Subject - M.Sc Botany, (Sem-IV)

MBOTEC – 1, Paper : Cytogenetics and Crop Improvement

Topic – Incompatibility and its role in Plant Breeding (UNIT IV)

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Incompatibility is a physiological mechanism which enforces outbreeding. Self-incompatibility and Male-sterility are the two mechanisms, which encourage cross-pollination. It is widespread throughout the families of flowering plants. More than 300 species belonging to 20 families of angiosperms show self incompatibility.

Self-incompatibility (SI); inability to set seeds after self pollination; is a general name for several genetic mechanisms in angiosperms, which prevent self-fertilization and thus encourage out-crossing and allogamy.

- In the 18th century, **Koelreuter** was first reported Self incompatibility (SI) in *Verbascum phoeniceum* plants. The term "Self-incompatibility" was given by **Stout** in 1917.
- SI is due to morphological, genetic, physiological and biochemical cause.
- SI species do not produce seed on self-fertilization but lead to normal seed set on cross pollination.
- SI species maintain high degree of hetrozygosity in the species due to outbreeding and reduce homozygosity due to elimination of inbreeding or selfing.

Classification of Self-incompatibility

Basis of Self incompatibility	**Type of self-incompatibility (SI)**	**Description**
1. Flower morphology	a. Heteromorphic	Due to difference in flower morphology
	i. Distyly	Style and stamen are of different size i.e short and long
	ii. Tristyly	Style and stamen have three different position i.e short, medium and long
	b. Homomorphic	Flower do not differe in morphology
	i. Sporophytic	SI depends on Genotype

		of pollen producing plant
	ii. Gametophytic	SI depends on Genetic constitution of gametes
2. Genes involved	a. Monoallelic	SI is goverened by single gene
	b. Diallelic	SI is goverened by two gene
	c. Polyallelic	SI is goverened by several gene
3. Site of expression	a. Stigmatic	Stigma has specific SI gene expression
	b. Stylar	Style has specific SI gene expression
	c. Ovarian	Ovary has specific SI gene expression
4. Pollen cytology	a. Binucleate	Pollen grains with two nuclei
	b. Trinucleate	Pollen grains with three nuclei

According to Lewis (1954) the self incompatibility (SI) is classified broadly under two categories; Heteromorphic and Homomorphic.

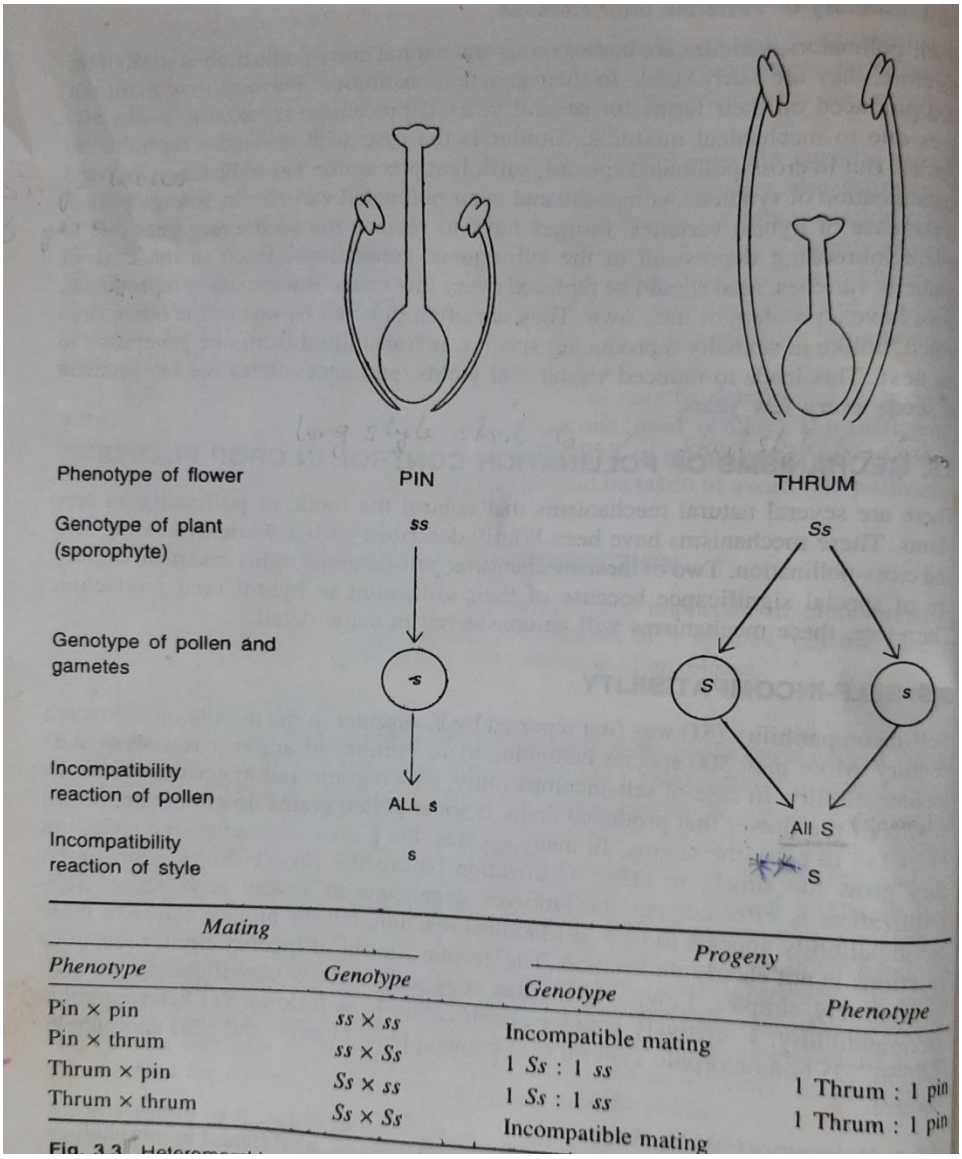
Heteromorphic system -

This system of SI is due to difference in the morphology of the flowers; namely of two types **Distyly** and **Tristyly.**

There are two types of flowers in **Distyly** (eg. *Primula sp*); namely PIN and THRUM. PIN flowers have **long** style and **short** stamens and THRUM flowers have **short** style and **long** stamens. The mating in between PIN and THRUM is compatible. The relative position of anthers is determined by single gene **S/s**. The recessive as produces PIN and heterozygotes **Ss** produces THRUM. Homozygous dominant **SS** is lethal and do not exist. The incompatibility reaction of pollen is determined by the genotype of the plant producing them. Allele **S** is dominant over **s**. This system is also known as heteromorphic – sporophytic system. Pollen grains produced by PIN flowers will be all s in genotype as well as in incompatibility

reaction: Whereas THRUM flowers will produce two types of gametes S and s but all of them would be S phenotypically. The mating between PIN and THRUM would produce Ss and ss progeny in equal frequencies. This system is of little importance in crop plants. It occurs in sweet potato and bulk wheat.

The locus s may have several genes, thus there may be dimorphism for more than one trait (like style length, size of stigmatic cell, anther length etc).



Mating		Progeny	
Phenotype	*Genotype*	*Genotype*	*Phenotype*
Pin × pin	*ss* × *ss*	Incompatible mating	
Pin × thrum	*ss* × *Ss*	1 *Ss* : 1 *ss*	
Thrum × pin	*Ss* × *ss*	1 *Ss* : 1 *ss*	1 Thrum : 1 pin
Thrum × thrum	*Ss* × *Ss*	Incompatible mating	1 Thrum : 1 pin

Figure 1- Heteromorphic sporophytic system of incompatibility

From Plant Breeding by B. D. Singh

In **Tristyly** there are three morphological forms (eg. *Lythrum salicaria*); like three different size of style **short, medium** and **long**. It is goverened by two dominant genes S and M: gene S shows masking effect on the expression of gene M. Allele S specifies short styly, while allele M determines medium style.

Thus the, short style genotype will be - Ss Mm, Ss mm, or Ss MM

medium style genotype will be - ss MM or ss Mm

long style genotype will be - ss mm

Compatible matings will be long x medium, long x short and medium x short.

Homomorphic System -

Here the incompatibility is not associated with morphological difference among flower. The incompatibility reaction of pollen may be controlled by the genotype of the plant on which it is produced – (**Sporophytic** control) or by its own genotype – (**Gametophytic** control).

Gametophytic system: It was discovered by East and Mangelsdorf (1925) in *Nicotiana sanderae*. Here the incompatible reaction of pollen is determined by its own genotype and not by the genotype of the plant on which pollen is produced. Single gene having multiple allele with co-dominance is responsible for the incompatibility reaction. Eg. *Trifolium Nicotiana, Lycopersicon, Solanum,* and *Petunia*.

Sometimes, polyploidy may cause loss of incompatibility due to competition between two S alleles present in the diploid pollen. Irradiation of pollen with gamma or x-ray may also suppress incompatibility temporarily.

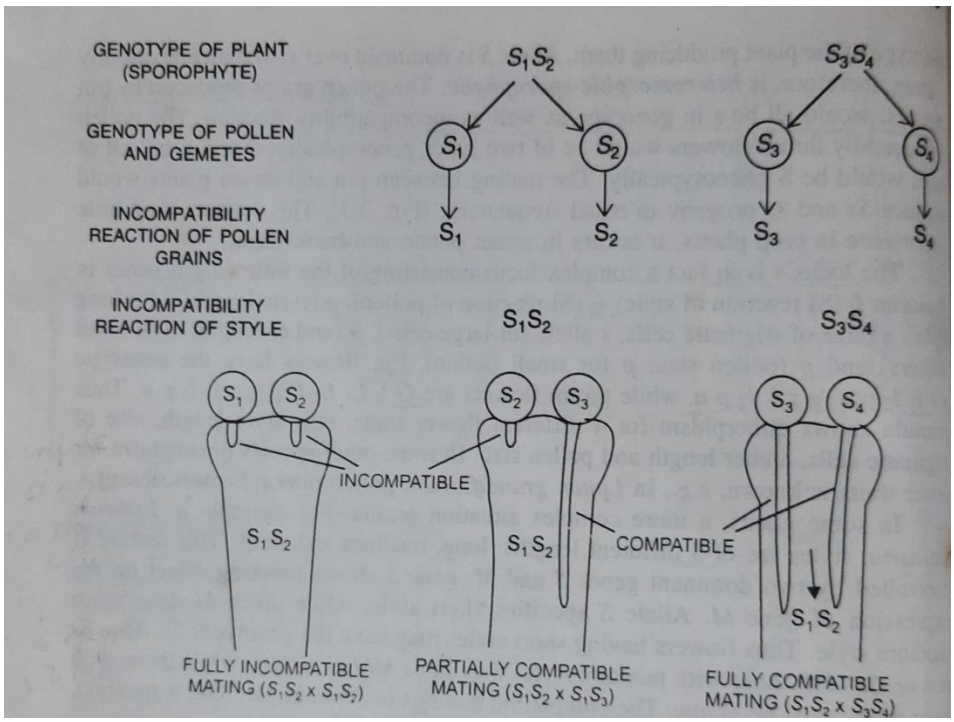


Figure 2- Homomorphic gametophytic system of incompatibility

From Plant Breeding by B. D. Singh

Sporophytic system: This system was first reported by Hugues and Babcock (1950) in *Crepis foetida* and by Gerstal in *Parthenium argentatum*. The incompatibility reaction is determined by the genotype of the plant on which pollen grain is produced and not by the genotype of the pollen. Here also the self incompatibility is governed by a single gene S with multiple alleles. More than 30 alleles are known in *Brassica oleracea*. Thus this system is more complicated. The allele may exhibit dominance, co-dominance or competition. The sporophytic system is found in radish, brassicas and spinach.

Lewis has summarized following characteristics of sporophytic system:

1. There are frequent reciprocal differences

2. Incompatibility can occur with female parent

3. A family can consist of three incompatibility groups

4. Homozygotes are a normal part of the system

5. An incompatibility group may contain two genotypes.

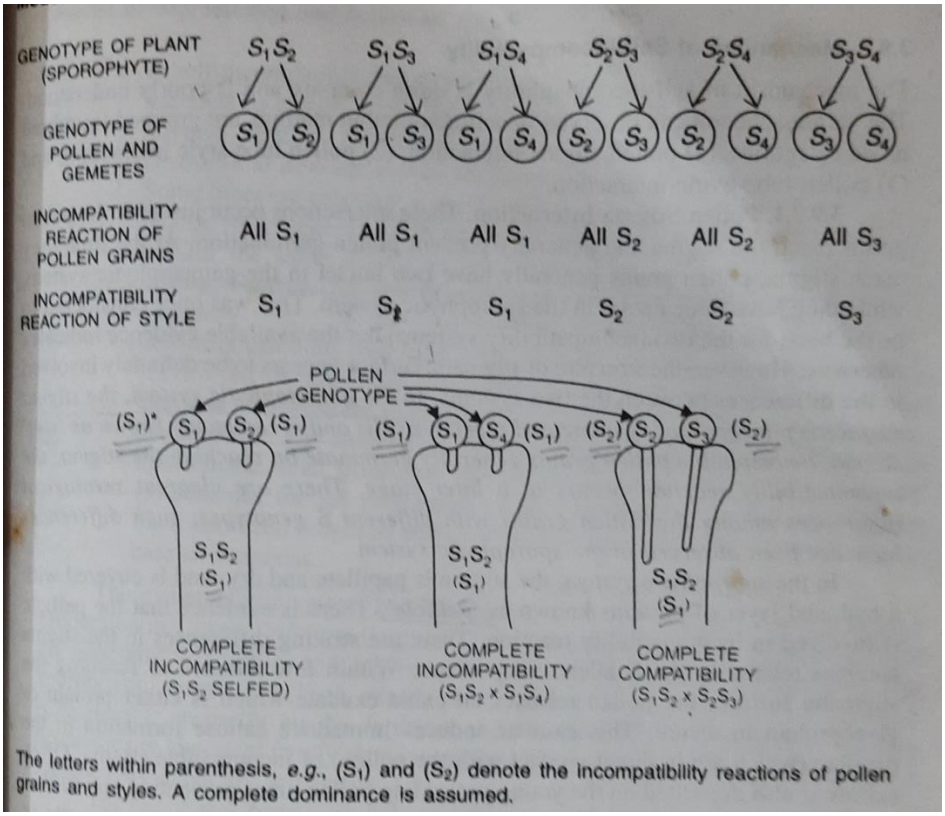


Figure 3- Homomorphic sporophytic system of incompatibility

From Plant Breeding by B. D. Singh

Mechanism of Self- incompatibility

Various phenomena involved in determining SI, are grouped in three broad categories –

1. Pollen - Stigma Interaction- In homomorphic system of incompatibility there are differences in the stigmatic surface which prevents pollen germination.

- In gametophytic system the stigma surface is plumose having elongated receptive cells which are commonly known as wet stigma. Here S locus products are synthesized after meiosis. The pollen grain germinates on reaching the stigma and incompatibility reaction occurs at a later stage.
- In the sporophytic system, stigma is papillate and dry, covered by a hydrated layer of proteins called pellicle. S locus products are synthesized before completion of meiosis. Growth of the pollen tube arrested at the surface of the stigma. Pollen grain releases exine exudate which is protein or Glyco-protein, interaction causes callose formation.

2. Pollen Tube - Style interaction - Pollen grains germinate and pollen tube penetrates the stigmatic surface. But in incompatible combinations the growth of pollen tube is retarded with in the style as in Petunia, Lycopersicon, & Lilium. The protein and poly saccharine synthesis in the pollen tube stops resulting in bursting up of pollen tube and leading to death of nuclei.

3. Pollen tube - Ovule interaction - In Theobroma cacao pollen tube reaches the ovule and fertilization occurs but the embryo degenerates later due to some biochemical reaction.

As we see the mechanism of self incompatibility has different patterns in different plants, the biochemical and molecular phenomenon behind many of these patterns have been studied in detail. For example two molecular mechanisms one of Solanaceae and other of *Papaver rhoeus* , are mentioned here -

- Molecular mechanism in Solanaceae : here evidences are available for involvement of pistil S-RNases in the recognition and rejection of self-incompatible pollen. It has been confirmed by several transgenic analyses utilizing loss- and gain-of-function approaches. (Figure 4)
- Molecular mechanism in *Papaver rhoeus* : evidence has been found for the involvement of a phosphoinositide signalling pathway and transient increases in intracellular calcium levels in the pollen tube as part of the self-incompatibility response. Other events include protein phosphorylation and

possibly gene expression and, more recently, evidence has been presented for the involvement of programmed cell death in the inhibition of incompatible pollen tubes. (Figure 5)

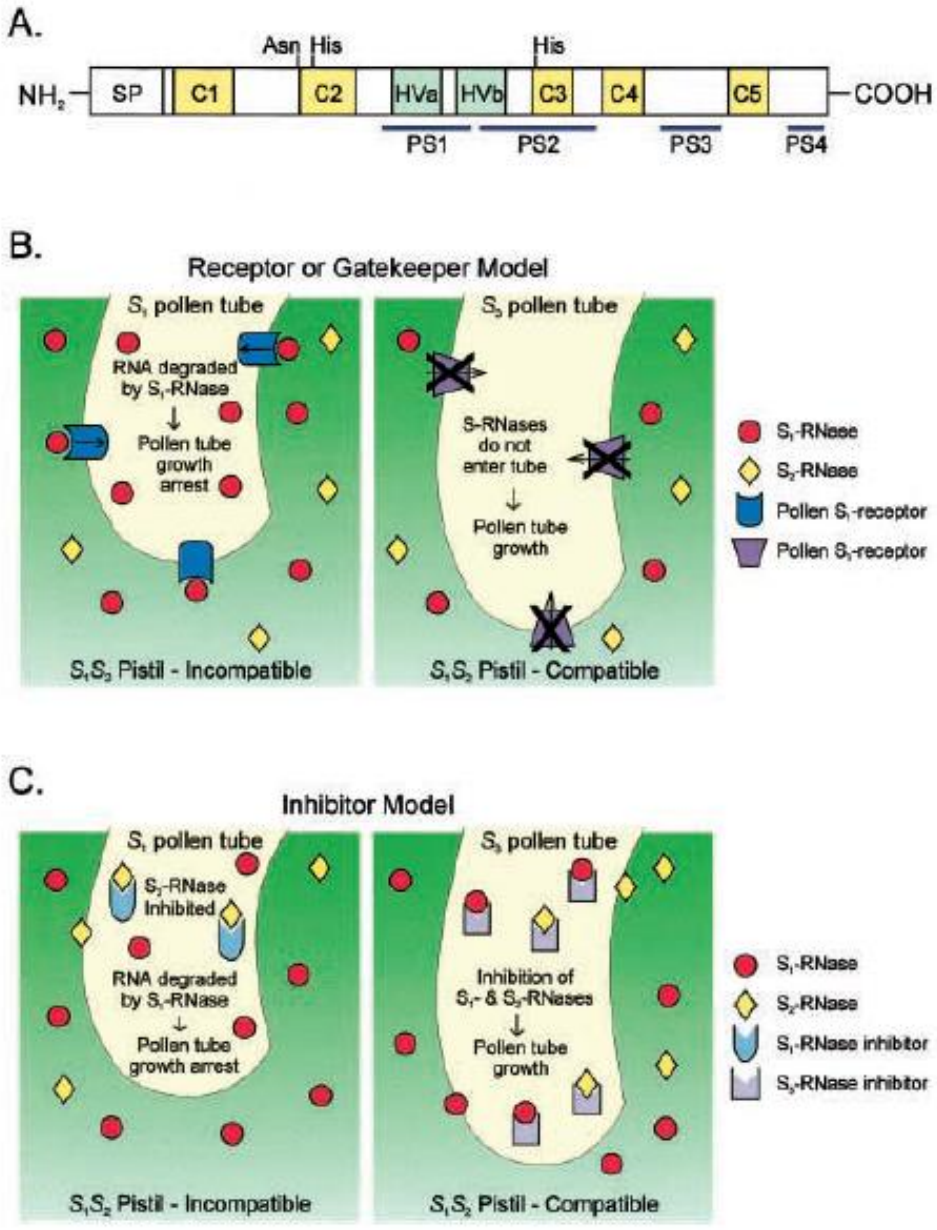


Figure 4: Self incompatibility in Solanaceae, showing S-RNase structure, and model for S-Rnase mediated pollen rejection.

From N.F. Silva and D.R. Goring. (2001)

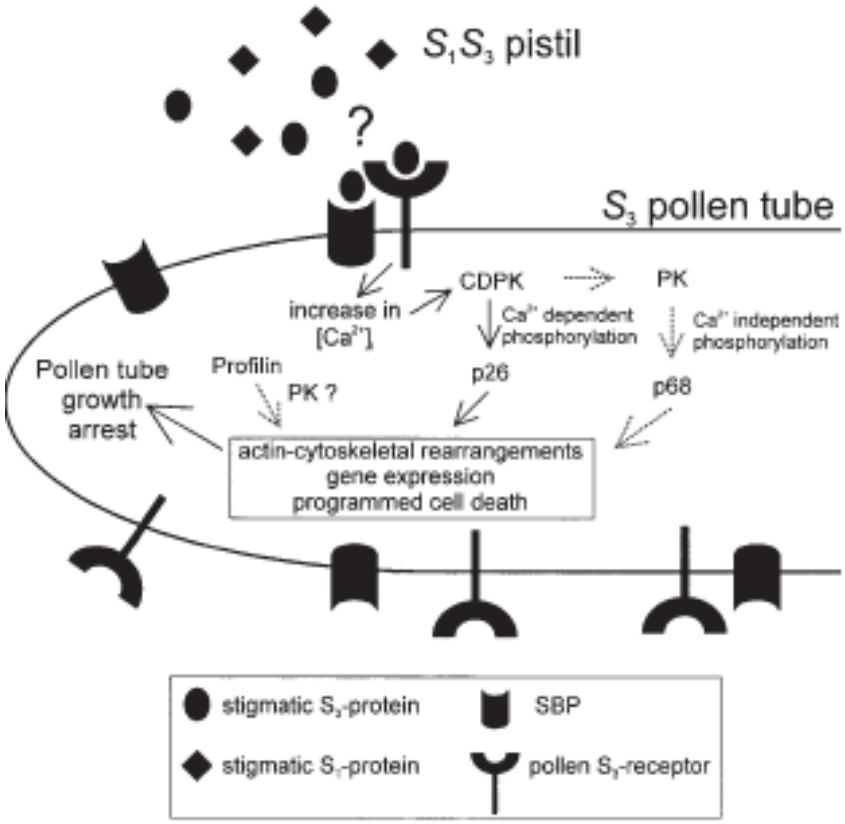


Figure 5 – Model for stigmatic S protein mediated pollen rejection in

Papaver rhoeas

From N.F. Silva and D.R. Goring. (2001)

Role of Self incompatibility in Crop improvement –

SI effectively prevents self pollination thus it has a profound effect on breeding approaches. SI can be manipulated to some extent to achieve desired goal, like it can be eliminated or temporarily suppressed.

In many cases, self fertile forms will be highly desirable and, in such cases, it would be useful to eliminate SI. Doubling the chromosome number in case of single locus gametophytic system, may eliminate SI. Isolation of self fertile mutants is also an important technique for elimination of self incompatibility. To

introduce SI, Self incompatibility allele may be transferred from related species or varities of the same species through backcross.

Sometime it is essential to temporarily suppress SI, like for production of inbreds. Such temporary suppression of SI leads to self fertility called as **pseudofertility**. It can be achieved by following technique.

- Bud pollination
- Surgical technique
- End of season pollination
- High temperature
- Irradiation
- Grafting
- Double pollination etc

Thus self incompatibility is important aspect to consider in plant breeding. Self incompatible fruit trees needs other compatible plants for fruitfulness. SI can be exploited as tool for hybrid production but at the same time SI makes tedious to get inbreds, which is a prerequisite for hybrid production. Thus to exploit SI as a tool in crop improvement, understanding the exact mechanism of SI involved, molecular phenomenon, and techniques to remove, temporarily suppress or introducing SI, are important.

Suggested Books and References

1. Plant Breeding Principles and Methods by B. D. Singh.
2. P. E. Gibbs (1988), Self Incompatibility mechanism in flowering Plants: Some complications and clarifications. Lagascalia 15 (Extra) 17-28.
3. N.F. Silva and D.R. Goring. (2001), Review, Mechanisms of self-incompatibility in flowering plants. CMLS, Cell. Mol. Life Sci. 58.