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BREEDING HYBRID COTTON

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INTRODUCTION

Heterosis refers to the superiority of F_1 hybrid in one or more characters over the parental values. In current stage, heterosis and hybrid vigour are used as synonyms and interchangeable. Generally, positive heterosis is considered desirable, but for some characters negative heterosis is also desirable. In cotton, negative heterosis for plant height, micronaire value, maturity duration and gossypol content is desirable because it shows superiority over the parents. The ture heterosis differs from pseudo-heterosis (luxuriance). In case of heterosis, there is increase in general vigour, yield and adaptation. In case of pseudo-heterosis, the F_1 exhibits increase in vegetative growth but not in yield and adaptation. Various factors that help in commercial exploitation of heterosis include (1) enough magnitude of heterosis, (2) high percentage of natural out crossing, (3) flower biology, and (4) availability of male sterility system.

Magnitude of Heterosis: For development of hybrid cultivars, there should be enough magnitude of heterosis. In cotton, heterosis of 50% over the popular variety and 20% over the popular hybrid is considered significant for development of hybrid.

Percentage of out crossing: There should be high percentage of out crossing. Cotton pollen is sticky and hence wind population is not possible. Cross pollination occurs by insects mainly honey bees and bumble bees. In cotton, natural cross pollination varies from nil to 60% depending upon climatic conditions and bee activity. In India, average out crossing of 6% is observed.

Floral Biology: The flower biology should permit large scale production of hybrid seed with less expenditure. In cotton, floral biology is amenable for hybrid seed production.

Availability of Male Sterility: Availability of male sterility helps in reducing the cost of hybrid seed by eliminating the process of hand emasculation. There should be proper nicked in the flowering time of A and R lines. The A line should have good stigma receptivity and R line should have high pollen production efficiency and pollen longevity. In upland cotton, both genetic male sterility and cytoplasmic genic male sterility systems are available. Genic male sterility is also available in *G.arboreum* cotton.

GENETIC BASIS OF HETEROSIS

There are three possible genetic causes of heterosis, viz. (1) partial to complete dominance, (2) overdominance, and epistasis. According to dominance theory, heterosis is directly proportional to the number of dominant genes contributed to F_1 by each parent. Both the parents differ for dominant genes. Suppose genetic constitution of one parent is AA BB cc dd and that of another parent as aa bb CC DD. A hybrid between these two parents will have four dominant genes (AaBbCcDd) and exhibit superiority over both the parents, each having two dominant genes.

According to over dominance hypothesis, heterosis is the result of the superiority of heterozygote over its both homozygotes. Thus heterosis is directly proportional to heterozygosis. Dominance and overdominance involve intra-allelic interaction. Dominance hypothesis is the most widely accepted explanation of heterosis. Epistasis refers to interaction between alleles of two or more different loci. Epistasis is also known as non-allelic interaction. Epistasis is of three types, viz. additive x additive, additive x dominance and dominance x dominance effects has been reported in cotton.

Heterosis in seed cotton yield and boll number results mainly due to non-additive (dominance and epistatic) gene action, both in interspecific and intraspecific diploid crosses. In upland cotton, a cytoplasmic genomic interaction determining heterosis for seed cotton yield and boll number is reported. In the same species, heterosis in yield is also reported due to overdominance for boll number and boll weight.

ESTIMATION OF HETEROSIS

Heterosis is estimated in three different ways, viz. (1) over mid-parent, (2) over better parent , and (3) over commercial cultivar of a region. The first is called mid – parent heterosis, second as heterobeltiosis and last one as useful heterosis or economic heterosis. The useful heterosis is estimated over the highest yielding and adapted commercial check cultivar. Sometimes, the heterosis is worked out over the standard commercial hybrid. It is estimated in those crops where hybrids are already available for comparison. This is known as standard heterosis. The various types of heterosis are estimated as follows.

Mid-parent Heterosis = $[(F_1 - MP)/MP] \times 100$
Heterobeltiosis = $[(F_1 - BP)/BP] \times 100$
Useful Heterosis = $[(F_1 - CC)/CC] \times 100$
Standard Heterosis = $[(F_1 - SH)/SH] \times 100$

Where,

F_1 = Mean of a particular F_1 cross
MP = Mean value of two parents involved in a cross
BP = Mean value of better parent of the particular cross
SH = Mean value of the check hybrid or Standard Hybrid
CC = Mean value of the best commercial cultivar.

Useful and standard heteroses have direct practical significance in plant breeding.

LEVEL OF HETEROSIS

In cotton, level of heterosis has been extensively studied over mid-parent, better parent and commercial cultivar in intra and interspecific crosses of both tetraploid and diploid cotton.

In general, the level of heterosis is observed higher in interspecific crosses than in intraspecific crosses. However, it is not always true. In tetraploid cotton, boll weight in intraspecific hybrids and boll number in interspecific hybrids are reported as major components of heterosis in yield. Similar trend is found in diploid cottons. Heterosis for boll weight is usually observed in *G.hirsutum* crosses but not always in *G.barbadense* crosses. Bolls per plant and possibly seeds per boll are the most important components of heterosis in seed cotton yield. Higher heterosis has been observed in agronomic characters than in technological properties or fibre characters. Moderate heterosis is observed for seed oil content. Hybrids of interspecific origin have poor fibre quality than those of intraspecific origin (intraspecific hybrids) or *G.barbadense* variety. Thus heterosis is high for yield and boll number, moderate for boll size and seed oil content; and low for ginning out turn and various fibre properties.

FACTORS AFFECTING HETEROSIS

Several genetical factors like geographical and genetic diversity, agronomic performance, adaptability and genetic base of parental lines are reported to play an important role in the manifestation of heterosis in cotton. The role of each of these factors is discussed below:

Geographical and Genetic Diversity: In upland cotton, a close relationship is observed between the genetic diversity of parental varieties and performance of their hybrids for lint yield. In intra and interspecific hybrids of cotton, the highest heterosis is observed in the cross combinations involving ecologically distant parents. Heterosis is also related to genetic divergence of sympodia and bolls per plant. High heterosis is observed in crosses involving local x exotic lines.

Agronomic Performance: High heterosis can be obtained from the crosses of two low yielded inbreds but absolute yield of such hybrids is lower than the adapted varieties. To produce good hybrids, varieties with high per se performance must be chosen. The magnitude of heterosis in tetraploid cotton is dependent on the agronomic performance of parental lines involved in the hybrid combinations both in intra and interspecific hybrids. There is a high positive correlation between parental performance and hybrid vigour. The performance of any trait in a hybrid is dependent upon the relative performance of its parental varieties. The high heterotic combinations, in upland cotton, involved high x low and high x moderate yielding parents.

Adaptability: A close association is observed between the adaptability the hybrids and their parents. In India, several hybrids have been developed at intra and intersepcific levels especially in tetraploid cotton. The G in Hybrid 4, Khandwa 2 in JKHy 1, SRT 1 in Hybrid 6, DHY 286 in PKV Hy – 2, Laxmi in Hybrid Varalaxmi and Khandwa 2 in JKHY 11 are some examples of parents with wider adaptability. Highly heterotic combinations involves at least one of the parents with wider adaptability.

Genetic Base: Genetic base of parental lines is found to play important role in the manifestation of heterosis in their hybrids as there is a close relationship between the genetic base and adaptability of varieties. Hybrids with high levels of heterosis involves at least one of the parents with broad genetic base.

TYPES OF HYBRIDS

In cotton, different types of hybrids are developed for commercial cultivation which can be classified into various groups on the basis of species involved (intraspecific and intersepcific), ploidy level or chromosome number (tetraploid and diploid), and method of hybrid seed production (conventional and male sterility based hybrids). A brief description of different types of hybrids is given below:

Intraspecific hybrids: A hybrid between genetically different genotypes of the same species is referred to as intraspecific hybrid. It is also known as intervarietal hybrid. Intraspecific hybrids are always fertile. In cotton, intraspecific hybrids have been released for commercial cultivation in *G.hirsutum* at tetraploid level and in *G.arboreum* at diploid level.

Interspecific Hybrids: The F_1 progeny between two different species of the same genus is referred to as interspecific hybrid. This is also known as intrageneric hybrid. Development of fully fertile interspecific hybrids is possible only between those species that have complete chromosomal homology. In cotton, interspecific hybrids are fully fertile between *G.hirsutum* and *G.barbadense* and between *G.herbaceum* and *G.arboreum.*

Table 1: Classification of cotton hybrids released in India.

Basis of classification	Types of Hybrids	Examples
1. Species Involved	1. Intraspecific hybrids a. Intra-hirsutum hybrids	H 4, H6,H 8,H 10, JKHy 1, JKHy 2, PKV Hy 2, NHH 44, Savita, Surya, Fateh, LHH 144, Dhanlaxmi, Maruvikas, Omshankar, DHH 11, CICR HH 1
	b. Intra-arboreum hybrids	LDH 11, AAH1
	2. Interspecific hybrids a. Tetraploid hybrids	Varalaxmi, DCH 32, NHB 12, HB 224, DHB 105, TCHB 213, NHB 302, Sruthi
	b. Diploid hybrids	DH 7, DH 9, DDH 2, pha 46
2. Ploidy Level	1. Tetraploid hybrids	All intra hirsutum and interspecific hybrids between G.hirsutum and G.barbadense
	2. Diploid hybrids	All intra arboreum and interspecific hybrids between G.herbaceum and G.arboreum
3. Methods of Hybrid Seed Production	1. Conventional hybrids	All the above mentioned hybrids.
	2. Male sterility based hybrids	Sununa, PKV Hy3, PKV Hy4, MECH 4, AAH 1

Tetraploid Hybrids: Tetraploid hybrids are developed in *G.hirsutum* and *G.barbadense*. tetraploid hybrids are of two types, viz. intraspecific and interspecific. Intraspecific hybrids have been developed in *G.hirsutum* only. Intra-hirsutum hybrids have been released for commercial cultivation in all three zones. Intra-hirsutum hybrids can be cultivated both under irrigated and rainfed conditions. Interspecific hybrids have been released between G.hirsutum and *G.barbadense* for commercial cultivation in central and south zones. These hybrids are grown under irrigated conditions only.

Diploid Hybrids: Diploid hybrids are developed between *G.arboreum* and *G.herbaceum*. Diploid hybrids are of two types, viz. intraspecific and interspecific. Intraspecific hybrids have been developed in *G.arboreum* only. Intra-arboreum hybrids can be cultivated both under irrigated as well as rainfed conditions. Interspecific hybrids between *G.herbaceum* and *G.arboreum* have been released for commercial cultivation in central and south zones. Diploid hybrids have high degree of resistance to insect pests, diseases and drought conditions. The main drawback of diploid hybrids is that the hybrid seed production is a problem due to poor seed setting in crossed bolls.

Conventional Hybrids: Such hybrids are produced by hand emasculation and pollination method. Majority of cotton hybrids are developed by conventional method. Conventional hybrids have been developed in tetraploid and diploid cottons both at intraspecific and interspecific levels. There are two main drawbacks of conventional hybrids. Firstly, the seed of such hybrids is very expensive because several labourers are engaged daily for emasculation process during crossing period. Secondly, hand emasculation causes some injury to the female part resulting in poor hybrid seed setting.

Male Sterility Based Hybrids: Such hybrids are developed through the use of either genic male sterility or cytoplasmic genic male sterility. In cotton, very few hybrids have been developed through the use of male sterility. All the male sterility based hybrids have been released in *G.hirsutum* so far. The first hybrid was developed in 1978 under the name Suguna through the use of genic male sterility. Now three hybrids, viz. PKV Hy 3, PKV Hy 4, and MECH 4 have been developed through the use of cytoplasmic genic male sterility. There are two main advantages of male sterility based hybrids. Firstly, the seed of such hybrids is cheaper due to elimination of emasculation process. Secondly, the seed setting in such hybrids is higher because there is no mutilation of ovary due to elimination of emasculation process. However, the yield of presently released male sterility based hybrids is 10-15% lower than the conventional hybrids involving same parents.

HYBRIDS SEED PRODUCTION

Pure seed of parental lines of a hybrid is used for the production of hybrid seed. Generally, breeder, foundation or certified seed is used for production of hybrid seed. Generally, breeder, foundation or certified seed is used for production of hybrid seed. The hybrid seed production is carried out under irrigated conditions to get continuous flush of flower for a longer period. In India, production of hybrid seed is carried out by two types or organizations, viz. (1) public sector agencies, and (2) private sector agencies.

Public Sector Agencies: Public sector agencies or organizations include (1) State Seeds Corporation (SSC) of the cotton growing states and (2) the state Farms Corporation of India (SFCI). They produce seeds of hybrids developed by National or Central Institutes and State Agricultural Universities. In other words, public sector agencies take up hybrid seed production of only those hybrids which have been developed by public sector research centres. The cotton hybrids developed by public sector research centers are registered and notified so that their seeds can be certified by the State Seed Certification Agencies (SSCA).

Private Sector Agencies: Private Sector organizations include various seed companies which are engaged in the production of hybrid seed. Various Indian and Multinational Seed Companies are engaged in the production of hybrid seed of different field crops including cotton. Private seed companies produce seed of both the hybrids developed by public sector as well as by them. It is estimated that about 55% of the hybrid seed requirement is met by the private sector. Both Indian and Multinational Seed Companies play an important role in hybrid cotton seed production.

AREA OF SEED PRODUCTION

The hybrid seed production of cotton is carried out in the central and south cotton growing zones. The central zone includes Maharashtra, Gujarat and Madhya Pradesh, and south zone includes, Andhra Pradesh, Karnataka and Tamil Nadu. The hybrid seed production is carried out by the state Seed Corporations of these six states and also by the private seed companies. Private seed companies are mainly concentrated in Gujarat and Maharashtra in the central India and Andhra Pradesh, Karnataka and Tamil Nadu in south India. A list of State Seed Corporations and some private Seed Companies engaged in hybrid seed production of cotton is given in Table 2.

Table-2: List of Public and Private Sector Agencies engaged in hybrid seed production.

	Name of Organization / Agency	Location
A.	**Public Sector Agencies**	
	Maharashtra State Seed Corporation	Pune
	Gujarat State Seed Corporation	Ahmedabad
	Madhya Pradesh State Seed Corporation	Bhopal
	Karnataka State Seed Corporation	Bangalore
	Andhra Pradesh State Seed Corporation	Hyderabad
	Central State Farm, Chengam	Chengam (T.N.)
B.	**Some Private Sector Agencies**	
	Maharashtra Hybrid Seed Corporation	Jalna
	Nath Seed Company Pvt. Ltd.	Aurangabad
	Mahendra Seed Company	Jalna
	Vijay Seed Company	Jalna
	Ankur Seed Company	Nagpur
	Pioneer Seed Company	Hyderabad
	Proagro Seed Company	Hyderabad
	Hindustan Lever Limited	Mumbai

The release or development of new hybrid consists of four major steps, viz. (1) development of new cross combination, (2) evaluation of performance, (3) identification of superior entries, and (4) release and notification.

METHODS OF HYBRID SEED PRODUCTION

In cotton, there are two methods of hybrid seed production, viz. (1) conventional method, and (2) male sterility based method. These are briefly discussed below**:**

Conventional Method: In this method, hybrid seed production is carried out by hand emasculation and pollination. Breeder, foundation or certified seed of male and female parents is used for the production.of hybrid seed. This ensure genetic purity in seed production. The female and male parents are planted in the same field in separate plots in 4 : 1 or 3:1 ratio. The sowing of parental material is done in such a way that there should be nicking in the flowering time of both the parents. For example, the female parent of hybrid 4 i.e. G 67 flowers one month later than the male parent (American Nectariless). Here sowing of G 67 is done one month before the sowing of male parent for nicking in their flowering period. The off type plants are rogued out before initiation of crossing programme.

Male Sterility Method: This method is used for hybrid seed production of only those hybrids which have been developed through the use of male sterility. Use of male sterility reduces only the cost of emasculation. Pollination has to be done manually. Two types of male sterility systems are used in cotton, viz.(1) genic male sterility, and (2) cytoplasmic genic male sterility.

Use of Genic Male Sterility: In cotton, Gregg male sterility source is used. The male sterility is transferred to female parent through backcross technique. The male sterility is governed by two recessive genes (ms_5ms_6). A heterozygous male fertile genotype which segregates at one locus only (ms_5 ms_5 / Ms_6 ms_6 or Ms_5 ms_5 / ms_6 ms_6) is identified. Cross of this male fertile genotype with sterile line will always produce male sterile and male fertile plants in 1:1 ratio. Fertile plants are identified only when flowering starts. These are removed. The male sterile plants are pollinated with the pollen of male parent to get hybrid seed. In case of male sterile parent, 3-4 seeds should be sown per hill because 50% of the population (male fertile) is removed when flowering starts.

Use of Cytoplasmic Genic Male Sterility: In cotton, *G.harknessii* cytoplasm is used as a source of cytoplasmic genic male sterility. The male sterility is transferred to the female parent and restorer gene to the male parent by backcross technique. The male sterile and restorer lines are planted in the same field but in separate plots in 4:1 or 3:1 ratio. The crop is grown at wider spacing under irrigated conditions to get continuous flush of flowers for seed production. Crossing is started after one week of flower initiation. The male sterile parent (female) is pollinated with the pollen of restorer (male) parent. After pollination, flowers are covered with tissue paper bags to avoid natural outcrossing with other plants.

MATERIAL REQUIRED

The material which is required for production of hybrid seed in cotton includes : (1) tissue paper bags or straw tubes, (2) magnifying glass, (3) tray, (4) thread, (5) note book and pencil etc. Tissue paper bags of 10 x 15 cm size are required in white and red colour. Red coloured tissue paper bags are used for covering the flower bud after emasculation and white tissue paper bags are used to cover the flower bud after pollination. It helps in the identification of emasculated and pollinated buds. Some people use straw tube for covering the buds. Magnifying glass is required to examine the presence of pollen grains in the emasculated buds. The emasculated bud should be free from anthers and pollen grains. A plastic tray is required for collection of male flowers for pollination. The thread is required for tying pollinated buds for easy identification. The note book and pencil are required for keeping the record of crossing work. When the hybrid seed is produced using male sterile line, only one colour of tissue bag is required.

CROSSING TECHNIQUE

In cotton, hybrid seed production is carried out by artifical crossing. The crossing refers to hand pollination. The crossing technique consists of three main steps, viz. (1) selection of bud, (2) emasculation, and (3) pollination.

Selection of Bud: The selection of flower bud for emasculation is an important step in hybrid seed production. The crossing work is started after one week of flower initiation. The flower buds of proper stage are selected for emasculation. Flower buds which are likely to open the next day are chosen for emasculation. Such buds have generally cream colour and are well developed.

Emasculation: The process of removal of anthers from the selected flower bud is referred to as emasculation. Anthers of selected buds are gently removed with the help of nail of the thumb. The emasculated buds are covered with tissue paper bag of red colour to prevent natural outcrossing. The best time for emasculation is 3-6 PM. Some people use straw tube to cover the ovary of emasculated bud. Emasculation is not required when hybrid seed is produced using male sterility.

Pollination: Emasculated buds are pollinated the next morning with the pollen of male parent. The best time for pollination is 8-11 AM, because the stigma respectively is maximum during this period. Generally, 4-5 buds are pollinated by one flower of male parent. After pollination, the red tissue paper bags are replaced by white tissue paper bags for identification. A label or thread is also tied on the pedicel of crossed bud for identification of crossed bolls.

In cotton, fertilization occurs after 12 – 30 hours of pollination. Hence, the crossed buds should remain covered for 3-4 days after pollination. The straw tube used for cold drink is also used for covering the stigma of emasculated buds before and after pollination.

PROBLEMS ASSOCIATED WITH HYBRID SEED PRODUCTION

There are three main problems which are associated with hybrid seed production in cotton. These are : (1) poor setting of crossed bolls, (2) non-availability of laborers and (3) in some cases lack of synchrony in the flowering period of parental lines.

The main problem in the hybrid seed production of diploid hybrids is that of low \ setting of crossed bolls. Due to this problem, diploid hybrids could not spread under cultivation. In diploid hybrids, the crossed boll setting is about 20-25%, whereas in the tetraploid hybrids the crossed boll setting is upon 50%. Non- availability of female labourers for emasculation and pollination, sometimes becomes a major constraint in the hybrid seed production. In some hybrids, the female and male parents flower at different times. The sowing of parents of such hybrids has to be done in such a way their flowering time should coincide.

STANDARDS FOR CETIFIED HYBRID SEED

There are four basic requirements for production of certified hybrid seed. These are: notified hybrid, genetic purity, physical purity, and proper germination. A hybrid released either by State Variety Release Committee or Central Variety Release Committee is selected for production of certified hybrid seed. It is also essential that the hybrid should be notified one. Genetic purity refers to absence of seeds of other variety. Genetic purity is determined by grow out test. In hybrid seed of cotton produced by hand emasculation and pollination, minimum genetic purity of 90% is required. Selfed plants are permitted upto 8.5% and off types upto 1.5% (Table-3). Physical purity means freedom from insert matter and defective seeds. Insert matter includes non-living materials such as sand, pebbles, soil particles, straw etc. defective seeds are those that are broken, disease infected, insect damaged, undeveloped and unfit for germination. The germination should not be less than 65%. Hybrids deteriorate due to deterioration of their parental lines and evolution of new races of pathogens.

Table-3 : Standards for certified hybrids seed of cotton

Particulars	Percentage in conventional hybrid	CMS hybrids
Pure seeds (Minimum)	98	98
Inert matter (Maximum)	2.0	2.0
Other Crop Seeds (Maximum)	10/kg	10/kg
Weed Seeds (Maximum)	10/kg	10/kg
Genetic purity (Minimum)	90	95
Germination (Minimum)	65	65
Moisture :		
Ordinary container	10	10
Vapour proof container	6	6
Self plants	8.5	4
Off types	1.5	1

COST OF HYBRID SEED PRODUCTION

The cost of hybrid seed production is worked out by adding expenditure on various items such as preparatory tillage, cost of parental seed, registration and inspection charges, cost of fertilizers, sowing, hoeing and weeding (interculture operations), plant protection, emasculation and pollination, irrigation, picking of seed cotton, transportation to gin and ginning and cost of land lease (Table-4).

Table – 4: Cost of hybrid cotton seed production per hectare

	particulars	**Expenditure Rupees**	**Per hectare in US Dollars**
A.	**Expenditure**		
1.	Preparatory tillage	1170	30
2.	Cost of parental seed, registration and inspection charges	2100	52
3.	Sowing	300	8
4.	Fertilizers	4500	112
5.	Hoeing and weeding	1100	28
6.	Plant protection	5500	138
7.	Emasculation and pollination	27000	675
8.	Irrigation	1600	40
9.	Picking of seed cotton	750	19
10.	Transportation to gin and ginning	500	13
11.	Land lease	6000	150
	Total Expenditure	50450	1261
B.	**Income**		
12.	Seed yield (7.5 q/ha x Rs.1100/q)	82500	2062
13.	Lint (3 q/ha x Rs.2500/q)	7500	188
	Total Income	90000	2250
	Net Income	39550	989

From above calculations, the production cost of kg. hybrid seed comes to Rs.110/- (approximately 3 US Dollars per kg).

SEED TESTING

Seed testing is essential for seed certification. Seed testing is carried out in the seed testing laboratory. Seed testing includes (1) physical purity test, (2) genetic purity test, and (3) germination test. The minimum seed certification standards prescribed by International Seed Testing Association (ISTA) are given in Table (4) the physical purity should be 98%. The minimum standard of genetic purity is 90% for conventional hybrids and 95% for cytoplasmic genic male sterility based hybrids. The self plants should not be more than 8.5% in case of conventional hybrids and 4% in CGMS based hybrid. The maximum off types permitted are 1.5% in conventional hybrids and 1% in CGMS based hybrids. The genetic purity is determined by grow out test. The minimum germination percentage prescribed by ISTA is 65%.

PRATICAL ACHIEVEMENTS

There are three types of hybrids viz. (1) intra-hirsutum, (2) interspecific between *G.hirsutum* and *G.barbadense*, and (3) diploid hybrids. About 43 hybrids have been released for commercial cultivation in all these categories so far by public sector organizations. However, only few hybrids could become popular for commercial cultivation. The most popular hybrids include H 4, H 6, PKV Hy-2, JKHy 1 and NHH 44 in the intra-hirsutum group and Varalaxmi and DCH 32 in interspecfic tetraploid (*G.hirsutum x G.barbadense*) group. Recently, several new hybrids, viz. Savita, Surya, H8, H10, DHH 11 (intra-hirsutum) ; and DHB 105, TCHB 213 and Sruthi (interspecific)have been released by public sector research centres which are becoming popular. Four diploid interspecific (*G. herbaceum x G.arboreum*) hybrids have been released (DH 7, DH 9, DDH 2 and Pha 46) so far. However, these diploid hybrids could not spread mainly due to constraints in seed production. Cotton hybrids released so far by Government organizations and their important features are presented in Table-5.

REASONS FOR UNSUCCESS IN NORTH ZONE

Hybrids could not become popular in north cotton growing zone, despite release of hybrids for this zone. In north zone, two intra-*arboreum* hybrids (LDH 11 and AAH 1) and five intra- hirsutum hybrids, viz. Fateh and LHH 144 for Punjab, Dhanalaxmi for Haryana, Maruvikas for Rajasthan and Om Shankar for entire north zone have been released for commercial cultivation. However, these hybrids cover less than 1% cotton area in this zone. There are two main reasons for unsuccess of cotton hybrids in north zone, viz. (1) high cost of hybrid seed, and (2) late maturity.

High Cost of hybrid Seed: In northern zone, cotton sowing is done with seed drill which requires higher seed rate (10 kg/ha). The cost of hybrid seed varies from Rs.500 to Rs.700 per kg. This makes hybrids cultivation uneconomical in the northern zone. Farmers have to purchase fresh seed every year. Moreover, north zone is not suitable for hybrid seed production due to continuous rainfall during peak bolling period and non availability of labourers.

Late Maturity : North zone is double or multiple cropping region due to irrigation facilities. In this zone, cotton- wheat is a common cropping system. Hence, there is need of early maturity hybrids which should vacate the field latest by 15th November for wheat sowing. Moreover, boll bursting is ceased after 15th November due to sudden fall in temperature. This prohibits cultivation of late maturing hybrids in north zone. The yield of early maturing hybrids is low which is not much profitable.

ROLE OF HYBRIDS

Commercial cultivation of hybrids has resulted in significant changes in cotton scenario in India both in quality and production. The major contributions of cotton hybrids include: (1) self sufficiency in production, (2) improvement in fibre quality, (3) stability in production, (4) generation of employment, (5) earning of foreign exchange, and (6) development of seed industry.

Self Sufficient in Production: Cultivation of hybrids has helped in achieving self sufficiency in cotton production. The yield of cotton hybrids is about 50% higher than straight varieties. Sufficient improvement has been achieved in yield after the release of cotton hybrids for commercial cultivation. The first cotton hybrids i.e. H 4 was released in 1970 and another (Varalaxmi) in 1972. soon after the release of these two hybrids, area under hybrid cotton started increasing. Later on, several other high yielding hybrids were released which replaced straight varieties on vast areas. In 1975, the area under hybrids was 3% of total cotton area which has increased to 45% in 1999-2000. The present lint yield is about 320 kg/ha which was only 151 kg/ha during 1970. This quantum jump in lint yield has been achieved mainly due to release of various high yielding hybrids. The first cotton hybrid i.e. H4 was released from Surat and second hybrid i.e. Varalaxmi from Dharwad, Karnataka. Subsequently, several high yielding hybrids were released at intra and interspecific levels in tetraploid cottons for central and south zones. High yielding hybrids have also been released at diploid level (DH 7, DH 9, DDH 2, Pha 46) for central and south zones. Two intra-*arboreum* hybrids i.e. LDH 11 and AAH 1 have been released for north zone. Now intra-hirsutum hybrids (Fateh, LHH 144, Dhanlaxmi, Maruvikas and Om Shankar) have been released for cultivation in northern zone. All India Coordinated Cotton Improvement Project (AICCIP) has played significant role in the release of high yielding cotton hybrids for different agroclimatic regions. The area under hybrids is continuously increasing since 1975 and as a result average lint yield is also increasing. India attained self sufficiency in cotton production in 1980 i.e. within one decade after the release of first cotton hybrid. Now we have exportable surplus. Hybrids have played key role in increasing cotton production due to their high yielding ability.

Table -5: Important Features of Cotton Hybrids Released from Different Status of India.

Name of Hybrid	Species involved	Year of Release	Yield (q/ha)	Duration (Days)	Ginning Outturn (%)	M.H.L. (mm)	Spinning Counts	Area of Cultivation
GUJARAT								
H 4	HH	1970	35	230	33	28	50	Gujarat,Andhra Pradesh, Karnataka, Maharashtra
H 6	HH	1980	35	210	34	27	60	Gujarat, Maharashtra, Andhra Pradesh
DH 7	hA	1985	15 R	190	37	22	30	Gujarat State
DH 9	hA	1988	15 R	190	34	28	40	Gujarat State, M.P.
H 8	HH	1989	35	180	36	28	50	Gujarat State
H 10	HH	1995	18 R	150	35	26	40	Gujarat State
KARNATAKA								
VARALAXMI	HB	1972	30	210	35	31	80	South Zone and Maharashtra
DCH 32	HB	1981	35	190	36	33	80	South Zone and Maharashtra
DDH 2	hA	1992	12 R	180	34	22	20	South Zone
DHB 105	HB	1996	30	190	34	33	80	South Zone
DHH 11	HH	1996	30	190	35	27	50	South Zone
Tamil Nadu								
CBS 156	HB	1974	30	180	32	33	100	Tamil Nadu
SUGUNA	HH	1978	30	150	35	25	40	Tamil Nadu
KCH 1	HB	1980	30	150	34	31	60	Tamil Nadu
SAVITA	HH	1987	30	170	34	30	60	Tamil Nadu and Andhra Pradesh
HB 224	HB	1989	30	170	33	31	80	Tamil Nadu
TCHB 213	HB	1990	30	190	32	33	80	Tamil Nadu
SURYA	HH	1997	25	170	38	31	60	South Zone
SRUTHI	HB	1997	30	150	33	37	80	South Zone
MAHARASHTRA								
GODAVARI (NHH 1)	HH	1978	15 R	180	35	28	50	Marathwada Region

SAVITRI (RHR 253)	HB	1978	28	175	32	30	60	Deccan Canal Area
PKV HY2	HH	1981	12 R	180	36	27	40	Maharashtra, Vidarbha
NHH 44	HH	1983	23	180	35	24	50	Marathwada
RHH 195 (SAMPADA)	HH	1986	21	160	36	24	40	Deccan Canal Area
NHB 12	HB	1989	30	180	33	33	80	Marathwada
CICR HH 1	HH	1991	25	185	35	25	36	Marathwada
NHH 302	HH	1991	20	170	35	25	40	Marathwada
PKV HY3	HH	1994	15 R	180	37	25	40	Marathwada and Gujarat
PKV HY4	HH	1996	20	165	35	28	50	Marathwada
PhA 46	HA	1996	17	180	32	28	40	Marathwada
Madhya Pradesh								
JKHY 1	HH	1976	25	210	35	27	50	Madhya Pradesh and A.P.
JKHY 11	HB	1982	18	240	31	31	60	Irrigated areas of M.P.
JKHY 2	HH	1997	30,15 R	180	34	27	50	Madhya Prasedh
Andhra Pradesh								
NHB 80	HB	1982	20	170	34	27	50	NSP area of A.P
LAHH 1	HH	1987	28	150	35	29	60	Andhra Pradesh
LAHH 4	HH	1997	30	170	35	31	40	All three zones
PUNJAB								
FATEH	HH	1994	30	180	34	25	30	Punjab
LDH 11	AA	1994	20	175	36	25	20	Punjab
LHH 144	HH	1998	28	180	35	28	50	Punjab
HARYANA								
DHANLAXMI	HH	1994	25	180	35	26	40	Haryana
OM SHANKAR	HH	1996	28	165	34	25	40	North Zone
AAH 1	AA	1999	24	180	38	16	Below 100	Haryana
RAJASTHAN								
MARU VIKAS	HH	1994	30	180	34	24	30	Rajasthan

Improvement in Fibre Quality: In cotton, lint is the main product. The quality of lint is adjudged by various fibre parameters such as length, strength, fineness, maturity and uniformity. The spinning capacity is also an indication of fibre quality. Significant improvement has been achieved in fibre quality especially fibre length and spinning capacity through the release of cotton hybrids. Several hybrids have been released in long and extra long staple groups. Such hybrids include H4, H6, JKHy 1, Savita, PKVHy3, PKVHy4, DHH 11, Varalaxmi, DCH 32, NHB 12, HB 224, TCHB 213 and DHB 105 in tetraploid cottons. One long staple hybrid has been released in diploid cotton (DH 9). Interspecific hybrids between G.hissutum and G.barbadense are capable of spinning upto 80 counts. Release of interspecific teraploid hybrids is an important achievement in quality improvement. Hybrids fetch higher price because of their better fibre quality. Thus, hybrids are more profitable to the farmers than varieties. In the beginning, more emphasis was laid on the development of hybrids with long and extra long staple to meet the shortage of such cotton in the country. Later on, hybrids were also released in medium and superior medium staple categories to correct the production imbalance in all fibre categories. Now hybrids are available in medium, long and extra long staple categories which are capable of spinning from 30 counts to 80 counts.

Stability in production: Varietal adaptability to environmental fluctuation is important for stabilization of crop production over regions and seasons. Its also helps in extending the cultivation of a cultivar in different agroclimatic regions. In cotton, some of the hybrids have wide adaptability, which has played significant role in stabilizing cotton production. Hybrids with wide adaptability include H4, H6, JKHy1, Varalaxmi, DCH 32, NHH44 etc. The hybrid H4, which was released in 1970 for Gujarat State, soon spread to other states such as Maharashtra, Andhra Pradesh, Karnataka and Madhya Pradesh due to its wide adaptability. Hybrid JKHy 1 was released from Indore for Madhya Pradesh, but due to its wide adaptability it became popular in Andhra Pradesh. Interspecific hybrids Varalaxmi and DCH 32 released for Karnataka State, spread to Andhra Pradesh, Tamil Nadu and Maharashtra due to their wide adaptation. Hybrid NHH 44 released from Marathwada has become popular in entire Maharashtra, parts of Andhra Pradesh and Madhya Pradesh. Thus, wide adaptability of cotton hybrids has helped in stabilization of cotton production to considerable extent in different regions and years.

Generation of Employment : There are two methods of hybrid seed production, viz. (1) hand emasculation and pollination method, and (2) use of male sterility. In the first method, lot of labour is required for emasculation and pollination and in the second method, labour is required for pollination. Thus, hybrid seed is produced with the help of labourers. The hybrid seed production is carried out by the farmers under the supervision of Stated Seed Corporation. Hybrid seed is also produced by Private Seed Companies. Both State Seed Corporations and Private Seed Companies have trained farmers in hybrid seed production in the central and south cotton growing zones. Hybrid seed production programme provides employment to millions of rural people. About 60% of the labour force employment for hybrid seed production of cotton is women labour. Hybrid seed production programme alone has generated employment for 25 million additional rural labour units. Due to increase in area under hybrids, this estimate would be still higher.

Foreign Exchange: India attained self sufficiency in cotton production within one decade after the release of first cotton hybrid. Now India is exporting cotton to various countries. Export of cotton in the form of lint, yarn and textiles constitute about 33% of the total export of the country. The major share of the exported cotton belongs to the long and extra long staple which is contributed mainly by the tetraploid hybrids (H6, H8,DCH 32, JKHy 1 etc.). Now India earns foreign exchange worth Rupees 420 thousand millions annually by way of cotton export in the form of lint, yarn and textiles.

Development of Seed Industry: Commercial cultivation of hybrids in various crops like cotton, sorghum, pearlmillet and maize has helped in the development of seed industry in India. Now more than 100 National and multinational seed companies are actively engaged in the production of hybrid cotton seed in India. These seed companies produce hybrid seed of the hybrids released by public sector as well as private sector agencies.

HYBRID RESEARCH CENTRES

In 1989, Indian Council of Agricultural Research launched a Hybrid Research Project on nine crops including cotton to develop high yielding and superior quality hybrids. Now there are 12 hybrid cotton research centres (Table -6). Remarkable progress has been made by these research centres. Till 1999, these centres have released 19 hybrids for commercial cultivation in different states. The Central Institute for Cotton Research (CICR), Nagpur is the coordinating centre.

Table-6: Hybrids released from different research centres during 1989- 1999

Name of Research Centre	Hybrids Released
PAU, Ludhiana	Fateh, LHH 44 LDH 1
HAU, Hisar	Dhanlaxmi, AAH 1 **
RAU, Sriganganagar	Maruvikas
CICR,Sirsa	Om Shankar
GAU, Surat	Hybrid 10
JNKVV, Khandwa	JKHy 2
PDKV, Akola	PKV Hy3*, PKV Hy4*
MAU, Nanded	NHH 302
CICR, Nagpur	CICR HHH 1 (Kirti)
APAU, Guntur	LAHH 4
UAS, Dharwad	DHH 11, DHB 105, DDH 2
CICR, Coimbatore	Surya,Sruthi

* = CMS based hybrids * * = GMS based hybrid

Remarkable achievements have been made in heterosis breeding after inception of Hybrid Cotton Research Project. Several high yielding hybrids with good fibre quality and resistance to insects and diseases have been released for commercial cultivation for all the three zones. From 12 research centres, 19 hybrids have been released for commercial cultivation in different states. Two hybrids viz. PKVHy 3 and PKVHy 4 have been released through the use of cytoplasmic genic male sterility.

AREA AND PRODUCTION OF HYBRIDS

The first cotton hybrid was released in 1970 (H4) and second in 1972 (Varalaxmi). Later on, several other hybrids were released for cultivation in different states. In 1975, the area under hybrids was 3% of total cotton area in India, which increased to 11% in 1980, 26% in 1985, 36% in 1990, 40% in 1995 and 45% in 1999-2000 (Table-7).

Table-7: Area and production of hybrid in different years in India.

Year	Area (%)	Production (%)
1975	3	4
1980	11	16
1985	26	32
1990	36	42
1995	40	48
1999-2000	45	55

Hybrids cover 50 % Area in Gujarat and Maharashtra, 65% in Andhra Pradesh, 70% in Karnataka, 42% in Madhya Pradesh, 20% in Tamil Nadu and less than 1% in Punjab, Haryana and Rajasthan.

LIMITATIONS OF HYBRIDS

There are four main problems of cotton hybrids, viz. (1) high cost of seed, (2) high cost of cultivation, (3) difficult in seed production and (4) neps and motes especially in interspecific hybrids.

High Cost of Seed : In cotton, the hybrid seed is usually produced by hand emasculation and pollination which is very costly. The cost of hybrid seed varies from Rs. 500 to Rs. 700 per kg. This high cost of seed cannot be afforded by small and marginal farmers. Even if the male sterile line is used, the pollination has to be done by hand because extent of hybrid seed production.

High Cost of Cultivation: The cultivation of hybrids is input intensive. Hybrids require more inputs in term of fertilizers and pesticides than varieties. The high cost of cultivation cannot be afforded by small and marginal farmers. The high cost of seed and cultivation acts as barriers in the expansion of area under hybrid cotton. Hence, there is need to develop cotton hybrids for low input technology.

Difficulty in Seed Production: The diploid hybrids could not become popular among the farmers due to difficulty in seed production. The seed setting in diploid crosses is very low (about 25%) which poses problems in hybrid seed production.

Neps and Motes: The problem of neps and motes is more in interspecific hybrids than in intraspecific ones. Presence of neps and motes affects the yarn quality. Their presence leads to ugly appearance of yarn. Hence efforts should be made top develop interspecific hybrids with as low mote contents as possible. In future, efforts should be made to develop male sterility based hybrids, with multiple resistance to diseases and insects suitable for cultivation under low input technology under rainfed conditions.

FUTURE PROSPECTS

In India, remarkable progress has been made in the development of commercially cultivated hybrids. Hybrids have helped in achieving self sufficiency in cotton production. Hybrids have been developed at both tetraploid and diploid levels. The future work on hybrid cotton research needs to be directed towards the following thrust areas.

1. The north zone is very productive. Some hybrids have been released for north zone but their yield is only slightly higher than varieties. There is need to develop intraspecific hybrids in G.hirsutum and G.arboreum with high level of heterosis (at least 4 tonnes/ha) suitable for cotton-wheat cropping system of northern zone.

2. All cotton hybrids are susceptible to bollworms. There is need to develop transgenic hybrids with resistance to bollworms. Transgenic hybrids can be developed through the use of transgenic line as one of the parent of a hybrid.

3. About 70% of the cotton crop is grown under rainfed conditions. There is need to develop cotton hybrids resistant to drought conditions of south and central zones. In some areas, there is problem of soil salinity. Hence, there is need to develop hybrids resistant to soil salinity.

4. Most of cotton hybrids have been developed by hand emasculation and pollination method. Very few hybrids have been developed through the use of male sterility. The cost of hybrid seed of conventional hybrids is very high and the yield of male sterility based hybrids is 10-15% lower than conventional hybrids. Hence, there is need to develop high yielding hybrids through the use of male sterility specially cytoplasmic genic male sterility.

5. The interspecific hybrids suffer from neps and motes resulting in poor yarn. There is need to develop interspecific hybrids with minimum neps and motes contents.

6. Intraspecific hybrids have been developed in G.hirsutum and G. arboretum only. These is ample scope for developing intra barbadense hybrids. Such hybrids will be free from problems of neps and motes.

7. The labour problem is becoming acute day by day. At present, cotton picking is done by manual labour which is very expensive. There is need to develop cotton hybrids suitable for machine picking.

8. The cultivation of present cotton hybrids is high input oriented. There is need to develop cotton hybrids suitable for low input technology.

9. The main constraint in the spread of diploid cotton hybrids is problem of hybrid seed production. The hybrid seed setting in diploid hybrids is very poor (about 25%). Hence, efforts should be made to improve hybrid seed setting in diploid hybrids.

10. All the cotton hybrids developed so far have white lint. There is some demand of naturally coloured lint from western countries like Germany, France and U.K. Hence, there is need to develop naturally coloured linted hybrids of cotton. However, work on development of coloured linted hybrids should be restricted to one or two centres only to avoid contamination of white linted cotton.

11. There is also demand of organic cotton from some western countries. Organic cotton refers to the cotton that is produced without the use of any chemical such as chemical fertilizers, insecticides, fungicides, weedicides, hormones etc. Hence, there is need to develop high yielding hybrids for organic cultivation. Such hybrids are expected to fetch premium price.

----The End---