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Breeding in *Hibiscus*: A review

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ABSTRACT

Among the 300 *Hibiscus* species, the most popular ornamental species is *H. rosa-sinensis*, used both as an indoor and outdoor potted and landscape plant. A variety of forms, flower colours, and growth forms exist. This species is a complex hybrid arising from several *Hibiscus* species, viz. *H. liliflorus*, *H. kokio*, *H. storckii*, *H. denisonii*, *H. fragilis*, *H. boryanus* and *H. arnottianus*. Knowledge of genetic diversity and its response to natural/ human selection through hybridization is necessary for future breeding plan. All the present day colourful varieties of *Hibiscus rosa-sinesis* were developed through complex interspecific crosses, open pollination, indiscriminate intervarietal hybridization, spontaneous and induced mutation. There is no record of total hibiscus varieties developed through conventional breeding in different countries. Present article will provide maximum information generated in India and abroad on classical and mutation breeding on hibiscus along with important publications in hibiscus by other research institutions/universities. Little genetic information and trait heritability has been established for this crop, plant breeding continues to produce new variants for commercial production. Future breeding and genetic studies are needed to further transform this crop.

Key words: Breeding, Hibiscus, Polyploidy, Interspecific hybridization, Varieties

Hibiscus is one of the most beautiful shrubs grown in tropical and sub-tropical gardens. In vernacular language it is known as *Rudrapushpa*, *Sthalpaddo*, *Bettada Tavare*, and *Dasala*. It commonly called as Chinese hibiscus or Rose of China or Hawaiian hibiscus or Blacking plant or Shoe flower is a flowering plant of hot and warm climate, and hence, known as Queen of Tropics. Florida is the prominent hibiscus growing centre of the world. The American Hibiscus Society helps to evolve worthwhile novelties through breeding achievements.

Hibiscus L. belongs to the tribe Hibisceae of the family Malvaceae or Mallow family (Borssum- Waalkes 1966, Ghazali 1999). Genus *Hibiscus* is polymorphic containing about 300 species of trees, shrubs and herbs. Geographically *Hibiscus* is mainly situated in tropical and sub-tropical regions of the world, with some species extending into the temperate regions of the world, i.e. *H. syriacus* and *H. sinosyraicus* (Bates 1965, Willis 1966, Heywood 1978). It bears large flowers on the bushy hedges. These enormous flowers are usually dark red in colour and are not usually fragrant. The huge size and the reddish colour and hues attract humming birds and the gardens growing these flowers are regularly visited by the humming birds. Many of the species yield fibers, notably, *H. cannabinus* L., *H. sabdariffa* L., *H. surattensis* L., *H. planifolius* Sweet., *H. flococcus* Mast., and *H. macrophyllus* Roxb., are locally used for fiber in Asia. Some species are good source of food and medicines, e.g. *H. cannabinus* and *H. sabdariffa* leaves are consumed as green vegetables while swollen calyces of *H. sabdariffa* are eaten raw in salads (Wilson and Menzel 1964, Gasim 1994). The flowers of hibiscus have hypoglycaemic (Sachdewa *et al*. 1999) and hypotensive (Ahmed *et al*. 2001) action. Several species of genus are used as ornamentals. *Hibiscus rosa-sinensis* (shoe flower) has long been cultivated in China, India, Japan, and the Pacific islands. The east-African *H. shizopetalous* Hook. (Coral hibiscus/ Chinese lanterns) is also grown as an ornamental and its hybrids with *H. rosa-sinensis* do occur. *Hibiscus acetosella* Welw. (African rose mallow) is widely grown in Nigeria and other African countries. *H. mutabilis* L. (Changeable rose/Persian rose) has long been cultivated in China (Wilson and Menzel 1964, Purseglove 1974, Akpan 1991).

Breeding history

There is no authentic record of the history of the domestication of *H. rosa-sinensis*. It is believed that the species is a native to China, and was first cultivated by the Chinese for its showy flowers (Kimbrough 1997). No extant wild population been reported from that country. Another view holds that the species is a native of Indian Ocean islands of which Madagascar, the Mascarene Islands and the Rodriguez Islands are a part (Borssum-Waalkes 1966).

In Hawaiian Islands, hibiscus breeding dates back to

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the 1870's when the Hon. Archibald Cleghorn of Oahu, then governor of Hawaii, developed 12 new varieties. Later he enthused numerous amateur hybridizers to produce thousands of complex hybrids whose parentage is now impossible to trace (Roe 1961). The white-flowered *Hibiscus arnottianus* Gray was used extensively. Waianae White, a botanical variety of *H. arnottianus* Gray, *H. brackenridgei* Gray, a native species with sulfur-yellow flowers, and *H. youngianus* Gaud, a native pink, were found to be sterile after repeated attempts to hybridize them. The latter two, however, were prolific self-seeders. *Hibiscus kokio* Hillebrand was a forerunner of the red varieties. Among the introduced species used extensively in hybridization are the common single red, *H. rosa-sinensis* L., coral hibiscus, *H. schizopetalus* Hooker, narrow-petaled white, *Hibiscus* sp. from Fiji, and the common pink hedge hibiscus, possibly a hybrid of *H. cameroni*. *Hibiscus rosa-sinensis* cultivars are the result of crosses (both ancient and modern) between a limited number of species-the majority from the Mascarene Islands in the Indian Ocean, and Hawaiian Islands in the Pacific. Three *Hibiscus* species native to this area are genetically compatible with *H. rosa-sinensis* (Singh and Khoshoo 1970). Singh and Khoshoo (1989) reported that species is complex in origin and produced by hybridization of mainly two groups of species, one is from Indian Ocean Islands and East African Coast and consists of *H. schizopetalus* Hook., *H. liliiflorus* Cav., *H. fragilis* and *H. boryanus* Hook. The other group is from Pacific islands, consists of *H. arnottianus* Gray., *H. genevii* L., *H. kokio* Hillebrand, *H. storckii* Seeman and *H. denisonii* (Roe 1961, Skovsted 1941). These species are fully incompatible and hybridize freely without regard to chromosome number of the parents. The present day cultivars are highly polymorphic and highly heterozygous and produce a wide range of growth habits, vigour, and flower colours and form. These wide ranges are believed to be the result of introgressive segregation and interaction of gene combinations produced during recombination (Singh and Khoshoo 1989). Sadly, nearly all of these are (as well as numerous other Malvaceae species) are now considered extinct or facing extinction in their natural habitats. Over 9 000 *H. rosa-sinensis* cultivars are reported in the International Hibiscus Society web site (http://www.internationalhibiscussociety.org), including sports as well as derivatives of wide hybridization between species complexes originating from different geographic origins.

Cytologically, the species contains polyploidy-aneuploid range, as well as varying base numbers (X=7, 11, 12, 15, 16, 17, 18, 19, 20) (Darlington and Ammal 1945). However, there are 27 different aneuploid chromosome numbers within *H. rosa-sinensis*, starting with Queen (2n=46) to 'Giant Rose' (2n=144). The level of polyploidy has arisen to between 4x and 25x probably due to fertilization involving 2n or unreduced gametes (Sharma and Sharma 1962).

Centers of diversity

Hibiscus is grown all over the tropics and sub-tropics but by far the greatest diversity of cultivars can be found in India, China, South-East Asia as well as the South Indian Ocean islands. It is widely believed that these are the areas where the primitive forms of the species were first cultivated. Some of these areas may still harbur the original primitive forms. Secondary centers of diversity can be found in Canary Islands, Madiera and Mascarene Islands. Both these islands were centers for the acclimatization of tropical and sub-tropical plants, including ornamentals. Hawaiian *Hibiscus* includes species which closely resemble *H. rosa-sinensis* in vegetative and floral characteristics, and can easily cross with each other and with varieties of *H. rosa-sinensis* thereby contributing genomes to the *H. rosa-sinensis* complex (Singh and Khoshoo 1989). The East African Coast, Mauritius and Rodridguez islands are the homes of *H. schizopetalus*, *H. lilliiflorus*, *H. fragilis* and *H. boryanus*, respectively, which also contributed genomes to *H. rosa-sinensis* complex.

Genetics of characters

Due to complex nature of the species not much information is available on heritability and genetics of characters. It is not yet understood how such a vast diversity exists in *H. rosa-sinensis* in flower colour, form and size. Hybridization coupled with vegetative propagation has played an important role in the evolution of this ornamental.

Studies have indicated that pink flower colour is dominant over red flower colour (Gast 1968, Singh and Khoshoo 1989). Stem pigmentation is monogenically inherited in varieties of *H. sabdariffa* (Falusi 2005). Both bushy plant habit and edible calyx are monogenic dominant. Factor pairs *Bu-bu* and *Eb-eb*, control the habit (Bu-bushy and bu-non-bushy) and calyx nature (Eb-edible and eb-non-edible calyx), respectively. Two pairs of factors present separately in two parents control the leaf shape. Monogenic dominant resistance to root knot nematode has been described in interspecific hybrid between *H. cannabinus* and *H. sabdariffa* (Wilson and Menzel 1967). Falusi (2008) reported inheritance of pink flowers and nematode resistance was governed principally by two independently assorting dominant genes '*P*' and '*R*'; while their recessive alleles '*p*' and '*r*' produce plants having light-yellow flowers and susceptible to root knot nematode, respectively.

Crop ideotype

An ideal hibiscus plant should be ~ 2m tall, well branched, with a hemispherical form. Leaves should be luxuriant and counter balance the brightly coloured flowers. The flowers should be profusely produced more or less throughout the year. Plant should be perennial in warmer climate, slow growing or amenable to pruning, not growing into a tall rambling plant within few years. Plant should not be susceptible to fungal, insect and nematode attacks.

An ideal potted plant should be able to establish quickly, grow vigorously with strong roots (Miller 1987, Clatfelter 1997). A potted hibiscus plant should be able to grow back quickly after pruning. It must tolerate regular application of fertilizer and frequent irrigation (Hughes and Hughes

2003, Forsling 2004).

Breeding constraints

Self and cross incompatibility in cultivars, highly heterozygous nature, pollen sterility, fruit shedding, very rare seed set, failure of endosperm to develop and polyploid-aneuploid complex are some of the breeding constraints.

Breeding objectives

The breeding objectives are- 1. Extended blooming period under poor light condition. 2. Good growth habit, vigour, strong root system, attractive foliage. 3. Varieties suitable for pot culture or as garden display. 4. New flower colour, form, size, shape and good keeping quality. 5. Double flower varieties with variegated leaves. 6. Develop new ideotype hybrid varieties with multiple flower colours. 7. To evolve varieties resistant to various pests and diseases, and 8. To evolve varieties resistant to drought and winter hardy.

Breeding methods followed

Hibiscus improvement through conventional and modern breeding techniques mostly done in Hawaii, California, Florida, Mauritius, Australia, Denmark, Thailand, Fiji, and India. Hawaii is reputed as world's centre for evolving magnificent varieties through planned hybridization. Large number of varieties with spectacular flowers has been developed from Hawaiian types. The breeding and selection of hibiscus have been conducted since 1995 at the breeding nursey of the Institute of Plant Breeding (IPB), Crop Science Cluster (CSC), and University of the Philipppines Los Banos (UPLB), to continuously develop new hybrids. In India, many hybrids were developed during 1920-45 using *H. cameronii* as seed parent, which is still popular. The traditional methods of varietal upgradation in hibiscus are introduction, hybridization and mutation. Mostly improvement of hibiscus has been taken place by simple selection of clones within the existing cultivars and by hybridization between cultivars followed by selection of the highly, heterozygous progeny. Both interspecific and intergeneric hybridization has been carried out at different research stations.

Introduction

Enrichment of germplasm is first step towards improvement of this crop. Variety, Hybrida Monstrous (EC43423) was introduced from USSR in 1968 at NBPGR regional station, Shimla. Cultivars Battalion, Beach Girl, Chester Frowe, Comet, Cromwell, Debby Ann, Florence Nightingale, Golden Belle, Grace Goo, Hawaii, Honi Honi, Huba Huba, Hula Blue, Kanaka Nui, Lahiana, Leberacea, Madame Florence, Mai Mai, Morley Theaker, Niumalu, Polly King, Roosevelt, Ruffle, Sebactani, Splash, Suzan, Vasco and White Pink Centre are introductions to India from Hawaii during 1961-62-64 at Lal Bagh Botanical garden, Bengaluru (Bhat 1995). These cultivars bear flowers of enormous size and wide array of colours. Varieties/ hybrids of *H. rosa-sinensis* which are floriferous and bear attractive single or double flowers are mentioned in Table 1.

Table 1 Introduced hibiscus varieties (Randhawa and Mukhopadhya 1986, Bhat 1995)

Cultivars	Flower colour
Single flowered	
Agnes	Cyclamen-pink & deep pink centre
Alipore Beauty	Deep rosy
Glowing Sunset	Salmon orange
Lipstick	Bright red with dark centre
My Beauty	Pink with a prominent maroon centre
Netaji	White flowers with crimson centre
Viceroy	Deep rose-red
Waimeae	Snow white
Double flowered	
Australian Single	Deep rose with maroon centre
Aurora	Flesh pink colour
Battlion	Light biscuit colour
Beach Girl	Dutch Vermillion with red centre
Chester Frowe	Deep red with white & yellow diffused patches
Chitra	Marigold orange
Comet	Bright ruby red to turkey red
Cromwell	Cream white, very light pink veins
Daffodil	Daffodil yellow
Debby Ann	Bright rose pink
Dream	Large mauve
Florence Nightingale	Light mauve with pink centre
Golden Gleam	Buttercup yellow
Golden Belle	Golden yellow
Grace Goo	Deep biscuit with buff & red centre
Hawaii	Sulphur yellow with deep red at centre
Honi Honi	Saffron yellow with medium red centre
Hubba Hubba	Neyron rose with tips of petals amber yellow
Hula Blue	Bright carmine to crimson red
Juno	Cerise colour
Kanaka Nui	Coppery red to orange
Lahiana	Self pink white with white shadings
Leberacea	Light yellow with white centre
Madame Florence	Saffron red with distinct yellow streaks
Mahatma	Cadmium orange with red centre
Mai Mai	Honey red
Morley Theaker	Bright scarlet with white centre. Grey veins with side streaks
Niumalu	Saturn red and honey red at centre
Polly King	Garnet brown to orange with poppy red corolla
Roosvelt	Bright golden yellow
Ruffle	Indian yellow
Sebactani	Purple lavender mauve
Splash	Creamy white on petals
Suzan	Corolla light yellow with honey red centre
Vasco	Lemon yellow with creamy white centre
White Pink Centre	Whitish broad petals and pink centre

Table 2 Hibiscus cultivars evolved through seedling selection (Bhat 1995)

Cultivar	Derived from	Flower colour
Aphrodite	*H. syriacus*	Dark pink
Bharat Sundari (1976)	IIHR-1	Deep neyron rose
CO.1 (syn. Punnagai, 1981)	Chandrika	Apricot yellow
Dr B P Pal (1969)	Lahiana	Whitish pink turns to rose pink
Gnat	Lahiana	Pink with red margin
President	Hula Bule	Red base changing to cherry red
Rashtrapati	Lahiana	Rose opal coloured & terminates to peach colour
Soyang (1997)	*H. syriacus*	Reddish pink with red eye spot

Selection

Many promising cultivars have been developed through seedling selection from open pollination (OP) at Lalbagh Botanical garden, Bengaluru (Table 2).

Intervarietal hybridization

Intervarietal hybridization followed by careful selection is a recognized method to evolve high quality strains possessing desirable economic traits. Selection of desirable hybrid plants from out of 2 800 hybrid progenies planted in the hibiscus breeding blocks at the Crop Science Cluster and Institute of Plant Breeding resulted in the identification of seven outstanding hybrids. The seven hybrids, collectively called the 'Women in Public Series II', were named after outstanding and dedicated Filipina public servants (Table 3). Of the 1 200 hybrids developed through intervarietal hybridization more than 25 promising hybrids of *H. rosa-sinensis* have been released by IIHR, Bengaluru, Lalbagh Botanical garden, Bengaluru and TNAU, Coimbatore are mentioned in Table 3.

Intergeneric hybridization

The objectives of intergeneric hybridization are to generate variability so that useful variants with high seed yield, high germination, good flower quality, and disease resistance. This method of hybridization is successful to a lesser extent. *Hibiscus rosa-sinensis* and *Malvaviscus arboreus* are intercrossable. The successful hybrid Thilagum, renamed as CO.2 was released by TNAU, Coimbatore in 1981 (Abdul-Khader *et al*. 1985).

Interspecific hybridization

Hybridization among different species and genera is one of the most important breeding approaches used for improvement of ornamental plants. The main aim of this is to merge distant gene pools, hence broadening the genetic variability. However, hybridization barriers often occur in interspecific crosses hampering production of hybrids. Cochis (1965) reported that interspecific pollination is effective in *H. rosa-sinensis* × *H. schizopetalus* during autumn, winter and early spring season. Ideal time for effecting crosses is between 9.30 AM and 4.30 PM and this resulting in good seed set. Interspecific crosses were made by crossing three *Hibiscus* species, viz. *H. syriacus, H. paramutabilis* and *H. sinosyriacus* (Tachibana 1974). The F_1s ranged from partial fertile to complete sterile; viable seeds were obtained in F_2. '*Hibiscus* × *archeri*' is an old hybrid between *H. rosa-sinensis* and *H. schizopetalus*. It is upright, fast growing and often grown on its own roots. The 10 cm red flowers last for a day. Wide hybridization has been achieved in transferring traits from other *Hibiscus* spp. to Kenaf (*H. acetosella*) in India (Satya *et al*. 2012). Interspecific hybridization revealed the existence of cross compatibility barrier among three species namely, *H. rosa-sinensis, H. mutabilis* and *H. schizopetalus* (Table 4).

Mutation breeding

In India, lot of cultivars has been raised by selection of natural bud sports or mutations. Induction of mutation through chronic gamma irradiation in hibiscus was reported by Das (1971). Three somatic mutations have been isolated, one in cv. Cruenthus and two others, in cv. Alipore Beauty. Both the varieties were exposed in pots under semi-acute exposures. In cv. Cruenthus, a mutation with change of flower form from double to single type has been established. In cv. Alipore Beauty two somatic mutants one with deep red flower colour as against light red carmine colour and other with deep red flower colour coupled with semi-double form with an average 2-15 petals have been isolated. Banerji and Datta (1988) have developed a single flower mutant of cv. Alipore Beauty through induction of gamma rays and it has been named as Anjali. A spontaneous mutant in *H. syriacus* with change in flower colour from smoky red to yellow was selected by Misra (1978).

Polyploidy breeding

A spontaneous allododecaploid (2n=12=216) has been reported from a hybrid between *H. radiatus* × *H. diversifolius* having reduced vigor and smaller leaves than standard F_1 (Wilson and Menzel 1967). Failure of many species crosses due to hybrid sterility prompted Van Laere *et al*. (2006) to create hexaploid *H. syriacus* plants. This was obtained by crossing tetraploid *H. syriacus* 'Oiseau Blue' with colchicine doubled (octaploid) *H. syriacus* seedling. The generated hexaploid progeny had an increased growth vigour compared to tetraploid cultivars. The F_1 seedlings were also sterile. Out of this hexaploid F_1 population, an improved blue flowered plant was selected and multiplied. Kuwada (1967) synthesized a fertile amphidiploid by duplication of F_1 hybrid of Fuyo (*H. mutabilis*, 2n=92) and Momiji-Aoi (*H. coccineus*, 2n=38). The induced amphidiploid showed regular meiosis forming 65 bivalents. The amphidiploid was highly fertile (82.6% pollen fertility) having larger pollen grain size (217 µm dia.), five toothed calyx, large

Table 3 Hybrids developed through intervarietal hybridization (Devaiah 1968, Sundar 1971, Gangaswamy and Sundar 1972, Bhat 1995, Magdalita and Pimentel 2013)

Hybrid and year of release	Parents	Flower colour
IIHR, Bengaluru		
Aikta (1976)	Debby Ann × H.S.203	Post office red
Anuradha (1978)	Debby Ann × H.S.48	Golden buff with reddish border
Ashirwad (1978)	H.S.121 × Hombe Gowda	Cadmium orange-yellow
Arunodaya (1972)	IIHR-H-2 × Rachaiah	Nasturtium orange
Basant (1972)	IIHR-H-1 × Rachaiah	Sulphur yellow
Benazeer (1972)	H.S. (Red) × H.S.123	Capsicum red
Chitralekha (1976)	Debby Ann × H.S.203	China rose with white variegated petals
Dilruba (1976)	Debby Ann × H.S.203	Dark golden buff
Geetanjali (1972)	Debby Ann × Rachiah	Turkey red
Jogan (1972)	IIHR-H-1 × Rachaiah	Azalea pink
Nartaki (1972)	H.S.(red) × H.S.123	Marigold orange
Nazneen (1972)	H.S.203 × Rashtrapati	Tangerine orange
Neelofer (1979)	Seedling × Aldrin	Magenta Rose
Pakeezah (1972)	IIHR-H-1 × Rachaiah	Carmine red
Phulkari (1976)	H.S.139 × H.S.18	Delft Rose with light purple rays and yellow border
Priya (1972)	IIHR-H-2 × Rachaiah	Rose Bengal
Queen of Hessaraghatta (1976)	H.S. × H.S.123	Orange
Ratna (1979)	H.S. 127 × Ruffle	Light yellow with orange red stripes
Red Gold (1972)	IIHR-H-2 × Cronwell	Dutch vermillion
Red Saturn (1978)	H.S. 182 × Red Double	Signal red
Shanti (1972)	IIHR-H-1 ×x Rachaiah	Primrose yellow
Smt. Indira Gandhi (1974)	H.S.182 × Ruffle	Indian yellow with orange red margin
Smt. Kamla Nehru (1974)	Debby Inn × Nijalingappa	Rose Bengal
Tribal Queen (1972)	IIHR.H-1 × H.S.481	Cardinal Red with dark purple base
Lalbagh Botanical garden, Bengaluru		
Aurobindo	Leberacea × White Pink Centre	Aureolin & saffron yellow margined petals
Mother Teresa (1972)	Honi Honi × Comet	Capsicum red & saffron red margined petals
TNAU, Coimbatore		
CO.3 (1984)	Bright Yellow × Red Gold	Apricot yellow with signal red throat
University of Philippines		
Domini M. Torevillas	Marcela × Nelia T. Gonzales	Dark orange flower with dark red eye zone
Cynthia A. Villar	Tangerine Orange x Loren B. Legarda	Orange flower with red eye zone
Marilyn D. Maranon	Perla Santos-Ocampo × Loren B. Legarda	Lemon yellow flower with white eye zone
Maria Rosario O. Montejo	Perla Santos-Ocampo × Loren B. Legarda	Red orange flower with pinkish red eye
Arlene B. Arcillas	Nazaria × Loren B. Legarda	Carmine rose flower with cardinal red eye
Connie S. Angeles	Tangerine Orange × Loren B. Legarda	Orpiment orange flower with cardinal red
Sylvia P. Lina	Nazaria × Loren B. Legarda	Neyron rose flower with magenta eye

petal and flower size.

Molecular breeding

Genetic diversity of *H. tiliaceus* using AFLP markers was assessed by Tang *et al*. (2003). Out of total 145 samples, 20 samples showed no polymorphism while 125 samples showed 501 of 566 polymorphic bands (88.5%). Estimates of genetic diversity agreed with life history traits and geographic distribution.

Satya *et al*. (2012) reported first time use of molecular characterization of interspecific hybrids in hibiscus. Use of AFLP markers was efficient in rapid screening of genetic diversity in *H. rosa-sinensis*, *H. syriacus*, *H. sinosyriacus* and *H. paramutabilis*. This modern study established genetic relationships and genetic background of species (Van Huylenbroeck *et al*. 2000, Braglia *et al*. 2010). RAPD

Table 4 Interspecific cross compatibility in *Hibiscus* species

Cross	Results	References
H. cannabinus × *H. acetosella*	Cross successful; hybrids exhibited characters intermediate of the parental species. Hybrids exhibited reddish tints in leaf & red patches in the stem & calyx	Satya *et al*. (2012)
H. acetosella × *H. cannabinus*	Cross successful; hybrids showed intermediate characters between two parents	
H. rosa-sinensis × *H. schizopetalus*	Cross successful; hybrids showed intermediate characters between two parents	Bhat and Verma (1980)
H. schizopetalus × *H. lilliiflorus*	Cv. Butterfly from Singapore botanical garden	Singh and Khoshoo (1989)
H. acetosella × *H. radiatus*	Cv. Panama Red; attractive foliage, vigorous growth & released for green industry	Contreras and Ruter (2009)
H. sinosyricus cv. Seobong × *H. syriacus* cv. Samchully	Cv. Tohagol Red; violet purple, ruffled flowers with intense red eye	Ha *et al*. (2014)
H. syriacus (tetraploid) × *H. syriacus* (octaploid)	No seed set	Van Laere *et al*. (2006)
H. syriacus (tetraploid) × *H. paramutabilis* (tetraploid)	Seed sets, fertile at same tetraploid level	
H. paramutabilis (tetraploid) × *H. syriacus* (tetraploid)	Failed to set fruits & no seed set	
H. syraicus (tetraploid) × *H. sinosyriacus* (tetraploid)	Vigorous seedlings & leaves have intermediate morphology	
H. syriacus cv. Oiseau Blue (tetraploid) × *H. syriacus* seedling (octaploid)	Progeny vigorous in growth, compared to tetraploid parent and F_1 sterile	
H. syriacus (octaploid) × *H. paramutabilis* (tetraploid)	Better fruit set, fruit abortion in early developmental stage; early germination; leaves have intermediate morphology compared to parents	
H. coccineus cv. Red Star × *H. laevis*	Lowest fruit set (20%); high seed germination; less number of seeds (<20); high seedling survival	Kuligowska *et al*. (2016)
H. laevis × *H. coccineus* cv. Red Star	High seed germination; high seedling survival	
H. coccineus cv. Red Star × *H. moscheutos* ssp. *palustris* Pink Mallow	High seed germination; seedlings show sign of chlorosis, necrosis & died	
H. coccineus cv. Red Star × *H. moscheutos* Disco Belle	Low pollen tubes reached the ovaries; high seedling survival; lowest fruit set (20%); low number of seeds (<20)	
H. coccineus cv. Red Star × *H. moscheutos* Pale Pink	Low pollen tubes reached ovary; high seedling survival; lowest fruit set (20%)	
H. moscheutos ssp. *palustris* Pink Mallow × *H. coccineus* cv. Red Star	High seed germination; seedlings show sign of chlorosis, necrosis & died	
H. moscheutos Disco Belle × *H. coccineus* cv. Red Star	Low pollen tubes reached ovary; no growth of pollen tubes in stigma; lowest fruit set (2%); high seedling survival	
H. moscheutos Pale Pink × *H. coccineus* cv. Red Star	High seed germination; high seedling survival	
H. laevis × *H. moscheutos* ssp. *palustris* Pink Mallow	High seed germination; meager seedling survival; seedlings show sign of chlorosis, necrosis & died	
H. laevis × *H. moscheutos* Disco Belle	High seed germination; high seedling survival	
H. laevis × *H. moscheutos* Pale Pink	High seed germination; high seedling survival	
H. moscheutos spp. *palustris* Pink Mallow × *H. laevis*	Low seed germination (26%); seedlings show sign of chlorosis, necrosis & died	
H. moscheutos Disco Belle × *H. laevis*	High seed germination; high seedling survival; plants exhibited albinism (31%)	
H. moscheutos Pale Pink × *H. laevis*	High seed germination; high seedling survival	

markers have been employed to discriminate two species of *Hibiscus* and 16 varieties of *H. rosa-sinensis* more efficiently and accurately (Barik *et al*. 2006). Genetic relationship within 9 varieties of *H. rosa-sinensis* through RAPD markers was studied by Prasad (2014). Genetic analysis was made by using 2 arbitrary decamer primers OPA9, OPD10. High degree of polymorphism was observed among the samples, suggesting the degree of genetic variability. In *Hibiscus* species, Kadve *et al*. (2012) conducted genetic analysis studies using 9 RAPD primers. Out of total 9 primers used, the primers RPI-07, RPI-08, RPI-10, RPI-19 and RPI-21 were more suitable for genetic variation analysis as it has shown maximum polymorphic bands. Such studies are helpful in hibiscus breeding programme and provide major input for further improvement of *Hibiscus* species and conservation biology.

Breeding for future research

Cytogenetic studies of the species should be enlarged and intensified with the aim of identifying the parental species of the present varieties. This will help in the planning breeding programmes. Modern biotechnological methods such as *in vitro* cell culture, embryo rescue, and protoplast fusion should be applied. Such information could lead to the production of new gene recombination and subsequent selection of new varieties.

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