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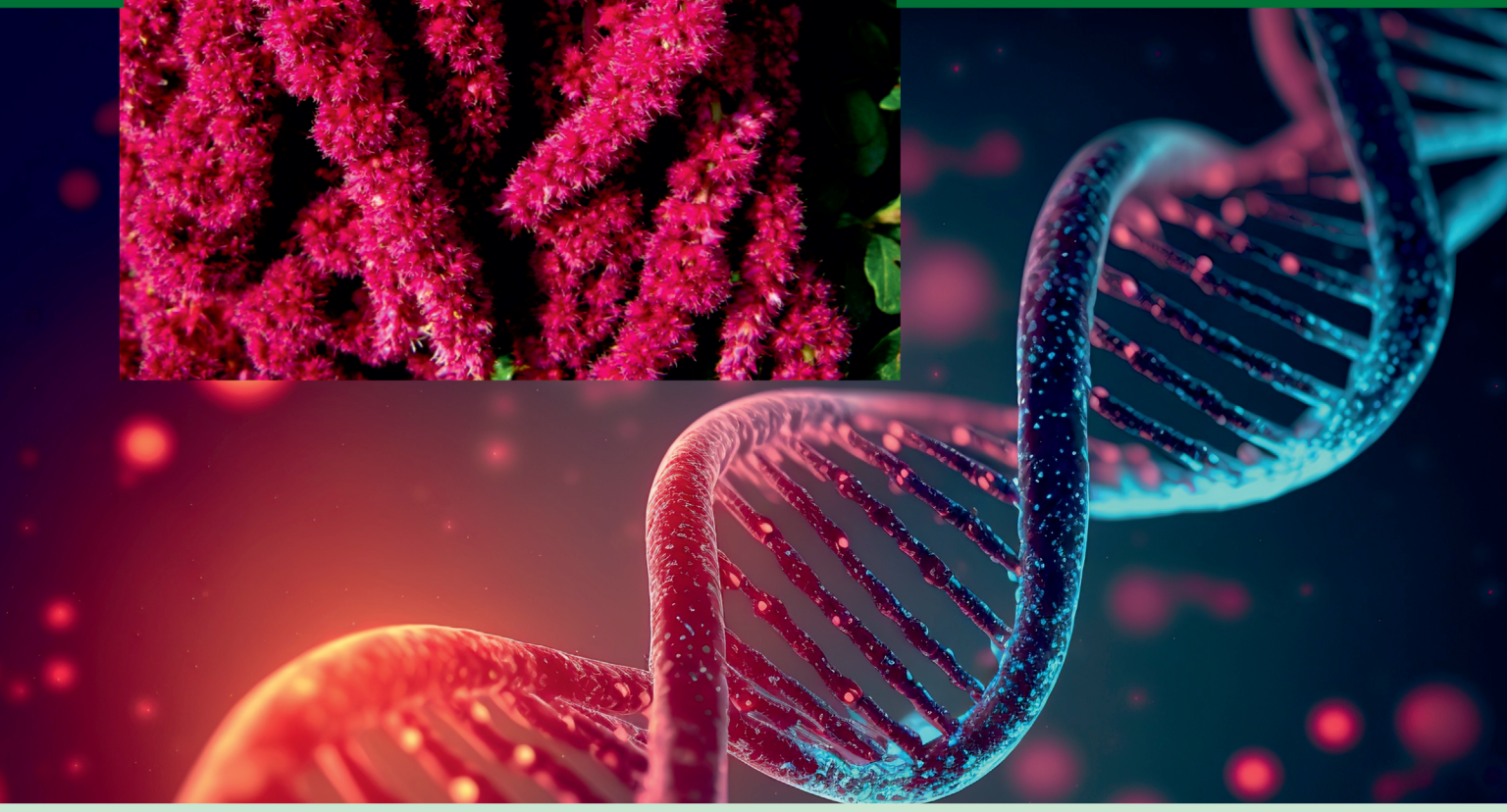
MINISTRY OF SCIENCE AND TECHNOLOGY

जैवप्रौद्योगिकी विभाग
DEPARTMENT OF
BIOTECHNOLOGY
सत्यमेव जयते

64K SNP Genotyping Chip for Grain Amaranth (रामदाना)

Advancing Viksit Bharat 2047



ICAR-National Bureau of Plant Genetic Resources
Pusa Campus, New Delhi-110012, India

The development of the 64,069-marker high-throughput SNP genotyping chip for Grain Amaranth represents a landmark achievement in India's agricultural biotechnology sector. This high-precision genomic tool delivers exceptional validation accuracy of 99.7%, positioning India at the forefront of nutritional crop improvement technologies.

Key highlights:

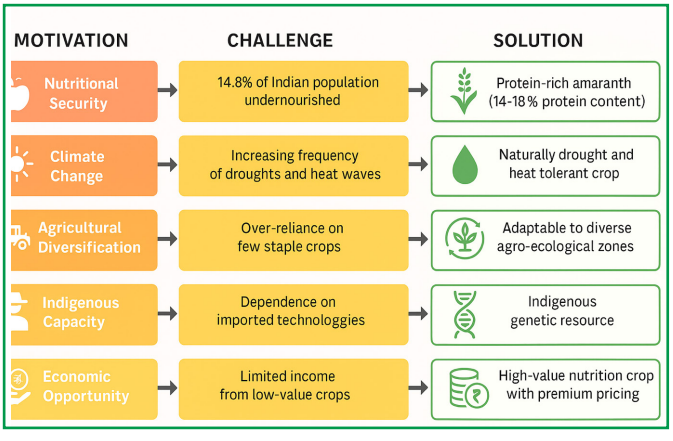
- **Technical innovation:** First-of-its-kind high-density SNP array for grain amaranth, enabling precise genetic characterization and accelerated breeding programs.
- **Validation success:** Achieved 99.7% validation accuracy, confirming reliability for research and commercial applications.
- **Commercial impact:** Successfully **licensed to Imperial Life Sciences via Agrinnovate** on April 15, 2025, exemplifying the complete innovation pipeline from idea to market.
- **Food security enabler:** Functions as a "Swiss knife" for grain amaranth breeding, supporting development of improved varieties with enhanced yield, nutrition, and climate resilience.
- **Strategic alignment:** Directly contributes to Viksit Bharat 2047 goals by strengthening nutritional security, promoting indigenous technology development, and enhancing agricultural sustainability.
- **Economic efficiency:** Delivers significant cost and time savings compared to whole genome sequencing approaches, democratizing access to advanced breeding technologies.

This technology exemplifies India's growing capabilities in agricultural genomics and represents a critical tool for addressing nutritional challenges through science-led innovation. The successful commercialization pathway demonstrates the maturation of India's bioeconomy ecosystem and provides a model for future biotechnology innovations targeting national priorities.

Amaranth, traditionally known as Ramdana (रामदाना), meaning **"God's Grain",** holds cultural and spiritual significance in India, symbolizing divine nourishment and being revered as a sacred grain since ancient times.

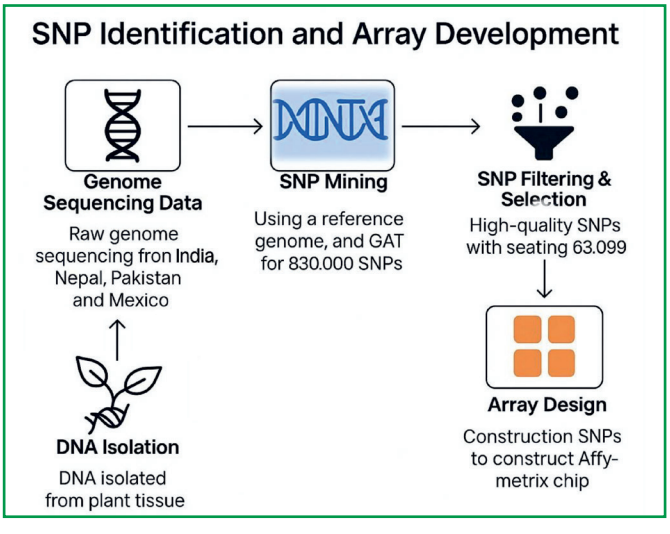
Grain amaranth (*Amaranthus hypochondriacus*) represents a crop of exceptional nutritional and agricultural significance for India's food security landscape. As a pseudo-cereal with remarkable protein content (14-18%), a balanced amino acid profile, and a rich micronutrient composition, amaranth offers a powerful solution to address malnutrition challenges while supporting agricultural diversification and climate resilience. Despite these advantages, amaranth improvement has historically lagged behind major cereal crops due to limited genomic resources and breeding tools.

The development of advanced genomic tools for underutilized, nutritionally rich crops aligns perfectly with India's **"Aatma Nirbhar Bharat" & "Viksit Bharat 2047 Vision"** of our honourable Prime Minister, Shri Narendra Modi, which emphasizes self-reliance in critical technologies, nutritional security, and sustainable agricultural systems. Modern crop improvement relies heavily on molecular breeding approaches that can accelerate genetic gain while precisely targeting traits of interest. High-density SNP genotyping arrays represent the gold standard platform for such applications, enabling everything from diversity assessment to marker-assisted selection and genomic prediction.

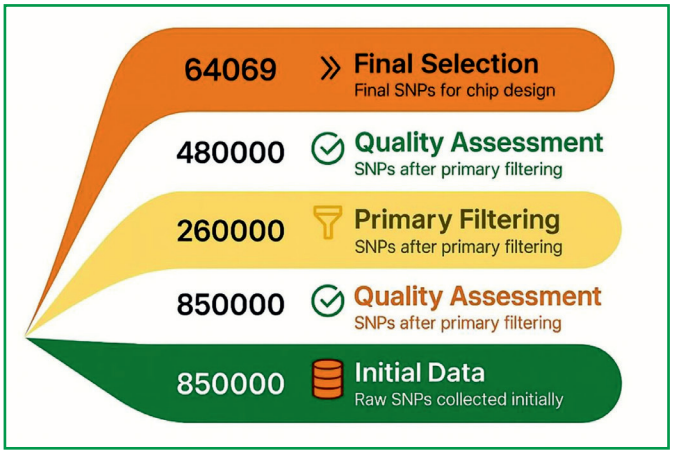


Genomic Data Collection and Processing:

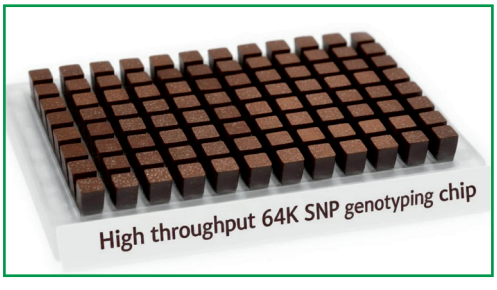
Genome-wide SNPs were identified by analyzing raw sequencing data downloaded free from NCBI database for amaranth accessions in India, Nepal, Pakistan, and Mexico using the high-quality reference genome published by Lightfoot et al. (2017).



SNP Discovery and Filtering Pipeline:

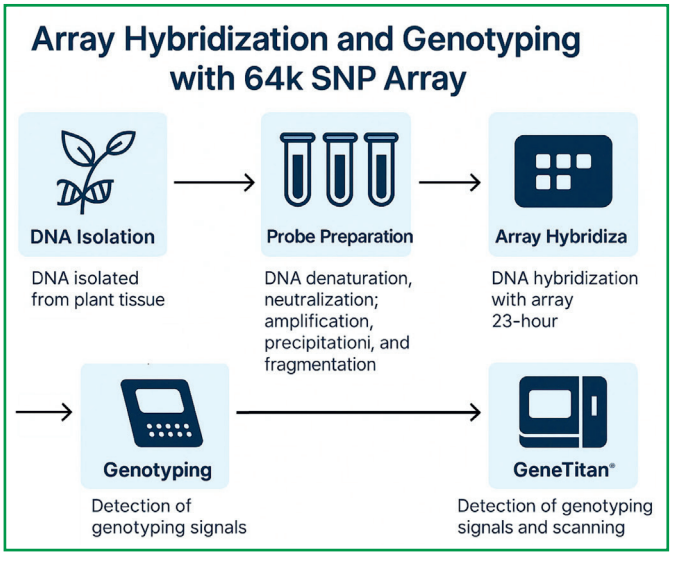


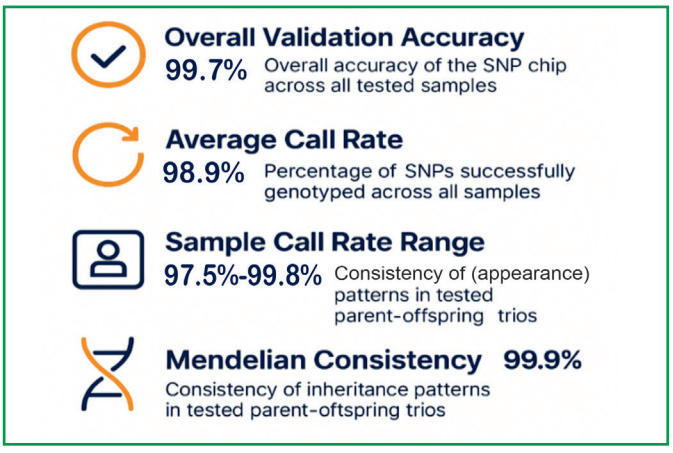
The selected 64,069 SNP markers were submitted to Affymetrix/Thermo Fisher for custom Axiom array design. Each SNP was represented by a set of probes designed to interrogate both forward and reverse strands. The design process included in silico validation to ensure probe specificity and minimize cross-hybridization potential. The final design was manufactured using Affymetrix's photolithographic synthesis process, resulting in the 64K SNP genotyping chip for grain amaranth.



Amaranthus 64K SNP chip validation:

A diverse panel of 917 genetically diverse grain amaranth accessions was used for validation, representing 22 distinct geographic locations across various agro-climatic regions of India.





The 64K SNP chip represents a democratizing technology that makes advanced genomic selection accessible to a much wider range of research and breeding programs across India. In this context, the Department of Biotechnology (DBT) and Indian Council of Agricultural Research (ICAR) identified the development of a high-throughput SNP genotyping platform for grain amaranth as a strategic priority.

These efficiency gains are particularly important for democratizing access to advanced genomic tools across India's diverse agricultural research ecosystem. The reduced cost, simplified technical requirements, and increased throughput enable broader adoption by research institutions and breeding programs with varying resource levels.

Cost-Time Savings vs. Whole Genome Sequencing

		Whole GenomeSquencning	64K SNP Chip	Savings
Cost:Metrics	Cost per sample	Cost per sample	₹45,000-60,000	-90%
		Equipment investment	₹3.5-5 crore	-80%
	Time	Data storage required	15-20 TB per 1000 samples	-99%
		Time to actionableresu-	2-3 weeks	-70%
TechnicalRequirements	Technical requlres-	Bioinformatics expertise	Advanced	Signiticant reduction
		Computing infrastructure	Basic-Intermediate	Significamt ruduction
		Technical training	6-2 weeks	-95%
	Scalability	Maximum throughput	34-48 samples/week	16x increase
		Field application potential	Possible with portable readers	New capability

Technology Commercialization

The successful commercialization of the 64K SNP chip represents the culmination of the complete innovation pipeline, from idea to market. On April 15, 2025, the technology was licensed to Imperial Life Sciences through Agrinnovate, ICAR's commercialization arm. This milestone marks the transition from research output to commercial product, making the technology widely available to researchers, breeders, and the agricultural industry.

This successful technology transfer exemplifies the maturation of India's bioeconomy ecosystem and provides a model for future biotechnology innovations targeting national priorities. The press releases by the

Ministry of Science and Technology on February 24 and March 27, 2025, highlighted this achievement as a significant contribution to India's agricultural biotechnology capabilities and nutritional security goals.


Research Unit
Press Information Bureau
Government of India

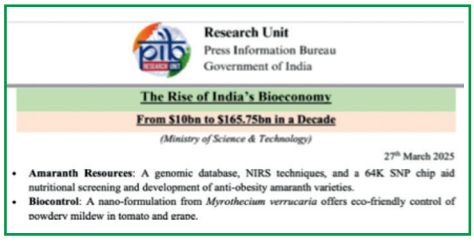
Cultivating the Future

Innovative Biotech Solutions for Farming, Livestock, and Aquaculture

(Ministry of Science and Technology)

24 February 2025

Amaranth Genetic Resources: The department of biotechnology has developed an **Amaranth Genomic Resource Database, Near Infrared Spectroscopy (NIRS)** techniques for screening nutritional qualities of amaranth grain, and a **64K SNP** chip. Amaranth accessions screened using the above resources have been shown to counteract high fat diet induced obesity. This is a significant enabler for rapid screening of amaranth accessions for cultivation as well as varietal development.


Research Unit
Press Information Bureau
Government of India

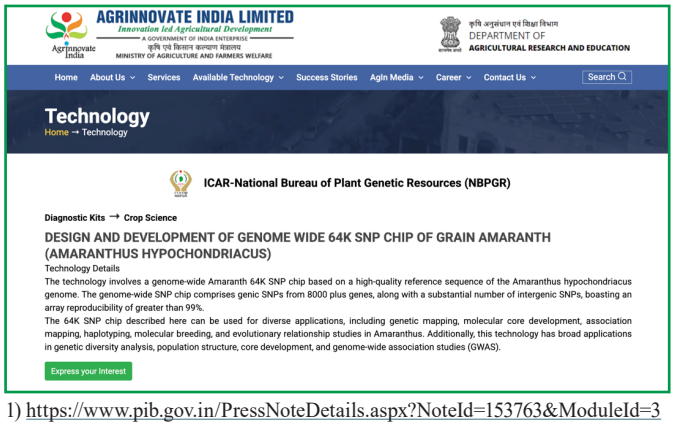
The Rise of India's Biocconomy

From $10bn to $165.75bn in a Decade

(Ministry of Science & Technology)

27th March 2025

- **Amaranth Resources**: A genomic database, NIRS techniques, and a 64K SNP chip aid nutritional screening and development of anti-obesity amaranth varieties.
- **Biocontrol**: A nano-formulation from *Myrothecium verrucaria* offers eco-friendly control of powdery mildew in tomato and grape.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Diagnostic Kits → Crop Science

DESIGN AND DEVELOPMENT OF GENOME WIDE 64K SNP CHIP OF GRAIN AMARANTH (AMARANTHUS HYPOCHONDRIACUS)

Technology Details

The technology involves a genome-wide Amaranth 64K SNP chip based on a high-quality reference sequence of the Amaranthus hypochondriacus genome. The genome-wide SNP chip comprises genic SNPs from 8000 plus genes, along with a substantial number of intergenic SNPs, boasting an array reproducibility of greater than 99%.

The 64K SNP chip described here can be used for diverse applications, including genetic mapping, molecular core development, association mapping, haplotyping, molecular breeding, and evolutionary relationship studies in Amaranthus. Additionally, this technology has broad applications in genetic diversity analysis, population structure, core development, and genome-wide association studies (GWAS).

Express your Interest

1) https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=153763&ModuleId=3
2) https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=154059&ModuleId=3
3) https://www.agrinnovateindia.com/technology.html?id=770#gsc.tab=0

Strategic Significance for Grain Amaranth Improvement

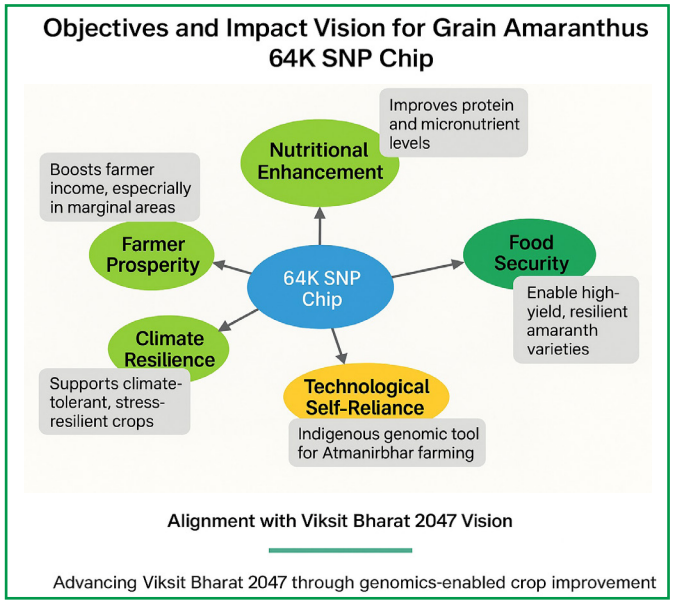
The 64K SNP genotyping chip represents a transformative tool for grain amaranth improvement, functioning as a veritable "Swiss-knife" for breeders and researchers. This comprehensive genomic platform enables multiple applications that were previously challenging or impossible with traditional approaches:

1. **Germplasm Characterization**: The chip allows precise fingerprinting of amaranth accessions, enabling accurate assessment of genetic diversity, population structure, and relationships among breeding materials. This facilitates the development of core collections that capture maximum genetic diversity in minimum accessions, optimizing germplasm conservation and utilization.
2. **Marker-Trait Associations**: By enabling genome-wide association studies (GWAS), the chip facilitates the identification of genetic markers linked to key traits such as yield, nutritional quality, and stress tolerance. These marker-trait associations provide the foundation for marker-assisted selection in breeding programs.
3. **Genomic Selection**: The high marker density supports implementation of genomic selection approaches, where breeding values are predicted based on genome-wide marker data. This can accelerate breeding cycles and increase genetic gain per unit time.
4. **Quality Control**: The chip provides a reliable tool for variety identification, genetic purity assessment, and intellectual property protection, supporting the seed production and distribution system.
5. **Evolutionary and Adaptation Studies**: The comprehensive marker set enables investigation of selection signatures and local adaptation patterns, informing breeding strategies for specific target environments.

The versatility of this platform makes it an essential resource for any serious amaranth improvement program, justifying its characterization as a "Swiss-knife" for breeders. By providing access to these advanced genomic approaches, the chip helps level the playing field between amaranth and major cereal crops in terms of breeding technology.

Contribution to Nutritional Security

Grain amaranth's exceptional nutritional profile makes it a strategic crop for addressing malnutrition challenges in India. With protein content (14-18%) significantly higher than conventional cereals, a balanced amino acid profile including lysine (often deficient in cereals), and rich micronutrient composition (calcium, iron, zinc, and vitamins), amaranth offers a powerful solution to protein-energy malnutrition and micronutrient deficiencies.



The 64K SNP chip directly contributes to nutritional security by accelerating the development of improved

amaranth varieties with: - Enhanced protein content and quality - Elevated levels of essential micronutrients - Improved processing quality and consumer acceptability - Reduced anti-nutritional factors - Adaptation to diverse agro-ecological zones.

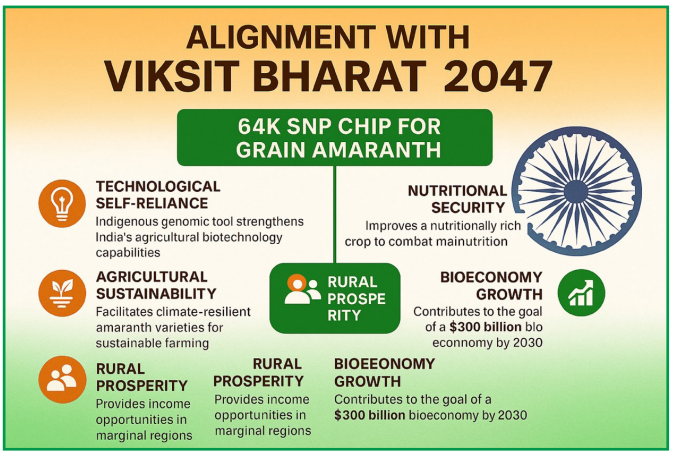
These improvements will expand the cultivation and consumption of this nutritionally superior crop, diversifying the food basket and enhancing dietary quality, particularly for vulnerable populations.

Alignment with Viksit Bharat 2047

The development and commercialization of the 64K SNP chip for grain amaranth aligns perfectly with multiple dimensions of the Viksit Bharat 2047 vision:

1. **Technological Self-Reliance**: The indigenous development of this advanced genomic tool demonstrates India's growing capabilities in agricultural biotechnology and reduces dependence on imported technologies. This contributes to the broader goal of technological sovereignty in critical sectors.
2. **Nutritional Security**: By accelerating the improvement of a nutritionally superior crop, the technology directly supports the goal of eliminating malnutrition and ensuring access to nutritious food for all citizens.
3. **Agricultural Sustainability**: Amaranth's natural resilience to environmental stressors makes it an ideal crop for sustainable farming systems. The chip facilitates the development of varieties with enhanced climate resilience, contributing to agricultural sustainability in the face of climate change.
4. **Rural Prosperity**: Expanded cultivation of improved amaranth varieties creates new economic opportunities for farmers, particularly in marginal agricultural areas where conventional crops may struggle. This supports the goal of reducing rural-urban disparities and enhancing rural livelihoods.
5. **Bioeconomy Growth**: The successful commercialization pathway demonstrates the maturation of India's bioeconomy ecosystem and contributes to the target of achieving a $300 billion bioeconomy by 2030, as highlighted in the March 27, 2025 press release.

The 64K SNP chip exemplifies how targeted investments in agricultural biotechnology can deliver innovations that simultaneously address multiple national priorities, creating synergies between technological advancement, nutritional security, and sustainable development.

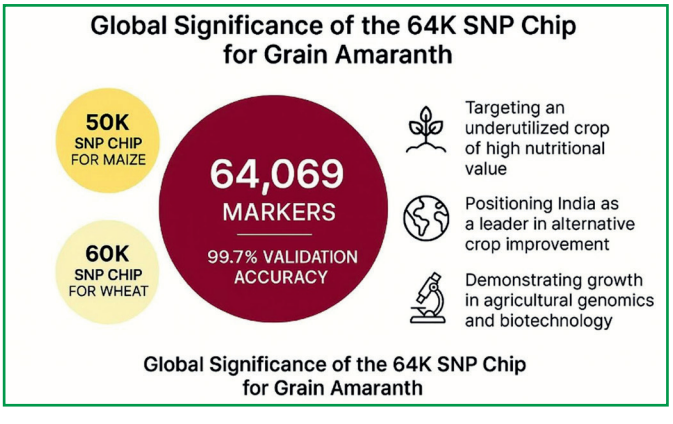


Comparison with Global Benchmarks

The 64K SNP chip for grain amaranth compares favorably with similar genomic tools developed for other crops globally. With 64,069 markers, it offers comparable or higher marker density than many commercial arrays for major crops, such as the 50K SNP chip for maize or the 60K chip for wheat. The validation accuracy of 99.7% meets or exceeds industry standards for similar platforms.

What distinguishes this achievement is its focus on an underutilized crop of high nutritional value, rather than a major commodity crop. This represents a strategic choice to invest in diversifying the food production system rather than simply intensifying existing staples. By developing this advanced genomic tool for amaranth, India has positioned itself as a global leader in the improvement of nutritionally superior alternative crops, an approach increasingly recognized as essential for sustainable food systems.

The successful development and commercialization of this technology also demonstrates India's growing capabilities in agricultural genomics and biotechnology, areas traditionally dominated by developed countries and multinational corporations. This achievement signals India's emergence as a significant player in the global agricultural biotechnology landscape, capable of developing sophisticated genomic tools tailored to national priorities.



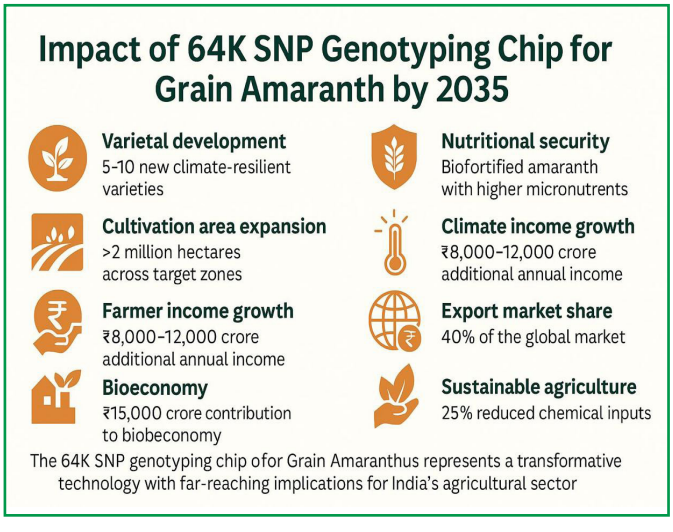
Impact & Vision 2047

The 64K SNP genotyping chip for Grain Amaranthus represents a transformative technology with far-reaching

implications for India's agricultural future and nutritional security. By 2047, this technology is projected to deliver the following impacts:

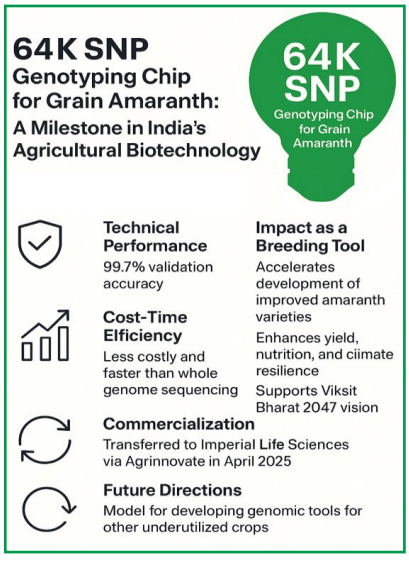
The 64K SNP genotyping chip for grain amaranth is a breakthrough technology with wide-ranging impact on India's agriculture, nutrition, and bioeconomy. By 2035, it is expected to:

- Develop 5–10 high-yielding, climate-resilient, and nutrient-rich amaranth varieties
- Enhance nutritional security with 50% higher protein and improved micronutrients
- Expand cultivation to over 2 million hectares, especially in marginal lands
- Boost climate resilience through stress-tolerant varieties
- Generate ₹8,000–12,000 crore in additional farm income
- Create around 100,000 new jobs across the value chain
- Capture 40% of the global grain amaranth export market
- Add ₹15,000 crore to India's bioeconomy
- Train 500 scientists, building genomics research capacity
- Promote sustainable farming by reducing chemical use by 25%
- Integrate traditional knowledge with modern genomics
- Serve as a model for 10+ public-private biotech collaborations



This innovation reflects the **Atmanirbhar Bharat vision,** showcasing India's leadership in developing and commercializing advanced agricultural genomic tools.

Conclusion



The successful development, validation, and commercialization of the 64K SNP genotyping chip for grain amaranth represents a significant milestone in India's agricultural biotechnology capabilities. The exceptional technical performance of the chip, with 99.7% validation accuracy, confirms its reliability as a research and breeding tool. Its cost and time efficiency compared to whole genome sequencing approaches democratizes access to advanced genomic technologies across India's diverse agricultural research ecosystem. The successful technology transfer to Imperial Life Sciences via Agrinnovate on April 15, 2025, completes the innovation pipeline from idea to market.

As a "Swiss-knife" for grain amaranth breeding, this technology will accelerate the development of improved varieties with enhanced yield, nutrition, and climate resilience. These improvements will expand the cultivation and consumption of this nutritionally superior crop, contributing significantly to India's nutritional security goals. The alignment with multiple dimensions of the Viksit Bharat 2047 vision—technological self-reliance, nutritional security, agricultural sustainability, rural prosperity, and bioeconomy growth—underscores the strategic importance of this innovation.

Looking forward, this achievement provides a model for similar initiatives targeting other underutilized crops of nutritional importance. By continuing to invest in such strategic biotechnology applications, India can build a more diverse, resilient, and nutritious food production system while establishing itself as a global leader in agricultural innovation.

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Acknowledgment: Indian Council of Agricultural Research and Department of Biotechnology, Government of India

Published By:
Director, ICAR-National Bureau of Plant Genetic Resources
Pusa Campus, New Delhi,
E-mail: director.nbpgr@icar.org.in, Ph: 011-25802780
November 2025