatum*
4. Largely dioecious : Eg. *Poa arachinifera* (Pasture grass)
5. Sterile : *Digitaria procumbens*

Breeding methods normally adopted are of three types

1. **Self pollinated crops** : Controlled hybridization and selection, back crossing and selection, mutation breeding.
2. **Cross pollinated crops**: Individual plant selection, Mass selection, Inbreeding and hybridization, Recurrent selection, Synthetics, Composites.
3. **Apomictics** : Clonal selection and propagation. Controlled hybridization and propagation where there is some amount of seed set.

A. Forage grasses

1. Guinea grass *Panicum maximum*

Origin : Africa

Breeding objective - To get high yielding varieties with drought and cold tolerance, more protein, high leafiness, amenable for frequent harvest.

Method

Though there is seed set in this crop, they do not mature simultaneously. So vegetative propagation is the best method.

Crosses can be made between selected parents and the best hybrid can be clonally propagated.

Introduction

True seed sowing & selection

Clonal selection

Hybridization and selection

Mutation

2. Napier grass : *Pennisetum purpureum* or Elephant grass

Origin : South Africa

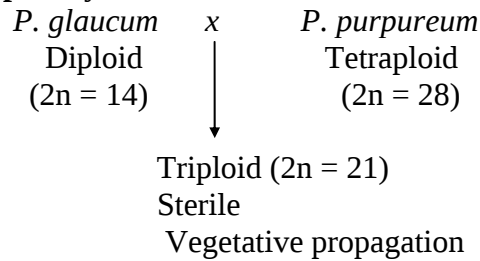
Clonal Napier identified this and it was named after him.

It is Rhizomatous, perennial and tall growing.

Improvement

Clonal propagation is the method. Another inter-specific cross and maintenance by vegetative propagation.

3. Cumbu Napier hybrids



Napier grass is season bound flowering will be during Oct-Dec only. So crossing between Cumbu x Napier grass is done at that time easily. Use of Cumbu as female - identification of selfed one in shorter period possible.

Breeding Objectives

1. High yielding varieties with less oxalate content.
2. Less pubescence and serration.
3. Drought resistant
4. More leafiness and amenable for multicut.

Methods

1. Introduction
2. Selection
3. Hybridization
 - Intervarietal
 - Interspecific

4. *Cenchrus* sp. Kolukkattai grass

Cenchrus ciliaris - White kolukkattai

Cenchrus setigerus - Black kolukkattai

Cenchrus glaucus - Blue buffel

Origin : India

Propagation by seeds and slips

Apomictic lines are also available

Pusa giant cenchrus : Hybrid between

Cenchrus ciliaris x *Pennisetum ciliare*

(India) (USA)

Sterile, Clonal propagation.

CO 1 Neela Kolukkattai pillu: released from Department of Forage crops, TNAU.

5. Marvel grass

Dicanthium annulatum

D. cariconum

A small genus of perennial grasses, rarely annuals, distributed in all tropical regions. Six species occur in India of which two are important as fodder grasses. It is considered as one of the best grasses in India.

Seed setting is poor. So rooted slips are used for propagation.

Improvement

By crossing and vegetative propagation.

6. Johnson grass - *S. halapense*

It is native of Africa. It was taken to USA by colonel Johnson and hence named after him. In S. India it occurs both as $2n = 20$ and 40 forms. Because of rhizomatous condition it will spread easily

Coll x *S. halapense* - CO 27 fodder cholam.

B. Forage legumes

- Based on pollination behaviours forage legumes can be classified as
1. Self pollinated
Arachis marginata, *Clitoria ternatia*.
Desmanthus virgatus, *Macrotylenema uniflorum*
Phaseolus trilobus, *Vigna trilobus*
 2. Often cross pollinated
Mass selection.
Single plant selection,
Hybridization and selection,
Mutation. Eg. *Vigna*. sp. Co5 (Co1 cowpea irradiated)
 3. Cross pollinated
Red clover, Lucerne
Many of the cross pollinated species are self sterile - Lucerne
Lucerne ; *Medicago sativa*
Origin : South West Africa
Bur clover *Medicago hispoda*
Black medicago *M. lupulina*

Medicago sp

The genus includes 65 species native to Europe. Some of them are weeds and some are useful for forage.

M. sativa - Lucerne

M. lupulina

M. falcata useful fodders

POLLINATION

In alfa alfa bees are the most important insect pollinators. Pollen is dispersed by an explosive action commonly known as **tripping**. When the keel petal is pressed by the weight of the bees, the stamens and stigma are snapped upward and came out free of keel just like a spring action. The insect is struck by the staminal column and a mass of pollen is carried by it.

Artificial pollination in Lucerne can be made without emasculation because of the self sterility nature. The occasional self fertile lines can be identified with the use of marker genes. While making artificial pollination care must be taken to take the operation in screen houses where the visit of insect (honey bee) is prevented.

Selfing is done with the help of bagging the flowers.

Breeding methods

1. Introduction
2. Mass selection
3. Hybridization and selection
4. Synthetics and composites
Ranger alfa alfa of USA
5. Poly cross method: in forage crops for the development of multiplant synthetic

This is adopted to develop a multiplant synthetic in vegetatively propagated forage crops. The first step is collect a number of desirable plants and form a source nursery. From the nursery twenty five to fifty superior plants are selected and grown in isolated nursery. Random cross pollination takes place in the isolation. The seeds are harvested and grown as progeny rows. Then the best ones are selected and clonally propagated.

These selected clones are again raised in isolation for random crossing and a synthetic is established.

SUGAR CANE

Saccharum sp

Six species of perennial grasses all of which originated in old world. Of these six two are occurring in a wild state. They are *S.spontaneum* with a wide distribution from North East Africa thro' Asia to pacific. *S.robustum* confined to New Guinea and neighbouring islands. The other four species are cultigens

1. *S.officinarum* - Noble cane of New guinea.
2. *S.barberi* - North Indian canes
3. *S.sinensis* - Chinese cane.
4. *S.edule* - Melenesian cane.

Systematics, origin and distribution

1. *Saccharum spontaneum* (2n = 40 - 128)

A perennial grass, free tillering, often with Rhizomes. *S.spontaneum* represents a polyploid series. Forms with the smallest chromosome numbers are found in North India which is probably the centre of origin. Natural hybridization with *S.officinarum* would have produced *S.barberi* and *S.sinense*

S.spontaneum is widely used in breeding of modern commercial hybrids by a process of nobilisation with *S.officinarum*. *Spontaneum* provides vigour, hardiness and resistance against diseases.

2. *Saccharum robustum* : (2n = 60 - 194)

Origin New guinea vigorous perennial. *robustum* would have given rise to *S.officinarum* with which it is interfertile. *S.robustum* is highly susceptible to mosaic virus and leaf scale and because of this its use in breeding programme is very much limited.

3. *Saccharum officinarum* (2n = 80)

Origin : South pacific.

Chewing cane.

Noble cane

This cane is suited to tropical conditions and requires favourable soil and climate for its performance. The stems are stout thick high in sucrose, low in fibre and with soft rind. The noble canes are susceptible to most of the diseases. Some of the earlier cultivars are Bourbon, Cheribon, noble canes.

4. *S. barberi* 2n = 82 - 124

S.barberi is short medium to slender in thickness, with high fibre content, medium sucrose content and poor yielder.

5. *S.sinense* : (2n = 18)

Chinese cane. Tall vigorous, slender, high fibre content. Poor juice quality.

6. *S.edule* : Polynesian cane (2n = 118)

Slender, weed like form. Seeds are edible. Not much used.

Nobilisation in Sugar cane.

Nobilisation is crossing the noble cane *S. officinatum* with *S. barberi*, *S. spontaneum* and infusing disease and pest resistance in the noble cane. The first successful use of nobilisation was made and variety cheribon was crossed with *S. barberi* variety and progenies having resistance to *sereh* disease were evolved. But they were susceptible to mosaic and inferior in sucrose content. By subsequent crossing with *S. officinatum* i.e. second and third nobilisation good varieties like POJ 2878 were evolved.

In India, nobilisation of local *spontaneum* was begun by Barber and Venkata raman in 1912 at SBI Coimbatore. At coimbatore crosses were initially made between local strains of *S. barberi* (Which is unproductive but adapted to climates of North India) and tropical noble cane (thick soft stem, high sucrose content but unsuited to climates of North India). Later on by crossing these resultant hybrid with wild cane *S. spontaneum* canes with high sucrose content suitable for North India were evolved. In this way a large number of tri hybrid canes were developed.

Breeding objectives.

1. Breeding varieties suitable for Jaggery making.

Co 853, Co 62175, CoC67

2. Breeding varieties for factory purposes - high Brix value and recovery %.

Co 658, Co 772, Coc 8001

3. Breeding varieties suitable for all the three seasons

Early - Dec - Jan

Mid - Feb - March

Late - April - May.

4. Breeding varieties resistant to shoot borer.

5. **Breeding varieties resistance to disease** shoot disease, Rust, Brown spot.

6. Breeding varieties with high ratooning ability.

7. Breeding varieties with drought resistance.

8. Breeding varieties with more number of productive tillers.

9. Varieties with shorter duration without yield less.

COC 671

Sugar cane varieties for Coimbatore :

Early		Mid		Late		Special
Factory	Jaggery	Factory	Jaggery	Factory	Jaggery	COC 90063
COC 91061	COC 91061	COC 776	COC 774	Co 740	Co 8201	Co 8021
Latest variety	COC 99061					
	(Co 6806 x Co 740)					
Suitable for mid and late season.						

SUGAR BEET

Beta vulgaris ($2n = 18$)

Chenopodiaceae

Place of origin : Northern Europe

Classification : The genus *Beta* includes thirteen species which have been grouped under Four sections. Viz.

- | | |
|----------------------|---------------------|
| 1. <i>Vulgares</i> | <i>B.vulgaris</i> |
| 2. <i>Caollinae</i> | <i>B.maritima</i> |
| 3. <i>Nanae</i> | <i>B.macrocarpa</i> |
| 4. <i>Patellares</i> | |

Includes both $2n = 18$ and 36 form

B.nanae

3 species all of them $2n = 18$

The cultivated *Beta vulgaris* includes Beet Sugar, Vegetable beet root and forage beet root. All the members of section *vulgares* inter cross freely.

Bolting in Sugar beet :

Sugar beet is normally a biennial. It develops a large succulent root the first year and a seed stalk the second year. Occasionally a plant will produce a seed stalk the first year itself which is known as **bolting**. The **bolters** do not make a normal. root development and so the yield will be reduced. Bolting can be induced by prolonged cool periods which is utilised for seed production. Certain wild species are annual in habit.

For rapid generation advancement in breeding programme as well as for seed production the process of **Photothermal induction** is used. This involves continuous artificial light and cool temperature.

The procedure for photothermal induction of sugar beet is as follows

a) **Pre induction period** : The plants are grown in pots for two weeks in screen house. Provide a continuous light from 150 watt electric bulb which is 30 inches height from pot.

b) Induction treatment :

Continue the provision of light but it must be from 20" ht. This is done for ten weeks. During this ten weeks period temp. Maintained at 46 to 49°F

c) **Post induction period** :

Transplant the seedlings in field. Continue the lighting for another two weeks. Prevent warm temperature. By this way we can get seeds with in 6 months. But seeds obtained will be smaller in quantity

Botany

Sugar beet is usually cross pollinated they exhibit a high degree of self incompatibility which is the main reason for cross pollination. The flowers produced singly or in dense clusters. the flowers are small, without petals and perfect. Stamens five in number. Ovary generally one seeded. the perianth of clusters of flowers fuse together forming a **multi seeded condition**. i.e. Seed Ball.

The seed Ball when germinate produces cluster of seedlings which requires the humidity. So mono seeded varieties are needed which is useful for the breeding objectives.

Crossing technique :

In self fertile lines selfing is done with paper covers. Emasculation in such lines is done by pulling out anther with needle and forceps. Dusting of pollen can be done with in a **week's time**. In self sterile lines use of red color hypocotyl lines as pollinators (male parent) we can easily identity F₁s.

Breeding objectives :

1. Breeding for disease resistance

Curly top Virus, *cercospora* leaf spot and root rot.

2. Breeding for Non-bolting types

Which allow earlier growing F₁ consequent longer growth period.

3. Breeding for monogerm seed

Flowers are produced singly.

4. Breeding for quality :

Between harvest and processing sugar beets are generally kept for a long periods in large piles where considerable storage loss of sugar will occur. Breeding for improved storage quality includes.

a) Selection for **low respiration** rate in roots.

b) Resistance of roots to storage rot.

Other quality characters are **TSS, purity of juice, raffinose content, ash and nitrogen content.**

Breeding Methods :

1. Mass selection :

This is utilised in developing curly top virus resistant varieties.

2. Family line breeding :

It is more or less similar to ear to row breeding Cross mother beets are carefully chosen for yield, sugar content and they are tested in progeny rows. While testing for performance in progeny rows, part of seed is kept as resistant seed. After identifying best performers in progeny rows, the remnant seeds are utilised for further multiplication.

3. Hybridization and selection

This is a time consuming process because of biennial nature of the crop. By following photo thermal induction rapid generation advancement is made possible.

POTATO
***Solanum tuberosum* (2n = 48)**

Tetraploid

Place of origin : South America.

Ancestry :

- a) Natural doubling of diploid cultivar *S. stenotomum* (2n = 24)
- b) By a natural crossing of diploid wild species
S. sparsipilum and *S. vernerii*

Classification : According Hawkes (1992) in addition to *solanum tuberosum* some six other cultivated species and over 230 wild species of potato are generally recognised.

Diploid (2n=24)

- 1. *S. ajanhuiri* - Frost resistant
- 2. *S. phureja* - Sort duration. 4 month no dormancy
- 3. *S. stenotomum* - Longer in duration 6 months dormancy.

Triploid (2n = 36)

- 4. *S. chaucha*
- 5. *S. juseczuki*

Tetraploid (2n = 48)

Solanum tuberosum

- 6. subspecies

S. t. ssp tuberosum

S. t. ssp andigena - High altitude potato

Pentaploids

- 7. *S. curtilobium* - Frost resistant.

Breeding objectives :

1. Breeding for high yield

Yield of tubers decided by number of tubers, tuber size and distribution of tuber.

2. Breeding for varieties having better morphology of tuber

Better morphology of tuber is determined by

- a) Eye depth
- b) flesh colour
- c) Growth cracks
- d) Hollow heart
- e) Shape
- f) Skin colour

3. Breeding for better quality:

Depends on many factors

- a) After cooking blackening

- b) Dry matter.
- c) Enzyme browning.
- d) Glycoalkaloid level
- e) reducing sugar content
- f) storage properties

4. **Breeding for disease resistance**

Early blight, late blight, powdery scab., *verticillium* wilt, virus diseases.

Resistant source : *S.demissum*, *S.acaule* ssp. *andigena*

5. **Breeding for pest resistance**

Nematode is the major pest ssp.*andigena* - tolerant.

S.verineii resistant to Aphids, Colorado beetle.

Breeding methods

1. **Clonal propagation ;**

Useful in case of inter-specific crosses where low fertility is often seen in the progenies. Further fixing of heterosis is easy. The disadvantage is keeping the stocks free from disease. But by following *invitro* propagation this can be over come.

2. **Controlled pollination :**

In potato it is some what easy because the anthers do not dehisce before or soon after flower opening. The pollen is not easily distributed by wind. If we raise crossing block in insect proof screen house use of selfing and crossing covers not needed.

Only difficulty is crossing in percentage of seed set. Crossing is to be done at 22°C. Pollen and ovule sterility occur.

3. **Population breeding**

This is followed to improve the base population.

4. **True potato seed (TPS)**

Propagation thro' use of seed - practiced in China. By this method virus diseases can be avoided.

5. **Production of diploids and monohaploids**

Originally diploid was produced by crossing *tuberosum* with diploid *s.phureja* and allowing for parthenogenesis. But now by anther culture it is easily produced.

6. **Mutation breeding**

To change the skin colour it is extensively used.

TAPIOCA (CASSAVA)
Manihot esculenta (2n = 36)

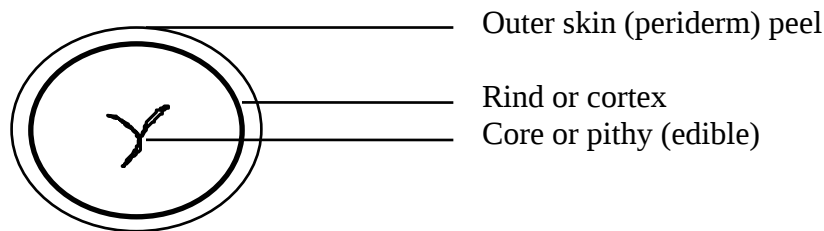
Family: Euphorbiaceae

Origin: Central America.

There are no wild species seen in the cultivated *Manihot esculenta*. The cultivated cassava can be classified into two broad groups viz. a) Sweet cassava and b) Bitter cassava.

- a) **Sweet cassava** : Shorter in duration tubers maturing in 6-9 months. The cynogenic glucoside is confined mainly to the outer skin (periderm).
- b) **Bitter cassava** : Longer in duration 12-18 months to mature, the cynogenic glucoside is distributed throughout the tuber including core. The glucoside will be more in varieties having yellow flesh.

Structure of tuber:



- i. **Periderm** : Composed of dead cells which seals the surface of the tuber. Normally brown in colour.
- ii. **Cortex**: 1- 2 mm thick, usually white in colour but may be some time pinkish or brown. The periderm and cortex are collectively known as peel.
- iii. **Core or pith**: It is the edible portion and consists mostly of parenchymatous cells containing large amount of stored starch. Latex in tuber occur in the flesh of the tuber and also on the cortex.

Root tuber development:

The cassava tuber originates when secondary thickening occurs in a fibrous root that has previously been entered in the soil. As such, tuber growth consists essentially of increase in girth of a root. The increase in girth commences by the end of second month after planting and accumulation of large amount of starch taken place. Accumulation of starch occurs first at proximal end (towards attachment of root) and later at distal end (away from attachment). Physiologically the cassava tuber is inactive, since no eyes or buds present, as such cassava tuber cannot be used as a means of propagation.

SWEET POTATO *Ipomoea batatas*
(Hexaploid - $2n = 90$)

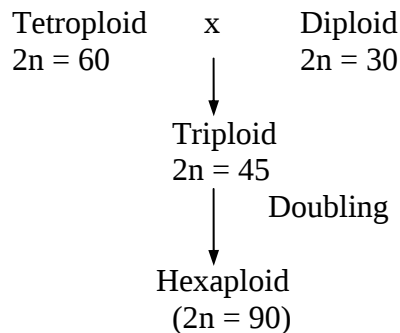
Family : Convolvulaceae

Origin : Central America

Progenitors: The probable ancestors are *Ipomoea tiliacea* – closely resembling *I.batatas*.

Weedy species - *I.trifida*

Sweet potato was derived by amphidiploidy by crossing a tetraploid ($2n = 60$) and a diploid ($2n = 30$) hybridization to produce a triploid ($2n = 45$), followed by subsequent doubling of chromosome to produce hexaploid ($2n = 90$)



Classification:

This family includes about 45 genera and 1000 species. But only *Ipomoea batatas* is of economic importance as food. A large number of tuber structure after cooking the cultivars can be grouped in to three.

- a) those with firm, dry, mealy flesh after cooking
- b) those with soft, moist, gelatinous flesh after cooking
- c) those with very coarse tubers which are suitable only for animal feed or for industrial use.

23. Breeding Fruit Crops

MANGO

Mangifera indica

Family : Anacardiaceae

Floral biology

Flower starts opening early in the morning from 4-7 a.m. and maximum flowers open between 9.30-10.30 a.m. and complete 11 a.m. Dehiscence of anthers takes place at 11.30 a.m. and it continues up to 3.45 p.m. The pollen grains are oval, or triangular or oblong. Stigma becomes receptive even 18 hours before flower opening. Mode of pollination is entomophily; nectar is present to attract the insects.

The flowering duration is usually of short i.e. 2 to 3 weeks. The mango inflorescence or panicle bears mainly two types of flowers – male and perfect. The number of flowers per panicle varies between 1000 to 6000 depending upon the variety and climatic factors. The percentage of perfect flowers varies between 0.74 per cent in Rumani, 16.41 to 55.7 per cent in Neelum and up to 69.8 per cent in Langra.

Hybridization: Since a large number of male and perfect flowers are borne on a mango panicle, it requires a special crossing technique.

The panicle should be bagged with a muslin bag (60 cm x 30 cm) fully stretched and fixed with two rings and a rod made of spliced bamboo. A piece of thick iron wire can also be made into a good frame for stretching the muslin bag over the panicle.

Staminate flowers of the selected panicle to be used as female parent should be removed daily before dehiscence. Panicles of the variety selected as male parent should also be bagged before their flowers begin to open. Freshly dehiscent male flowers should be carried in a small petridish lined with a filter paper and covered with another petridish to protect the flower from

contamination with foreign pollen carried by insects.

Perfect flowers should be emasculated early in the morning before dehisced. Freshly dehisced anther of the male parent should gently be brushed against the stigma which should then be examined under lens to see if pollen grains have adhered to it.

As the pollination of flowers in any one panicle is carried over a number of days, only the pollinated flowers should be allowed to remain on the panicle. It has been found advantageous to keep the panicles enclosed in bags till the fruits set and develop slightly.

The conventional method of pollination is time consuming, cost intensive and inefficient because of tallness and difficult to handle trees and poor fruit set. 'Caging technique' for crossing, developed at IARI following the discovery of self incompatibility in Dashehari, Langra, Chausa and Bombay Green, involves planting of grafted plants of the self incompatible varieties along with those of male parents enclosed in an insect proof cage and allowing pollination by freshly reared house flies and thus doing away with the tedious hand pollination.

BANANA

Musa sp.

Family : Musaceae

Floral Biology

Flowers are placed in the axils of the bracts, arranged biserially and number about 12 to 20 per node. Basal flowers behave as pistillate flowers while the terminal ones as staminate. At the bottom end, they form a bulbous male bud. Pistillate flowers are large in size and have well developed ovaries. Stamens (5) are reduced to staminodes, ovary inferior and trilobular. Style stiff and long, stigma club shaped and sticky. Staminate flowers have long stamens 5, filaments filiform, free, anthers two lobed. The female and male flowers open by 6.30-8.00 a.m.

Hybridization Technique

Undehiscent anthers of male flowers are collected and twisted gently to force them to dehisce. Using a soft hairbrush, the pollen grains are taken out and smeared gently over the stigmatic surface of the female flowers, which opened on the day of pollination. The pollinated

flowers are to be covered with soft cloth bag.

CITRUS

Citrus sp.

Family :Rutaceae

Floral biology

Flowers are produced on current season growth in cymes, both axillary and terminal position. Two types of flowers, perfect and imperfect are found. The flowers are white in colour in most of the species except lemon and citron where they are purplish on the outside.

Flower opening, starts from morning and extends up to evening but maximum anthesis is between 11.00 a.m. to 12.00 noon. The viability of pollen grains varies from 45-80% depending upon the season.

The dehiscence of anthers takes place there 45 minutes before anthesis or within 45 minutes after anthesis. It varies up to 5 hours after anthesis.

The receptivity of stigma starts either 15 minutes to 2 hours before anthesis or within 35 minutes to 5 hours after anthesis depending upon weather. The receptivity lasts for 4-8 days after anthesis.

Hybridization Technique

The mature flower buds on the female parent are emasculated early in the morning on the day of opening and are bagged. The flowers to be used as male parent are bagged the previous evening. The next morning as the day warms up; the anthers dehisce releasing the pollen grains when these flowers can be plucked to pollinate the receptive stigmas of emasculated flowers. The pollinated flowers are bagged, opened after about a week and allowed to mature into ripe fruits. In some cases, especially when the trifoliate orange is used as male parent, difficulties are encountered as its flowering is over before other citrus varieties flower. Therefore, pollen has to be stored at low humidity and temperature.

Seeds from mature fruits are extracted and sown immediately in sterilized sand and soil

mixture. When seedlings are about 15 cm high, hybrid seedlings are identified. Particularly those showing some morphological characters of male parent and others are rejected. Electrophoresis methods can also be employed for identification of zygotic seedlings. Identification of hybrid seedlings having *P. trifoliata* as male parent is easily done by looking for trifoliata character. The hybrid seedlings parent is easily done by looking for trifoliata character. The hybrid seedlings are grown to mature trees in the field and the seedlings raised from the fruits are evaluated for resistance to various disease, insect pests, nematodes and for suitability as scion or rootstock.

SAPOTA

Achras sapota

Family : Sapotaceae.

It is a wind pollinated one. Flowers are protogyny and the stigma grows out of the bud about two days before anthesis. Flowers open between 4-4.30 a.m. Anthers dehisce between 8-10 p.m. The flowers keep fresh for nearly two days. The stigma is found to be receptive two days before opening and continues to be like that up to 12 hours after opening. Peak receptivity is between 8-10 a.m. The total time taken from fruit set to maturity is 10-12 months under North Indian conditions but in Tamil Nadu it takes only 4-5 months.

Flowers are emasculated and bagged before 4-5 p.m. and well before the stigma protrudes out of the bud. The actual procedure consists of making a circular incision around the flower bud with sharp knife or blade, so that $\frac{2}{3}$ of the upper floral cup is removed including the portions of calyx, corolla and epipetalous stamens. The style is left in position in remaining $\frac{1}{3}^{\text{rd}}$ of the floral cup. Stamens from male parent, which should shed their pollen in the early hours of next day, are collected in the previous day evening and kept over night in a petridish. These are used to pollinate the receptive stigma of the emasculated flower between 8-10 a.m. in the next day.

POMEGRANATE

Punica granatum

Family:Punicaceae

Floral biology

The genus *Punica* belonging to the family Punicaceae has two species, *P. Protopunica* found wild in Socotra Island and the cultivated *P. granatum*. Both self and cross pollination were recorded in pomegranate. The pollen from male flowers gave higher fruit set than those from the hermaphrodite ones.

PAPAYA

Carica papaya

Family :Caricaceae

Hybridization

Using a dioecious lines

It has been established that female plants are more productive than hermaphrodite ones. Due to the crossing, most of the cultivars are highly variable. Hence it is considered appropriate to sibmate the selected female and male plants so as to bring homozygosity. Hence, suitable male plants are selected from the same progeny, which have resemblance to female plants in vegetative characters, such as stem and leaf colour, stem thickness and height at flowering etc. Progenies raised from SI inbreds are screened and desired male and female plants are selected for further sibmating. This process is to be continued for 7-8 generations to achieve uniformity of a group of characters.

Using gynodioecious lines

It involves selfing regular and prolific bearing hermaphrodite and or crossing (sibmating) the female with hermaphrodite. Suitable hermaphrodite plants, which do not vary with climatic changes, are selected. Of the various types of the flower produced by a hermaphrodite plants 'elongata' and 'pentandra' types are selected for selfing. Selfing is to be continued in selected hermaphrodite plants for atleast three generations for uniformity of characters. In the case of female and hermaphrodite plants, sibmating between desired types of female plants are selected and sibmated with hermaphrodite plant. Seedling raised from S1 inbred is screened and desired female and hermaphrodite plants are selected for further sibmating. This process is to be continued for 7-8 generations till homozygosity is achieved.

Crossing between two or more parents and selecting the derived progenies with good attributes in the advanced generations has been employed as a method to develop new cultivar. CO.3. is a hybrid derivative between CO.2 x Sunrise Solo. Similarly, CO.7 is a gynodioecious cultivar developed from the crosses of CP.75 (Pusa Delicious x CO.2) x Coorg Honey Dew. Fruits are with red flesh and very sweet in taste.

GUAVA

Psidium guajava

Family : Myrtaceae

Floral biology

The guava flower has a superior calyx with 5 lobes and the corolla of 6-10 petals arranged in one and two whorls. The androecium consists of 160 to 400 thin filaments carrying bilobed anthers closely packed together. The gynoecium consists of an inferior ovary, syncarpous with axile placentation and subulate terminal style. The style is smooth and red at the summit. It is larger than filaments but bent over stamens in bud stage .

Three flowering seasons were reported in the peninsular regions of India, namely, ambe bahar, mrig bahar and hatti or hastha bahar. In north Indian subtropics, there are only two flowering seasons, however, have reported three distinct flowering and fruiting periods in spring, rainy and winter seasons in Delhi.

The peak anthesis was found to be between 5.00 and 6.30 AM in most of the varieties. However, in Chittidar and Lucknow Round, it was observed between 6.30 and 7.00 AM

The dehiscence of anthers starts 15 to 30 minutes after anthesis in all the varieties and continues up to 2 hours. After dehiscence, the anthers assume a whitish colour caused by the pollen. No fixed relation has been observed between the atmospheric temperature and humidity and the time of anthesis and dehiscence. Pollen fertility has been found to be high in all the cultivars of guava.

GRAPES

Vitis vinifera

Family : Vitiaceae

Floral biology

Flowers are small, green, sweetly scented and are borne on panicles on current season growth. Three types of flowers viz., male, female and hermaphrodite occur in grapes. Varieties of *V. vinifera* are mostly hermaphrodite.

Perfect Flowers : Pistil is functional; stamens are erect and produced fertile pollen.

Female flowers: Pistil is well developed; stamens are reflexed and may produce abundant pollen, but remain sterile owing to the absence of germ pores.

Male flowers: Stamens are erect and anthers produced well-developed fertile pollen but pistil is only rudimentary without stigma and style with only a small ovary containing incompletely developed ovules.

The number of stamens varies from two to seven but majority of flowers have five stamens viz.,

1. Stamens having upright filament and
2. Those in which the filaments are bent backwards and downwards soon after the cap fall.

Petals and sepals are (five in number) fused and during anthesis the petals detach from the base forming a cap like structure called 'calyptra'.

Anthesis starts early in the morning and continues beyond 5.00 p.m., the peak between 6.00 to 10.00 a.m. The time taken for completion of anthesis varies from half a minute to one day, depending upon the variety, temperature etc. Stigmatic receptivity has been characterized by the presence of sugary secretion on the stigma, giving it a bright appearance. Once the stigmatic surface dries, it becomes black, indicating the loss of receptivity. Stigma becomes receptive one day prior to anthesis and remains so, a day after, with maximum receptivity on the day of anthesis.

Hybridization

Since most hermaphrodite vines are self-fertile, the buds must be emasculated for making desired crosses. Many female flowered vines, characterized by reflexed anthers and absence of germ pores in pollen, have complete pollen sterility and such male sterile line can be used to do away with the tedious process of emasculation.

The calyptra (corolla), which is made up of five greenish petals, is united at the tip. Hence, the grape flower does not open from the tip, instead the calyptra become detached at the base and develops as a little cap at the time of blooming. This point should be taken into account, while doing emasculation or preparing a flower for hybridization programme. In practice, if a cross is to be made between varieties A x B, the following steps must be taken.

Self-fertilization of variety 'A' must be prevented by doing emasculation. To begin with, the calyptra is carefully lifted with a pair of forceps exposing the stamens, stigma etc. Later, the stamens are gently removed before the pollen has been shed, several days before the flowers begin to open. Good number of flowers should be emasculated and the remaining flowers in the cluster are plucked off.

Pollen from variety 'B' is then dusted over the pistils of variety 'A'. It is also necessary to have the clusters of variety 'B' bagged to avoid contamination. Pollen may be collected in a vial or the entire cluster (pollen source) can be cut off for dusting. The treated cluster is then enclosed on a paper bag and tightly secured.

Good germination of hybrid seed is the prime requisite in grape breeding programme to raise a large population for evaluation. In North India, a period of over 20 months is required to obtain transplantable seedlings of hybrids mainly because of seed dormancy and slow growth of seedlings. Grapes seeds are normally extracted manually from ripe berries and are stratified at 40C for 75 to 90 days before sowing to break the dormancy. Sand is proved to be a better medium than moss for keeping seeds for stratification.

ONION *Allium cepa* var. *cepa* *Allium cepa* var.

aggregatum Family :*Alliaceae*

Hybridization

In onion, inflorescence is terminal umbel when flowering starts, umbels are covered with a butter paper bag. For emasculation, umbels having maximum buds at the emasculation stage are selected. Open flowers are removed and flower buds are emasculated in the usual manner and when a sufficient number of flowers are emasculated, the remaining small buds are removed.

AMARANTHUS

Amaranthus sp

Family :Amaranthaceae

Floral biology

Flowers are monoecious and the inflorescence is a branched compound spike, erect or pendulous, the spike is made up of a number of cymes. Each flower has 3-5 small bracteoles, male flowers with 3-5 stamens; female flowers with 2-3 styles and stigma. Flowers are protogynous; stigma becomes receptive several days before opening of staminate flowers. Dehiscence of anthers and release of pollen grains are maximum between 11 AM or 1 PM. **Hybridization technique**

Arrangements and sequence of anthesis favours a combination of self and crops pollination. Maturation of flowers takes place from bottom to top.

For crossing programme, only those flowers which are positioned in the middle portion of the inflorescence are selected. Male flowers which are situated above the middle portion are removed and are covered by a butter paper bag.

Pollen is collected from the male parent and is crossed between 10-11 am for maximum seed set.

ANNUAL MORINGA

Moringa pterygosperma

Family : Moringaceae.

Floral biology

Anthesis has been reported to commence as early as 4.30 AM and continue till 6.30 AM peak. Observed at 5.30 A.M In another report the anthesis was found to be from 5 to 9 hrs. In association with temperature range of 27.3 to 29.20C and RH 68 to 78%. At Horticultural College and Research Institute, Periyakulam the anthesis was reported to commence as early as 2.30 AM and continue till 7.00 AM peak being 5.40 AM. Anthesis was irregular. However no flower was found to open after 7.00AM. The anther dehiscence starts around 4.00 AM and continues upto 6.30 AM the peak at 5.30 to 5.45 AM. In anther of longest stamen dehisces first followed by the stamens in the descending order of filamental length. At full maturity the anthers are greenish yellow and after dehiscence they turn to pale colour. On an average each anther has 7400 pollen and the diameter of each pollen measures 5-4 microns. The stigma becomes receptive a day prior to opening of flowers and continues to be receptive on the day of opening. The receptivity is

lost on the next day of anthesis too. The flowers are good source of nectar and hence the pollination was predominantly by honeybees. Cross-pollination yields good fruit set and seed set than self-pollination. The pollen viability is 72% at anther dehiscence. Pollens stored beyond 66 hours were unable to germinate. By hand pollination using fertile pollens there was even 100 percent set. But under natural condition the fruit setting ranges from 11-15% depending upon the seasons.

Hybridization Techniques

The flowers of same parent, which are going to open in next day, should be emasculated in the evening and bagged with butter paper cover next day morning pollen grains are collected and dusted on the emasculated flowers of female parent between 6.30-8.30 AM and immediately covered with butter paper cover. Flowers are again dusted in the net day morning for effective fruit setting. The paper covers are removed 45 days after pollination.

BREEDING FOR INSECT RESISTANCE

Most important because many crops are affected by insects. For E.g. Cotton is attacked by more than 160 species of insects of these a dozen are major pests. The necessity for resistance breeding are.

- i) Environmental pollution prevention
- ii) Higher costs involved in spraying.
- iii) Death of beneficial predators and parasites.
- iv) Building up of resistance - E.g. Pyrethroid

Mechanism of insect resistance : Painter (1951)

1. Non preference
2. Anti biosis
3. Tolerance
4. Avoidance.

Non preference : Non acceptance or Antixenosis

Un attractive or unsuitable for colonization, Oviposition or both by an insect pest.

Aphid resistance in raspberry. It involves various morphological and biochemical features of host plants.

Antibiosis : Adverse effects caused by the host to an insect feeding on it. It may hinder the development, reproduction or in some cases death also. The antibiosis may be either.

- i) Morphological
- ii) Physiological
- iii) Biochemical features of the host plant. E.g. Gossypol content in cotton.

Tolerance : Able to tolerate the attack, withstand and give yield.

Avoidance : Insects avoid certain plants. Early maturing cotton varieties escape pink bollworm. Sorghum early lines escape shoot fly attack.

Nature of insect resistance :

1. **Hairiness :** Hairiness of leaves is associated with resistance.

Jassid resistance - cotton.
cereal leaf beetle -

2. **Colour of plant :** Induces non-preference for oviposition.

Red cabbage - Lepidopteran
Red colour Cotton - Boll worms.

3. **Thickness of plant Tissue :**

Cotton - Jassid resistance. Dense thick leaves - It is more of mechanical obstruction.

4. Presence of Silica in plant body

Shoot fly resistance in sorghum - Damage to mandibles.

5. Biochemical factor:

Gossypol content

DIMBOA content in leaves.

(Bio chemical) - Stem borer in maize.

6. Physiological factors

Osmotic concentration of cell sap, cell exudates etc.

Solanum sp - Gum exudate - Aphids are trapped in it.

Genetics of Insect resistance:

1. Oligo genic

Monogene 3 : 1

Jassid resistance Cotton Wheat rust resistance Green bug resistance

2. Poly genic

More durable Wheat cereal leaf beetle resistance.

3. Cytoplasmic

Plasmogenes

European corn borer in maize.

Sources of resistance:

1. Cultivated variety - TKM 6 Rice

Stem borer resistance

2. Germplasm Collection

3. Related Wild species -

S.nitidum - shoot fly resistance - Sorghum

G.anamalum - Jassid resistance - Cotton

Screening technique :

a) Field condition :

i) Infector rows are planted at regular intervals

ii) Testing in areas where ever the pest is recorded as endemic area.

Ground nut leaf miner - Aliyarnagar.

iii) Seasonal testing when insect population is most.

iv) Rearing the insect in lab and releasing them in fields. Or by transferring equal no of eggs of larvae to each plant.

b) Glass house Screening :

Raised in cages and definite number of larvae are released in the cage.

BREEDING FOR DISEASE RESISTANCE

Disease is an abnormal condition in the plant produced by an organism

Host : Plant affected by disease.

Pathogen : Organism that produces the disease.

Damage due to disease

- i) Reduces total Biomass leading to yield loss
- ii) Stunted growth
- iii) Sterility

Need for disease resistance breeding

- i) To prevent yield loss
- ii) High cost reduction
- iii) Prevention of environmental pollution

Kinds of disease reaction :

i). Susceptible reaction :

Disease reaction is profuse, if unchecked it may lead to total yield loss.

ii) Immune reaction :

Host does not show the symptoms of a disease

iii) Resistance reaction :

Infection and establishment takes place but growth of the pathogen in the host is restricted

iv). Tolerance :

Host is attacked by the pathogen in the same manner as the susceptible variety but there may not be yield loss.

Vertical and horizontal resistance

These terms were introduced by Van der plank.

Vertical resistance :

It is also known as race specific, pathotype specific or specific resistance

Vertical resistance is generally determined by major genes and is characterised by pathotypic specificity. Pathotype specificity denotes that the host carrying a gene for vertical resistance is attacked only by that pathotype which is virulent towards the resistant gene, to all other pathotypes the host will be resistant.

Only two types of disease reaction can be seen i.e. immune or susceptible reaction. When virulent pathotype becomes frequent. There may be epidemics.

Vertical resistance is not long lasting.

Horizontal resistance :

It is race non specific, pathotype non specific or general resistance.

Horizontal resistance is governed by polygenes, that is many genes with small effects and it is pathotype non-specific.

Horizontal resistance does not prevent the development of symptoms but it slows down the rate of spread to the disease in the population.

HR is more stable compared to VR.

Mechanism of disease resistance :

a) **Mechanical** : Certain mechanical or anatomical features of host may prevent infection. E.g. Closed flowering habit of wheat and barley prevents infection by spores of ovary infecting fungi.

b) **Hypersensitivity** : Immediately after infection several host cells surrounding the point of infection die. This leads to death of pathogen also. Phytoalexins present in plant body is responsible for hypersensitivity reaction.

c) **Antibiosis** : Presence of some toxic substance. This is more correct for insect resistance. E.g. Gossypol content in cotton.

d) **Nutritional factors** : The reduction in growth and spore formation may be due to nutritional factors of the host.

Genetics of disease resistance :**a) Oligogenic resistance :**

Resistance is governed by one or few major genes and resistance is generally dominant. The action of major genes may be altered by modifiers.

Gene for gene relationship

Flor (1956) proposed this based on his work in linseed rust. According to this for every resistance gene present in the host, the pathogen has a gene for virulence. Susceptible reaction will result when the pathogen is able to match all the resistant genes with virulence gene.

	R ₁	R ₂	R ₃	R ₄
Susceptible	V ₁	V ₂	V ₃	V ₄
Resistance	R ₁	R ₂	R ₃	R ₄
		V ₂		V ₄

b) Polygenic inheritance :

The genes show both additive and non - additive effects and there is large environmental effects.

c) Cytoplasmic inheritance :

T cytoplasm - Maize
Tift 23A cytoplasm - Cumbu
Susceptible to disease.

C and M cytoplasm of maize resistant to *Helminthosporium*.
L 111A and 732 A cytoplasm resistant to downy mildew in cumbu.

Methods of disease resistance breeding

1. Plant introduction :

Resistant varieties from other can be directly introduced for cultivation. E.g. IR 20 rice resistant to blast.

2. Selection :

This may be from local land races or from introduced cultivars. E.g. Co 4 Gobi Anaikomban resistance to blast. NCAC 17090 ground nut resistant against leaf spot.

3. Hybridisation and Selection:

- a) Intervarietal - Co37 Rice resistant to blast
- b) Inter specific - Powdery mildew resistance in *Sesamum*
- c) Inter generic - *Atylosia* for root rot in red gram.

Depending on gene action the selection procedure may vary. If the resistance is governed by polygenes, then pedigree method of selection is to be followed.

If the resistance is governed by major genes linked with other undesirable characters we have to go for back cross method of breeding. Here again for dominant gene the back cross method is different from recessive gene governed traits.

1. Mutation breeding

Co2. Ground nut tolerant to late leaf spot disease.

2. Polyploidy breeding:

Nicotiana crosses for resistance against leaf spot..

3. Tissue culture method.

Resistance reaction can be screened easily in test tubes and resistant lines can be mass multiplied. E.g. Banana, Cardomum.

Screening techniques for disease resistance

Depending on mode of spread of disease the screening technique may differ. The screening can be done both at screen or glass house level and field level. The different screening techniques are as follows.

Soil borne diseases :

Wilt, root rot are produced by soil borne fungi. In this case sick plot technique is followed. Susceptible varieties can be grown and infected plants can be ploughed *insitu* to maintain optimum condition for infection.

Air borne diseases:

E.g. Rust, Smut, mildews, blights.

For ground nut rust, infestor rows can be sown 15 days earlier as border rows and the disease will infest the susceptible infestor rows. After 15 days the varieties tested to be are to be sown. Spraying the spore suspension from affected leaves will also increase the load.

Seed borne disease :

Smut, bunt etc. Artificial inoculation can be done by soaking the seeds in solution of pathogen under *vaccum* condition.

Insect transmitted diseases.

Insect transmitted diseases :

E.g. virus diseases, Red gram sterility mosaic virus. Sap transmitted. Here the stapling technique is used. Leaves from affected plants can be stapled to the entries to be tested. The insect feeding in susceptible leaf will transmit virus to test entries.

BREEDING FOR ABIOTIC STRESS RESISTANCE **(Drought, Cold, Salinity and alkalinity)**

1. Temperature stress

a. Cold resistance / tolerance : This is applicable in case of rice grown in Gudalur taluk of Nilgiris and Cumbum valley. Numerous methods have been developed for the evaluation of cold hardiness. This included artificial low temperature and freeze tests. However, none of them is useful for single plant selection. This is a handicap for the breeder. Testing the segregating lines under field condition is the most suitable one. But this will be time consuming and often favorable conditions may not be available.

b. High temperature : Due to high temperature seed set may be affected. In case of male sterile lines, the sterility may be broken down. In this case also testing single plants for high temperature resistance is time consuming and skill is required. Tests like heat test with leaf discs and desiccation tolerance test are followed.

2. Water stress

a. Low water i.e., Drought resistance : This is more important for all the dry land crops. 75% of area is cultivated under rainfed conditions and drought tolerance is more important.

Drought resistance in crop plants can be divided into three categories.

- i. Drought escape - ability of a plant to complete its life cycle before serious soil and plant water deficit occurs.
- ii. Drought tolerance with high tissue water potential
- iii. Drought tolerance with low tissue water potential

Drought resistance in crop plants are more due to physiological conditions of plant like stomatal aperture and photosynthetic rates, root characteristics. Various techniques have been developed to test drought resistance. One e.g. is accumulation of proline in leaves. Because of the high skill needed in evaluating the single plants the process is tedious.

b. Excess water: This is the case in places like tail end areas of Cauvery delta. Here the paddy varieties must have long stem - i.e., deep water paddy. The screening procedure is done both under field conditions and laboratory conditions.

3. Chemical stress

a. Salinity and alkalinity : Screening for salinity and alkalinity can be done more successfully by in vitro techniques. Raising the seedling in test tube containing different concentration of salt is done in case of rice. This is followed in case of pesticide and herbicide tolerance also.

4. Wind tolerance

Wind with high velocity may cause evaporation of soil moisture and tip drying in many crops. But this stress is not a serious problem in Tamilnadu.

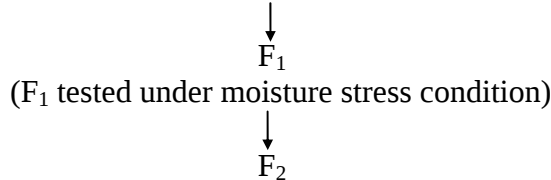
5. Difficulties in abiotic stress breeding

- i. Screening techniques require high skill and they are time consuming
- ii. Creation of artificial conditions is expensive.

- iii. Under field screening, nature may or may not provide optimum condition for screening.
- iv. In many cases *in vitro* techniques are to be followed which is expensive.
- v. Abiotic stress breeding depends mostly on physiological traits which are often not stable.

B. Breeding for Drought resistance variety

High yield x High cuticular wax content (Poor cuticular Transpiration)



1. Progeny rows screened in moisture stress nursery in two locations
2. Selection based on cuticular wax and no agronomic characters are considered

↓
F₃

Selected single plants - Screened under normal conditions for yield and then associated characters

↓
F₄

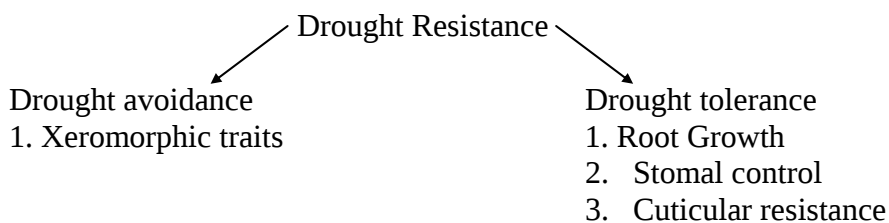
Selected single plants - Screened under stress situation

↓
F₅ - Normal condition - yield
↓
F₇/F₈

1. Homogeneity with relative resistance to drought and with considerable yield
2. Converge genes for yield and drought resistance

C. Breeding for Drought Resistance

1. Breeder search for a source for Drought resistance
2. Yield should be a secondary character Economic Parts
3. Partitioning of photosynthates Vegetative Parts
Total Dry matter should be taken as a criterion for selection.



- (water permeability of leaf cuticle
 4. Stomatal No.
 (transpiration low, low stomatal frequency and high photosynthetic rate)
 5. Cell turgor (Inhibit plant growth)
 (root water absorption $\Leftrightarrow$ stomatal water loss)

D. Screening for salt tolerance

Rice varieties of differing : IR.20 & IR.50 (susceptible)
 salt tolerance level : Co 43 & Manoharsali
 (Moderately tolerant)
 : Dasal & Pokkali
 (highly tolerant)

1. Salinized soil method

Crosses were made between susceptible and moderately tolerant; susceptible x highly tolerant; and moderately x highly tolerant types. The parents along with F1 progenies and subsequent segregating progenies have to be screened for their tolerance.

Plastic tubs (45 x 30 x 45 cm) with 10kg of soil was taken one with normal soil and others salinized with 6 liters of 0.3 % NaCl solution, so that the electrical conductivity was raised to 4.9 M m/cm uniformly in all the tubs. Then the plant materials (labeled 20 day old seedlings) to be tested are planted in the tub with a spacing of 15 x 10 cm so that each tub carries 6 seedlings. Normal cultural practices were followed and irrigated daily to maintain a water level of 1 cm above the soil level. Once a week the soil between the plants was carefully raked to facilitate mixing and aeration. The plants were grown to maturity and data were recorded for yield characters. The cultivar which recorded a grain yield on par with culture in control is selected as tolerant.

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. Opacity 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 north-east 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 79°C. 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. The Indian Varieties are generally intermediate in gelatinisation

temperature and amylose content. Dominance gene effect was highly significant for grain length and amylose content.

Wheat :

The quality criteria of wheat is milling quality, baking quality for bread making, biscuit making which again depends upon loaf volume, doughing, expansion of dough, loaf volume, degree of kernel hardness, colour etc. The quality is mainly dependant 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 for 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 selected genotype for protein, calcium, phosphate and total minerals of the grain. The genetic analysis revealed 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 hardness 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 toxic antinutritional factors. Improving the content of amino acids such as albumin, glutamin, methionine 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 glucoside, 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 haemagglutinin 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 ratio 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 linoleic 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.

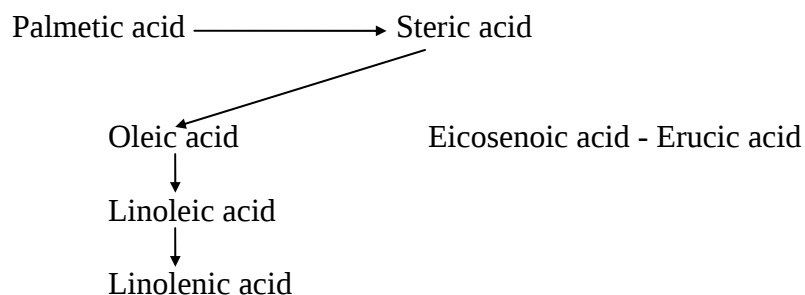
Safflower :

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 linoleic 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 biosynthesis (Johnson, 19977) is as follows.



The 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 levels 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 triglycerides of ricinolic acid. The unsaturated fatty acid in castor oil (Oleic 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 in turn 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 from 12 to 63mm. The fibre fineness i.e. weight per unit length of fibre is generally taken as a measure of fineness, it is closely related to the fibre maturity i.e. depends upon perimeters and wall thickness of the fibre. 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 from 50,000 to 1,25,000 lb / square 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 thickening 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, 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 for 2.5% span length, uniformity ratio, and elongation percent and heterosis for fibre fineness and 2.5% span length. The intra *hirsutum* hybrids showed relative and standard heterosis for uniformity ratio and low positive heterobeltiosis for maturity coefficient.

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 gelatinisation 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' rice 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 scented types 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 MULTIPLICATION AND RELEASE OF A VARIETY

A. Multiplication of seeds in a variety

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. Director 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, Agri. 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.

VARIETAL RUNDOWN AND RENOVATION

1) Causes for varietal run down or Genetic deterioration in released varieties

Normally the farmers are advised to renew the cultivars once in three years. The main reason is that a variety may undergo genetic deterioration by a number of ways. They are :

1. Presence of crossable genera or species in the near by field or bunds
E.g. (1) In the rice field there may be other graminaceous grasses which can hybridise with rice./ Presence of red rice in varieties is due to this.
(2) Presence of Johnson grass (*Sorghum halepense*) as weed in sorghum (*S. bicolor*) field will lead to varietal contamination due to natural crossing.
2. Lack of isolation distance in the seed production plots
Each crop variety requires proper isolation distance for maintenance of varietal purity.
For Eg. Sorghum : 400m
 Red gram : 200m
 Sunflower : 600m
Lack of isolation distance lead to natural crossing and genetic deterioration.
3. Genetic drift due to sampling error
The genetic equilibrium in a variety will be disturbed due to improper selection. This is high in case of small populations. This can be prevented by adopting proper selection procedure and following phenotypic disassortative mating.
4. Natural mutation :
Though the frequency of natural mutation is very low, it is also one of the causes of varietal rundown. Micro mutations which cannot be detected easily will lead to genetic deterioration in crop plants.
5. Admixture due to Farm machinery :
Improper cleaning of farm tools and machinery like threshers will also lead to varietal admixtures, natural crossing and rundown.
6. Threshing floor admixtures :
Threshing floor must be free from cracks and crevices so that while threshing and drying there is no chance for left over seed in threshing floor. Otherwise some seeds may be caught up in cracks and get admixed with other varieties.
7. Store room admixtures :
The gunny bags and other container used for seed storage must be properly cleaned; otherwise it will also lead to admixture.
8. Physiological stresses:
Extreme drought conditions will prevent panicle exertion in full e.g. sorghum. Growing rice in colder months may lead to physiological awning.
9. Not following proper crop rotation practices :
The left over seeds may germinate and contaminate the subsequent crop varieties. Eg. groundnut after groundnut.

2) Steps to prevent genetic deterioration

1. Nucleus seed production and maintenance

Cent per cent purity is to be maintained in nucleus seed production plot. Different methods are advocated for different crops in maintenance of nucleus seeds. For eg. in cotton mass pedigree method is followed for maintenance of nucleus seed. In this method 1000 to 2000 single plants are raised in replicated progeny row trial. Each and every single plant is examined for pollen colour and petal colour to maintain genetic purity. If off types are seen, then the whole line in all the replication will be rejected. Selfing is done to prevent contamination Harvest is done on single plant basis and progenies are selected on single norm.

2. By providing proper isolation distance for seed multiplication plots

For eg. for sorghum nucleus seed production plot 800 metre isolation distance is maintained. The single plants are raised and allowed for sibmating.

3. Removal of all grasses from field as well as bunds :

This is to be followed especially in case of rice.

4. By following proper crop rotation

5. By proper cleaning of farm equipments, tools, threshing floor, gunny bags and store room

6. By following proper selection procedures in seed production plots

For eg. in groundnut seed production plot, the plot mean for yield will be worked out. Then SE and CD will be worked out. The single plant yield which are around = 2 SE is to be selected for further maintenance.

7. By following the proper varietal maintenance technique

E.g. In sunflower, varietal renovation technique as advocated by *Pustovoit* will have to be followed.

3) Varietal renovation in sunflower

Russian scientist Pustovoit has given the method of varietal renovation. It is called as Pustovoit method of renovation. Sunflower varieties all called as population. Due to heterozygous nature, the variety to be renovated is raised under isolation of 600m. Rouging should be done. About 10,000-12,000 plants are selected based on head size, seed size, seed yield and oil content. The mean and standard deviation is calculated for each character. The average was taken. In all the characters value for an individual must exceed the value of mean +2 SD. Then that individual is selected.

Then the selected plants are studied for disease resistance and progeny row testing. Progeny row testing is replicated twice. In each time the plants are selected and the characters are recorded and Standard Deviation (SD) and mean are worked those individuals whose character value exceeding mean + 2 SD are selected. While using for progeny row testing only half of the seeds are reserved. After selecting the plants the remnant, seeds of the selected plants are used for raising super elite seeds at 600m isolation. Rouging should be done before and after flowering. Super elite seeds are used for raising the elite seeds or Stage I foundation seed. These seeds are used for raising Stage II foundation seed. These seeds are used for raising certified seeds and then for commercial cultivation. This seed renovation method maintain yield and oil content and also sometimes upgrade them.

