Advancing Cotton Breeding: Unlocking the Potential of *Gossypium hirsutum* × *Gossypium arboreum* Hybrids

S. Rama Devi, B. H. Chaithanya, M. Jhonson, K. Mohan Vishnu Vardhan, K. Ashok Kumar and M. Shivarama Krishna
Regional Agricultural Research Station (RARS), Nandyal, Acharya N.G. Ranga Aricultural Universty (ANGRAU), Andhra Pradesh
Corresponding Author: akashparuthi2003@gmail.com

Introduction

Cotton, often termed "white gold," is a critical crop in the global textile industry. Among cultivated species, *Gossypium hirsutum* dominates commercial cotton production due to its high yield and superior fiber quality. Conversely, *Gossypium arboreum* demonstrates greater resistance to environmental stresses and pests, making it suitable for sustainable and organic farming. A comparative analysis of these species is presented below:

Characteristic	*Gossypium hirsutum*	*Gossypium arboreum*
Origin	Central America, Mexico, Caribbean	India and Pakistan
Growth Habit	Herbaceous, shrubby plant	Perennial, tree-like plant
Chromosome Number	2n = 52 (Tetraploid)	2n = 26 (Diploid)
Fiber Quality	Longer, finer, stronger fibers	Shorter, coarser fibers
Yield	High yield	Low to moderate yield
Drought Resistance	Moderate	High
Pest & Disease Resistance	More susceptible	More resistant
Cultivation Area	USA, China, India (globally dominant)	India, some parts of Asia
Economic Importance	Major commercial crop	Less commercially significant
Flower Color	White or pale yellow with purple spots	Dark yellow with reddish centers
Leaf Shape	Broad, deeply lobed leaves	Narrower, less lobed leaves
Maturity Duration	150-180 days (early maturing)	More than 180 days (late maturing)
Ginning Percentage	Higher (35-40%)	Lower (25-30%)

The development of cotton interspecific species plays a crucial role in addressing the growing demands for sustainable cotton production in the face of challenges such as climate change and the need for more eco-friendly agricultural practices. Despite the potential benefits of interspecific hybridization between *G. hirsutum* and *G. arboreum*, genomic disparities pose significant challenges.

The key Genetic Barriers and Challenges in Hybridization include:

1. Pollen-Pistil Incompatibility: Prezygotic barriers prevent successful pollen tube growth, reducing fertilization rates.
2. Hybrid Seed Abortion: Genomic mismatches often cause embryo abortion post-fertilization, limiting viable seed production.
3. Sterility in Hybrids: Even when viable seeds develop, hybrids frequently exhibit sterility or reduced fertility, complicating further breeding efforts.

Strategies to Overcome Hybridization Barriers

1. Embryo Rescue

Embryo rescue is an advanced tissue culture technique employed to recover hybrid embryos that would otherwise fail to develop naturally. The procedure involves:

- Pollination & Fruit Collection: Controlled pollination of *G. hirsutum* (♀) and *G. arboreum* (♂), followed by the collection of bolls 10–15 days after pollination (DAP).
- Embryo Isolation: Surface sterilization and microscopic extraction of immature embryos.
- Culture Medium Preparation: Use of Murashige and Skoog (MS) medium supplemented with sucrose, gibberellic acid (GA_3), and kinetin.
- Embryo Culturing & Growth: Incubation at 25°C with a 16-hour photoperiod to facilitate growth.

- Germination & Hardening: Transition of seedlings to hormone-free MS medium and subsequent greenhouse acclimatization.

2. Chromosome Doubling

Hybrids between tetraploid *G. hirsutum* (AADD, 2n = 52) and diploid *G. arboreum* (AA, 2n = 26) result in triploid progeny (AAD, 2n = 39), leading to sterility. Chromosome doubling restores fertility through:

- Colchicine Treatment: Exposure of seedlings, root tips, or cotyledonary nodes to colchicine to induce chromosome duplication.
- Growth Monitoring: Identification of successfully doubled plants via morphological markers such as thicker leaves and larger stomata.
- Ploidy Confirmation: Use of cytogenetic techniques like chromosome counting and pollen viability assays.

3. Bridge Hybridization

Crossing hybrids with related species facilitates fertility restoration. Although this technique remains complex, advancements in breeding technology improve its success rates.

Agronomic Benefits of Interspecific Hybrids

Successful hybrids between *G. hirsutum* and *G. arboreum* exhibit multiple agronomic advantages:

1. Enhanced Pest and Disease Resistance: Resistance traits from *G. arboreum* improve tolerance against bollworms and bacterial blight.
2. Abiotic Stress Tolerance: Drought and salinity resilience is enhanced through the introgression of *G. arboreum* genes.
3. Improved Fiber Quality: Hybridization can combine *G. hirsutum's* fiber yield potential with *G. arboreum's* fiber fineness and strength.

Biotechnological Interventions in Hybrid Development: Modern biotechnology enhances interspecific hybridization through:

- Marker-Assisted Selection (MAS): Identifying genetic markers linked to desired traits.
- CRISPR-Cas9 Genome Editing: Precision modification of genes to integrate beneficial characteristics without compromising fiber yield.

Future Prospects and Challenges

Despite the promising benefits of interspecific hybridization, challenges such as low hybrid fertility and genetic instability persist. Future research should focus on:

- Backcrossing strategies to stabilize hybrids.
- Integration of genomic data with traditional breeding methods.
- Advanced biotechnological approaches to enhance genetic compatibility.

Conclusion

Hybridization between *G. hirsutum* and *G. arboreum* presents a viable strategy for improving cotton resilience, productivity, and fiber quality. By utilizing modern breeding technologies and genomic insights, researchers can develop superior cotton varieties, contributing to sustainable agricultural practices and the textile industry.

References

Altman, D. W. (1988). Cotton tissue culture and genetic transformation. *Advances in Agronomy*, 42, 265-287.

Beasley, J. O. (1940). The use of colchicine in artificially doubling the chromosome number in plants. *American Journal of Botany*, 27(2), 104-111.

Chen, Z. J. (2010). Molecular mechanisms of polyploidy and hybrid vigor in plants. *New Phytologist*, 186(1), 10-20.

Guo, W. et al. (2006). Chromosome doubling and genetic effects in *Gossypium* interspecific hybrids. *Euphytica*, 152, 367-378.

Renny-Byfield, S. & Wendel, J. F. (2014). Doubling genomes: Polyploidy and its impact on cotton evolution. *New Phytologist*, 202(4), 1280-1296.

Stewart, J. M. & Hsu, C. L. (1977). Interspecific hybridization of *Gossypium* species. *Crop Science*, 17(4), 508-511.

* * * * * * * * *