



Exploring the Status, Potential and Utilization of Banana Improvement and Development in India

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The International Transit Centre (ITC), located at KU Leuven in Belgium, houses the world's most extensive banana germplasm collection, comprising around 1,500 different accessions. Utilizing suitable germplasm in the breeding programme is the prime objective in any varietal development programme. ICAR–NRCB initiated a drive to utilize 124 accessions from ITC. These accessions have been shared with multiple centres of the All India Coordinated Research Project (AICRP) on Fruits throughout India. Different initiatives were undertaken by different institutes in the varietal development programmes in banana. However, till now, there has been no proper documentation of the current status, potential, and utilization of the ITC accessions received from Bioversity International. Hence, the present effort focuses on documenting various utilization methods of the ITC accessions across India. A systematic interview schedule was prepared and sent to all the researchers involved in banana breeding projects under AICRP. A one-day workshop and focused group discussion were organized to gather information about the ITC accessions from their respective states, and the data were compiled and presented systematically. This study shows that a few ITC accessions were directly utilized by the institutes as varieties and were released for farmers' cultivation due to their superior nature. A majority of the ITC accessions were used as one of the parents in breeding programmes. However, the adoption rate for ITC accessions by farmers has not been encouraging, as it takes a longer period to replace the existing varieties due to their market suitability. Further, this study concludes with the constraints involved in the utilization of the ITC accessions. Certainly, it will be useful for banana breeders and policy-makers to plan their strategies for developing an effective breeding policy for varietal development in India.

(Key words: Banana, Cultivation, Germplasm, Survey, Variety)

The International Transit Centre (ITC), hosted by KU Leuven in Belgium and operated by Bioversity International, serves as the world's primary repository for banana germplasm, preserving approximately 1,500 accessions (ProMusa, 2025). Several important collections have originated from this centre. Bioversity International, formerly known as the International Plant Genetic Resources Institute, is a global research organization and part of the CGIAR consortium of international agricultural research centres. It was founded as an independent international entity in 1991, following the signing of the 'Agreement on the Establishment of the International Plant Genetic Resources Institute' with the Government of Italy (ITPGRFA, 2025). Under this agreement, the Government of Italy recognized Bioversity as an international organization with international legal personality and established its headquarters in Rome,

Italy (Vezina *et al.*, 2003). Since January 1, 2020, Bioversity International has been a part of the Alliance formed with the International Centre for Tropical Agriculture (CIAT) (Alliance Bioversity - CIAT 2025).

The International Transit Centre (ITC) regularly shares banana germplasm with both national and international research institutions. According to the ICAR-NRCB Report (2023), a total of 124 accessions have been obtained from the ITC and are presently being conserved at ICAR-NRCB. These accessions are actively used in various breeding programmes and have been distributed across the country to support banana varietal improvement. Despite this, a systematic and in-depth assessment of the status, potential, and use of ITC accessions within India has yet to be conducted. Hence, the current study aims to evaluate the present status and potential of these accessions, assess their

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role in breeding initiatives, and identify the challenges hindering the adoption and dissemination of improved varieties or accessions within India's banana production systems.

In this study, the following research questions are addressed:

1. What is the current status of ITC accessions across India? To determine whether the accessions have been utilized directly as cultivars or served as parental material in banana improvement programmes.
2. Which are the research institutes currently utilizing or benefiting from ITC accessions for their banana varietal development programmes, and what is the pattern of inter-institutional exchange of ITC accessions in India?
3. Which ITC accessions are in the pipeline for direct recommendation for cultivation or for use in hybridization programmes?
4. Which ITC accessions are being used exclusively for disease-resistant breeding programmes in banana, and what are the constraints involved in the utilization of ITC accessions?

This is the first exploratory study of its kind aimed at assessing the status and utilization patterns of ITC banana accessions in India. Until now, no comprehensive research has been conducted on this subject. To ensure a rigorous and in-depth investigation, a structured and multi-step approach was adopted. The process began with literature reviews and preliminary surveys to collect foundational information. A pilot study was then carried out to refine the methodology and identify potential challenges (Karpagam *et al.*, 2023). Following this, an online consultation was held, allowing researchers from various regions to share insights on the status of ITC accessions in their areas. A well-designed interview schedule was developed to gather detailed and specific information across multiple aspects of the research. The collected data were systematically organized and analysed using a variety of methods to ensure comprehensive understanding. Finally, the findings were synthesized to draw meaningful conclusions. This study not only enhances our understanding of the topic but

also contributes significantly to the existing body of knowledge.

The systematic documentation of International Transit Centre (ITC) banana germplasm utilization in India assumes significance in the context of increasing biotic and abiotic stresses, market uniformity pressures and the urgent need for diversification beyond Cavendish monoculture. Despite the availability of diverse accessions conserved at ITC, structured national-level documentation of their utilization pathways, breeding contributions and strategic deployment has been limited. The present study therefore aimed to document institutional utilization patterns of ITC accessions across India and to identify strategic pathways for strengthening their evaluation, validation and deployment in banana breeding programmes, particularly under stress-prone and coastal agro-ecosystems.

MATERIALS AND METHODS

A structured multi-stage approach was adopted comprising pilot consultations, circulation of structured questionnaires to research centres, compilation of institutional records and validation through a consultative workshop. Responses were obtained from thirteen research centres actively involved in banana improvement programmes. The data primarily represent documented institutional utilization patterns, including direct varietal release, hybridization use and trait-specific breeding deployment. The study was exploratory in nature and did not constitute a nationwide farmer-level adoption survey; rather, it focused on institutional germplasm utilization trends and breeding contributions.

Preliminary pilot survey

ITC accessions have been utilized in various breeding programs and disease resistance technology developments. To assess the status of these accessions under field conditions, a preliminary pilot survey was conducted on February 22, 2023, in farmers' fields located in Muthalapuram village, Cumbum Block, Theni District, Tamil Nadu.

Pilot testing, survey and online workshop

In India, banana research is mainly carried out by ICAR-NRCB, while the All India Coordinated

Research Project (AICRP) on Fruits conducts trials for various key crops at multiple locations. The project operates through 67 centres, with 23 dedicated to mango, 16 to guava, 13 to banana, 12 to citrus, 9 to papaya, 8 each to litchi and grapes, 5 to jackfruit, and 4 to sapota. Consequently, an online survey was planned targeting scientists from the 13 AICRP centres focused on banana. A detailed questionnaire titled “Status of ITC Accessions in India within the Banana Production System” was developed and distributed via Google Forms to these centres, which include Arabhavi, Bhubaneswar, Coimbatore, Gandevi, Jalgaon, Jorhat, Kannara, Kovvur, Mohanpur, Pantnagar, Ludhiana, Pusa, Udaipur, Vengurla, and Port Blair. Thirty scientists with extensive experience in banana cultivation participated in the survey, but completed responses were received from only 13. Due to the limited number of responses, it was decided to broaden participation by organizing an online workshop on 14 July 2023 with representatives from the ICAR–AICRP (F) banana centres. Through this workshop, comprehensive data regarding the status, potential, and utilization of ITC accessions were collected. The survey results from all centres were then analyzed, and a final report was compiled.

RESULTS AND DISCUSSION

A total of 124 ITC accessions were introduced and evaluated across participating centres, of which several were directly released as varieties while

others served as parental lines in hybridization programmes. A substantial proportion of accessions contributed to disease resistance breeding, particularly for Fusarium wilt and nematode resistance. The distribution of accessions across institutions indicates active utilization in multiple agro-climatic regions, reflecting their adaptive potential and genetic relevance. The patterns of deployment underscore the strategic role of ITC germplasm not merely as conserved genetic resources but as functional breeding materials supporting varietal diversification and stress resilience.

ITC accession directly used as a variety

In general, the majority of the ITC accessions were utilized in breeding programmes as either of the parents. However, a few successful ITC accessions were directly utilized as varieties and adopted by farmers due to their unique characteristics. The adoption rate was also showing a significantly increasing trend. The ITC accessions that were directly utilized as varieties, along with their adoption areas and characteristics, are presented in Table 1 and Fig. 1.

In addition to the ongoing breeding programmes, this study identified several ITC accessions that were recommended for direct cultivation based on their superior field performance. These accessions demonstrated valuable agronomic characteristics, including high yield potential, resistance to biotic and abiotic stresses, and strong adaptability to local



Popoulu (AAB)



Kaveri Saba (ABB)



Kaveri Kalki (ABB)



Kaveri Kanchan (AAAB) -
Cv. Nendran x Pisang Lilin)

Fig. 1. ITC accessions for varietal development

Table 1. ITC accessions directly used as a variety

Parameters	Popoulu (AAB – Plantain)	Kaveri Saba (ABB – ITC 1138)	Kaveri Kalki / Namwa Khom (ITC 0659)
Recommended area and adopted area	Karnataka, Odisha, Tamil Nadu, Assam, Kerala, Andhra Pradesh, and West Bengal.	Regions with saline-sodic soils, low rainfall, and coastal low-lands.	Grown in regions susceptible to cyclones and strong winds
Characteristics	High-yielding and versatile, suitable for consumption as a dessert fruit as well as for chips production	Culinary and dessert type; suitable for soils with pH up to 8.8-9.0; performs well in marginal lands; Shows superior storage quality with a green life lasting 7 to 8 days	Dwarf type, suitable for high-density planting; short duration; high TSS content; good for banana fig preparation.
Uniqueness	Preferred for chip preparation compared to Manjeri Nendran-II and check variety Nendran.	Drought-tolerant.	Dwarf stature (2.40 m height); early maturity (360–370 days).
ICAR -NRCB developmental initiatives	Trials conducted at seven AICRP centres showed a good B:C ratio.	This accession was officially released under the name “Kaveri Saba” and has been promoted via KVK.	Planting materials were distributed to farmers during training programmes and through KVKs.
Farmers’ acceptance / upscaling activities	The Banana Research Station in Kannara, Kerala, produced tissue-cultured plants of the “Popoulu” variety.	Adopted in marginal lands with limited water availability.	Adoption rate is slowly increasing in cyclone-prone areas.

environmental conditions. Their selection bypassed the conventional hybridization pathway, emphasizing the potential of certain germplasm lines for immediate use

in cultivation. The specific details of the recommended ITC accessions, along with their key performance indicators, are presented in Table 2.

Table 2. ITC accessions in pipe line for direct recommendation for cultivation

ITC accessions	Characteristics
ITC 570	<ul style="list-style-type: none"> • High-yielding Cavendish type • Resistance to Foc (<i>Fusarium oxysporum</i> f. sp. <i>cubense</i>) race 1
ITC 553	<ul style="list-style-type: none"> • Aromatic and carotene-rich pulp • High-yielding Cavendish type • Good texture and high consumer acceptance
ITC 1437	<ul style="list-style-type: none"> • High-yielding • Resistance to Foc race 1

Other ITC accessions utilized in the breeding programme

The findings indicate that ITC accessions have been actively utilized in various banana breeding programmes aimed at developing new cultivars. Menon *et al.* (2016) used several ITC accessions from the AA genomic groups such as “Pisang Lilin,” “Pisang Madu,” “Pisang Jari Buaya,” “Pisang Berlin,” “Cv. Rose,” and “Tongat” as both male and female parents in breeding efforts targeting Sigatoka leaf spot resistance. Likewise, accessions like Cv. Rose, Pisang Berlin, Tongat, Kanai Bansi, and Balukpong wild have been identified as resistant to Fusarium wilt (Foc race 1) (Thangavelu *et al.*, 2011). In separate programmes, Sundararaju *et al.* (2008) and Backiyarani *et al.* (2015) employed Pisang Lilin as a male parent in breeding for nematode resistance. Several new varieties have emerged from these efforts. Kerala Agricultural University released BRS 1 and BRS 2, while Tamil Nadu Agricultural University developed Co 1, Co 2, and Co 3. The nematode-resistant cultivar Yankambi

KM5 was developed using ITC accessions, with Pisang Lilin playing a key parental role. Additionally, Mahatma Phule Krishi Vidyapeeth University in Maharashtra released the variety “Phule Pride (AAA),” which also originated from an ITC accession. Further details on the deployment of ITC accessions in breeding programmes are illustrated in Table 3 and Fig. 2.

ITC accessions in pipeline for hybridization programme

In addition to the direct recommendation of selected ITC accessions for cultivation, this study also noted that several accessions, viz., SH 3640, TMB 2 × 9128-3, Pisang Lilin and Cv. Rose (Fig.3) are currently being utilized as parental lines in the ongoing hybridization programmes. These accessions have been identified based on their desirable traits such as disease resistance, abiotic stress tolerance, fruit quality, and agronomic performance. Their inclusion in the breeding pipeline underscores their genetic potential in

Table 3. ITC accession utilised for different breeding programmes

Sl. No.	Name of the new variety/ hybrid	Year of release	Name and address of the institute	Whether ITC accession is used or not	If yes, name of the ITC accession used & purpose
1.	BRS 1	1998	Kerala Agricultural University	Yes	Pisang Lilin was used as male parent
2.	BRS 2	1998	Banana Research Centre, (KAU-BRS), Kannara, Kerala, India	Yes	
3.	Co 2	2020	Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India	Yes	Pisang Lilin was used as male parent
4.	Co 3	2022		Yes	Pisang Lilin was used as male parent
5.	Kaveri Kalki	2022	ICAR–National Research Centre for Banana, (ICAR–NRCB)	Yes	Namwa Khom
6.	Kaveri Saba	2019	Tiruchirappalli, Tamil Nadu, India	Yes	Saba
7.	Phule Pride	2018	Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra, India	Yes	Selection from Grand Naine
8.	Kaveri Kanchan	2024	ICAR–National Research Centre for Banana, (ICAR–NRCB) Tiruchirappalli, Tamil Nadu, India	Yes	Cv.Rose was used as male parent
9.	Gandevi Selection	2007	Junagadh Agricultural University , Junagadh	Yes	Selection from Cavendish

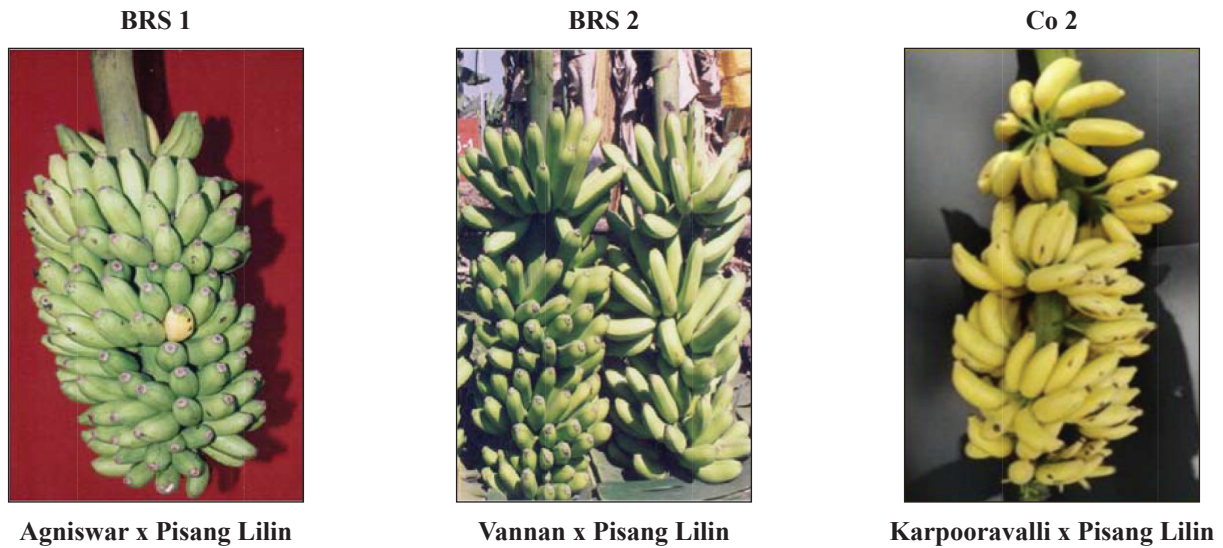


Fig. 2. ITC accessions utilised in breeding programme

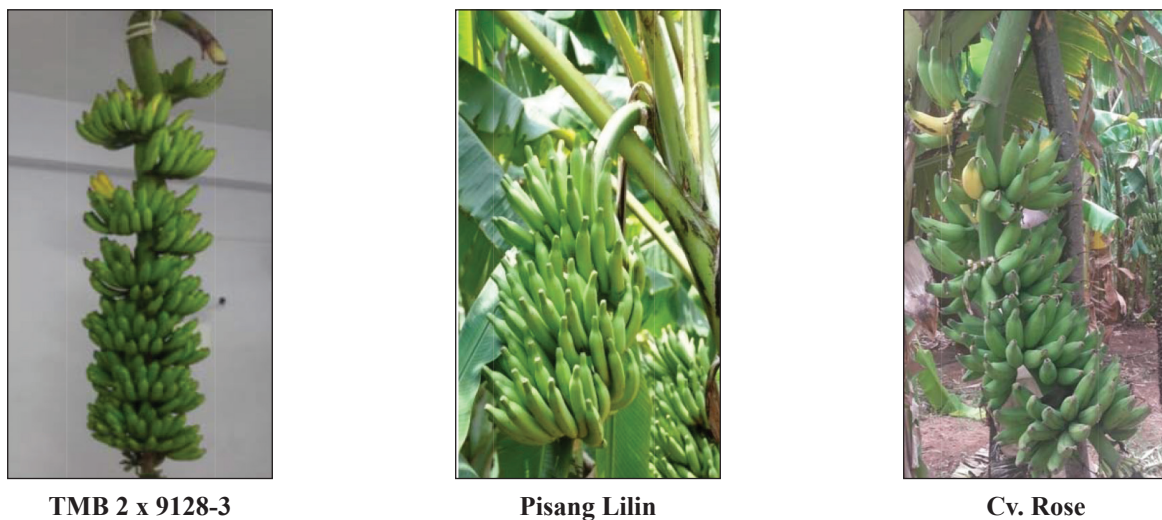


Fig. 3. ITC accessions in Hybridization programme

contributing to the development of improved banana cultivars. By incorporating these accessions into controlled crossing programmes, researchers aim to broaden the genetic base and enhance the expression of targeted traits in future hybrids. This strategic use of ITC germplasm plays a critical role in accelerating varietal improvement efforts within banana breeding initiatives.

ITC accession exclusively for disease-resistant breeding

This study indicates that NRCB 16, derived from

ITC 2390/2 (AAA) triploid unique type, is notable for its high carotenoid content and distinct aroma. It performs well in areas free from *Fusarium oxysporum* f. sp. *ubense* (Foc) race 1, which affects Cavendish bananas, but shows poor performance in Foc hotspot regions. In contrast, ITC 570 (Williams) thrives even in Foc race 1 hotspot areas. ITC 180, a Cavendish line, exhibits field resistance in hotspot zones and is characterized by a semi-dwarf stature within the Grand Naine group. The ITC accession Pisang Lilin has been extensively used as a parent in various breeding programs. Crosses involving Pisang Lilin with varieties

such as Udhayam, Saba, and Chinia have demonstrated enhanced disease resistance in farmers' fields. Several progenies with Pisang Lilin as one parent have shown field resistance to Foc races affecting Cavendish bananas. Additionally, NRCB 19, selected from ITC accession SH 3640, is performing well and enjoys high consumer preference.

ITC accessions exchange programme

Germplasm exchange plays a critical role in broadening the genetic base available for breeding and varietal improvement programs. In this context, the present study examined the patterns of germplasm exchange among research institutions within India, with a specific focus on accessions sourced from the ITC. The analysis revealed that ICAR–NRCB

serves as the principal node for the distribution of ITC accessions within the country. ICAR–NRCB has actively shared germplasm materials with various centres of the AICRP on Banana, which in turn have facilitated further dissemination and utilization. Table 4 presents a detailed overview of the inter-institutional exchange of ITC accessions, highlighting the flow and pattern of genetic material and collaborative efforts across different research centres for banana development in India.

Despite demonstrable trait advantages in certain accessions, large-scale replacement of commercially dominant cultivars such as Grand Naine remains constrained by market uniformity preferences, established supply chains and export-driven fruit

Table 4. Overview of the inter-institutional exchange of ITC accessions

Sl. No.	Name of the Institute	ITC accession	Source of ITC accession	From where it was obtained	Purpose of collection
1	Tamil Nadu Agricultural University, Coimbatore	Popoulu	Banana Research Station, Kannara	Banana Research Station, Kannara	AICRP trial purpose
		Pisang Lilin	ICAR–NRCB, Tiruchirappalli,	ICAR–NRCB, Tiruchirappalli,	Breeding
2	Mahatma Phule Krishi University, Maharashtra	Phule Pride	Population of Grand Nain	Experimental plot at the Banana Research Station in Jalgaon	To create a variety exhibiting a dwarf growth habit
3	Bidhan Chandra Krishi Viswavidyalaya, West Bengal	Namwa Khom and Popoulu	ICAR - NRCB, Tiruchirappalli	ICAR - NRCB, Tiruchirappalli	Assessment trials conducted under the ICAR-AICRP on Fruits
4	Dr. Y.S.R. Horticultural University –Horticultural Research Station, Kovvur, Andhra Pradesh	Pisang Lilin, cv. Rose, Popoulu, Namwa Khom Saba	ICAR–NRCB, Tiruchirappalli	ICAR–NRCB, Tiruchirappalli	Germplasm and MLT experiments
5	KRC college of Horticulture, Arabhavi (University of Horticultural Sciences Bagalkot)	Pisang Lilin, Popoulu, Namwa Khom, Saba	ICAR–NRCB, Tiruchirappalli, Banana Research Station, Kannara	ICAR–NRCB, Tiruchirappalli, Banana Research Station, Kannara	Research purpose
6	Banana Research Station, Kannara, Kerala Agricultural University	Popoulu	National Bureau of Plant Genetic Resources, New Delhi	National Bureau of Plant Genetic Resources, New Delhi	Germplasm introduction

quality standards. Farmers often exhibit risk aversion toward newly introduced genotypes due to uncertain price realization and lack of assured procurement channels. These socio-economic and market-linked factors significantly influence the pace of varietal diversification, even when genetic superiority is established under experimental conditions

Constraints analysis in utilising ITC accession

While ITC accessions have demonstrated considerable potential in breeding and varietal development, their large-scale deployment is influenced by several structural and systemic constraints. A major limitation is the absence of a coordinated national germplasm evaluation network integrating multi-location trials across diverse agro-climatic zones. Standardized trait screening protocols, particularly for resistance to *Fusarium oxysporum* f. sp. *ubense* (Foc), nematodes and Sigatoka leaf spot, need harmonization to ensure comparable performance benchmarking. Region-specific trait validation trials are essential to assess stability of resistance and adaptability under varied stress environments, including Foc hotspot areas, coastal saline belts, drought-prone tracts and cyclone-affected regions. Such targeted validation would enable more precise recommendation domains and minimize location-specific performance uncertainties. Strengthening inter-institutional germplasm exchange mechanisms is another critical requirement. Although accessions are distributed among research centres, streamlined digital inventory systems, transparent accession request protocols and collaborative evaluation platforms would enhance broader accessibility and utilization efficiency. Expanding participation beyond coordinated project centres to include state agricultural universities and regional research institutions would further democratize germplasm access. In addition, limited pre-release market assessment often constrains adoption of newly identified superior genotypes. Policy-level support for consumer preference studies, value-chain compatibility analysis and economic viability benchmarking prior to varietal notification could significantly enhance farmer confidence and commercial acceptance. Integrating market intelligence with breeding objectives would ensure that genetic improvement aligns with economic sustainability.

Limitations of the research

This research predominantly depends on the interview schedule and the responses received from farmers and researchers during surveys and online workshops. ICAR–NRCB has released three varieties, namely Popoulu (AAB, Plantain), Kaveri Saba (ABB–ITC 1138), and Kaveri Kalki/Namwa Khom (ITC 0659). Therefore, the effectiveness of all the ITC accessions cannot be compared or studied. Furthermore, different researchers have utilized the ITC accessions for various crosses in their breeding programmes. The authors have attempted to include the full range of utilization potential of ITC accessions based on the responses received. However, some may have been missed in this study. The primary focus was to explore the current status and the extent of ITC accession utilisation in banana breeding programmes in India. More research is needed to assess the effectiveness of individual ITC accessions and to identify accessions with specific traits such as Fusarium wilt (Foc) resistance, high yield, and fertilizer responsiveness. In a nutshell, this study is the first of its kind in India and is expected to pave the way for accelerating banana breeding programmes by effectively utilizing germplasm materials from various sources.

The findings of the present study are primarily based on institutional responses and documented utilization records from participating research centres. While this provides a comprehensive overview of germplasm deployment within organized breeding programmes, the study does not quantify farmer-level adoption rates or multi-year yield benchmarking across all agro-climatic zones. Future research involving large-scale field validation trials and quantitative adoption analysis would further strengthen the evidence base for strategic ITC germplasm deployment.

CONCLUSION

The present study provides the first structured national-level documentation of ITC banana accession utilization across Indian research institutions, highlighting their critical contribution to varietal development, hybridization programmes and disease resistance breeding. The findings demonstrate that ITC accessions have functioned not merely as

conserved genetic resources but as dynamic parental lines underpinning genetic diversification and stress resilience in banana improvement programmes. However, maximizing the impact of ITC germplasm requires transition from opportunistic utilization to a coordinated national evaluation strategy. Establishment of a National ITC Germplasm Evaluation Framework integrating multi-location trials, region-specific trait validation, participatory varietal selection and digital performance tracking is strongly recommended. Strengthened inter-institutional exchange mechanisms and integration of pre-release market assessment into breeding pipelines would further enhance adoption potential.

By aligning genetic resource conservation with systematic evaluation, policy support and market-responsive breeding strategies, ITC germplasm can play a transformative role in enhancing productivity, resilience and sustainability of banana cultivation in India, particularly under emerging biotic and climatic challenges.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest related to this work.

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