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Popular Article

Breeding modernization strategies for rapid product development in Rice considering future climate change

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Introduction

Central Indian state Chhattisgarh hosts huge rice diversity and it is being *ex-situ* stored at IGKV, Raipur. IGKV has a long history of rice breeding starting from 1906 till date and during the green revolution has done a significant contribution in terms of developing high-yielding rice varieties. The domestication and conventional breeding have led to more than 90 rice varieties suitable for the diverse ecology of Chhattisgarh. Plateau in yield over the last decades has been the point of concern for rice breeders and other stakeholders. Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, has been actively involved in rice research for over a century. The university is home to the world's second-largest rice biodiversity collection, which contains 23,250 rice accessions. This rich collection serves as a valuable source of unique traits and rare alleles/genes for developing modern rice varieties.

IGKV has collaborated with CGIAR-IRRI and CGIAR-EiB since 2017 to modernize its rice breeding programs in line with modern breeding principles and practices. The rice breeding program has been completely transformed under the "Breeding Program Modernization" program, with the goal of delivering higher genetic gain. IGKV is in the process of transforming all rice breeding pipelines in light of modern breeding principles and practices. The following modernization strategies have been integrated in the Rice Breeding program:

1) Shifting from Pedigree to modified Single Seed Descent (SSD) strategy:

The rice varietal development program at IGKV has undergone a major transformation from a conventional pedigree method to a modern breeding strategy introduced by CGIAR-IRRI. This shift in breeding strategy is focused on population breeding, which emphasizes the

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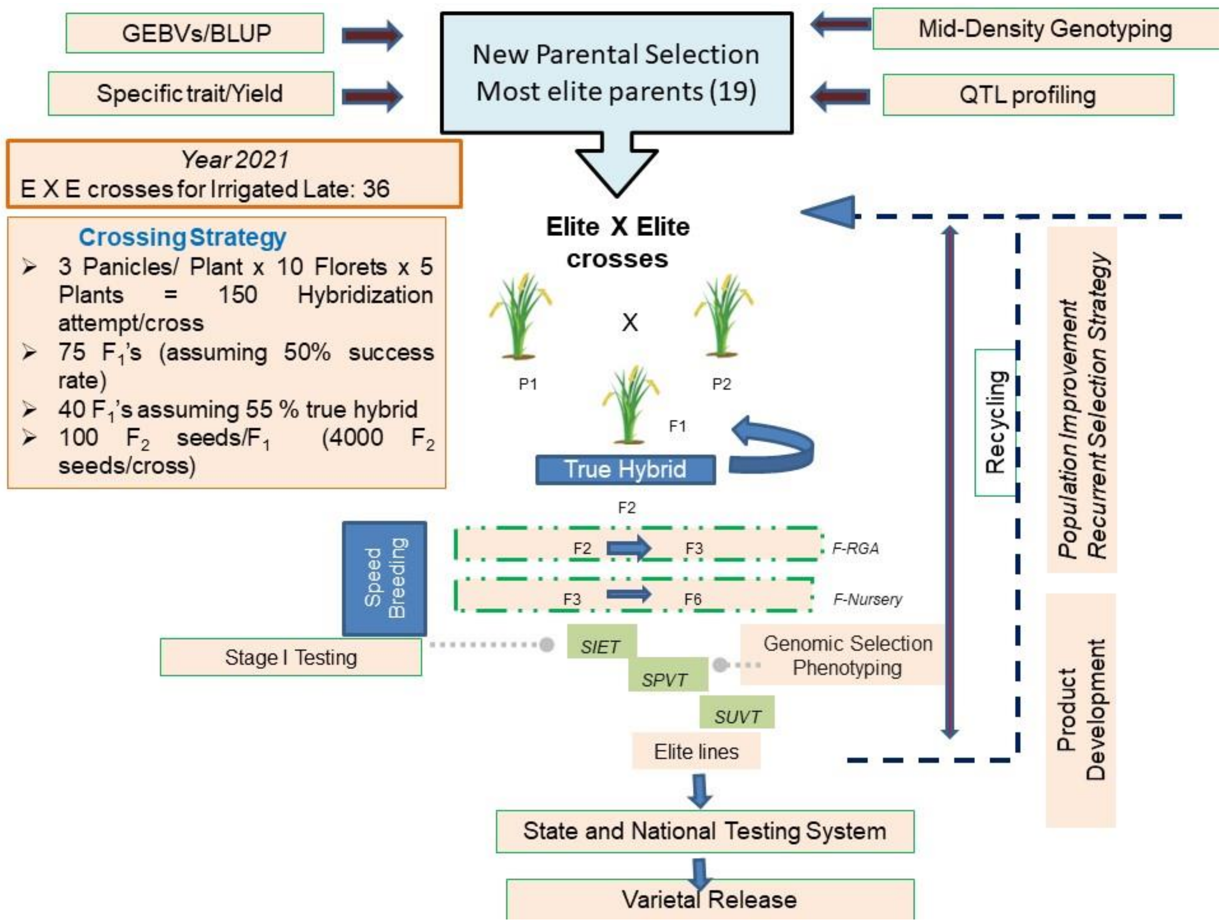
accumulation of favorable alleles of thousands of minor genes, integrated with accelerated product development technologies and genomic tools.

The modern breeding scheme of this program has integrated various components of "Breeding and Operational Excellence" to achieve the desired results. The program has also adopted modern crossing and hybridization strategies to maintain an optimum population size during the process of germplasm development and advancement.

Overall, the adoption of modern breeding strategies in rice varietal development programs is a significant step towards faster development of products and achieving sustainable agriculture. The modified SSD strategy, along with the use of genomic tools and accelerated product development technologies (as shown in Fig 1), has made the breeding process more efficient and less time-consuming. This approach will ultimately lead to the development of rice varieties that are better suited to meet the needs of farmers, consumers, and other stakeholders in the rice value chain.



2) QG based population breeding approach:

The new parental selection strategy adopted by IGKV is aimed at improving the efficiency and effectiveness of the breeding program by selecting elite parental lines based on their genetic merit, as measured by their genomic estimated breeding values (GEBVs) or best linear unbiased predictions (BLUPs). These values are calculated using sophisticated statistical models that integrate genomic and phenotypic data from multiple sources, such as pedigree records, marker data and field trials. By selecting parents with high genetic merit, the breeding program can increase the frequency of favorable alleles in the population and accelerate the genetic gain for complex traits, such as yield, quality and disease resistance. In addition, the redesigning of the crossing strategy for each breeding program, including the use of "Elite x Elite" breeding, can further increase the genetic diversity and improve the adaptation of the resulting varieties to local environments and farming systems. Overall, this approach can lead to the development of more productive, resilient, and sustainable rice varieties that meet the needs and preferences of farmers, consumers, and other stakeholders in the rice value chain.

3) **Separation of Pre-breeding strategy from the main breeding pipeline:**

The pre-breeding strategy in IGKV's rice breeding program focuses on selecting and introgressing genes of interest into elite lines through marker-assisted backcross breeding. Specifically, for three of the breeding programs, BLB genes (*xa5, xa13* and *Xa21*) and blast genes (*Pi2, Pi9* and *Pi54*) have been selected for introgression. This approach helps in developing elite lines with desirable traits for disease resistance and increasing the success rate of the Elite X Elite breeding strategy. The pre-breeding strategies have been developed and documented for all four breeding programs, contributing to the overall robustness of the breeding program.

4) **Incorporation of cost-effective speed breeding technology:**

Concept and technology of "Speed Breeding" for rice was introduced by CGIAR-IRRI through "Breeding Modernization" program in 2017. From that time onward three different speed breeding technologies were tested, modified to localconditions and implemented across all rice breeding programs at IGKV, Raipur.

Rapid Generation Advance (RGA)) is a technology that accelerates the breeding cycle by shortening the duration of each generation. This is done by manipulating the growing conditions and timing of planting and harvesting to allow for multiple generations of rice to be grown within a single year. The two strategies developed locally are:

1. **Field RGA (F-RGA) –** Under this modified version of RGA, single F_2 seedling is transplanted per cross in a small field plot of size 5 m x 1m at a close spacing of 5cm x 5cm to accommodate 2000 seedlings. At the maximum tillering stage, single main tiller is kept intact and rest of the tillers are cut down using scissors leading to development of single panicle per seedling. Single panicle per seedling is harvested. Same procedure is repeated in all seasons in advancing from F_2 to F_6

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generation optimizing the plot for 2000 seedlings in F_2 to > 1000 seedlings in F_6. This allows for a large number of seedlings to be produced in a small space, reducing the amount of time and resources required for generation advancement. Overall, the implementation of these speed breeding technologies has allowed for faster development and release of new rice varieties, helping to meet the growing demand for improved rice varieties in Chhattisgarh and beyond.

2. **Field nursery (F-Nursery)**: Under this method, harvested panicles are directly sown in raised bed of 1m size placing two panicles separately in a row in tail-to-tail fashion with a spacing of 10 cm row to row as shown in Figure …. Here, Advancement is done from F_3 generation to F_6 generation. Seedlings grow in dense fashion and single panicle is harvested per bunch. Expected loss of up to 10% lines are during generation advancement. Here there is less losses as compared to field RGA but space requirement is more.

Advantages of Speed breeding is:

- **Resource saving**: Land (1/10), labor, time and other resources.
- **Opportunity to increase the size of breeding program:** With in the given resources there is an opportunity to increase the size of the breeding program by ~10 times.
- Speed breeding technologies induces early flowering (by 15-20 days) and provide opportunities to take multiple generations per year.
- A total of 30 lakhs segregating lines can be accommodated per hectare in Field RGA against the 3.33 lakhs using conventional 20cm X 15 cm spacing.

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Aerial view of large-scale Speed Breeding activities at IGKV, Raipur

5) Utilization of High throughput SNP genotyping and precision breeding:

CGIAR-IRRI has provided a unique platform for exploiting high-throughput SNP genotyping of specific traits for key genes and forward-breeding in rice breeding. It is also commendable that more than 3000 advanced breeding lines and other genetic resources have been genotyped with the aim to explore the frequency of rare alleles in the elite pool/ IGKV breeding program, to search loops/ lacunas in IGKV breeding program and to formulate and design the molecular breeding strategies to increase the rate of genetic gain in rice breeding program of IGKV

Genomic selection and precision breeding are powerful approaches that can help improve the rate of genetic gain in rice breeding. The use of a "Global Estimation set/ Training population", which is genotyped at IRRI and phenotyped at the global level, including IGKV, is a great way to select elite parental lines based on "Genome Estimated Breeding Values" for specific breeding zones.

Low-density genotyping for F_1's hybridity testing and QTL profiling is ongoing at IGKV, Raipur and mid-density genotyping for DNA fingerprinting and genomic selection has been initiated in Rice breeding program in stage 2 where advanced breeding lines are tested at

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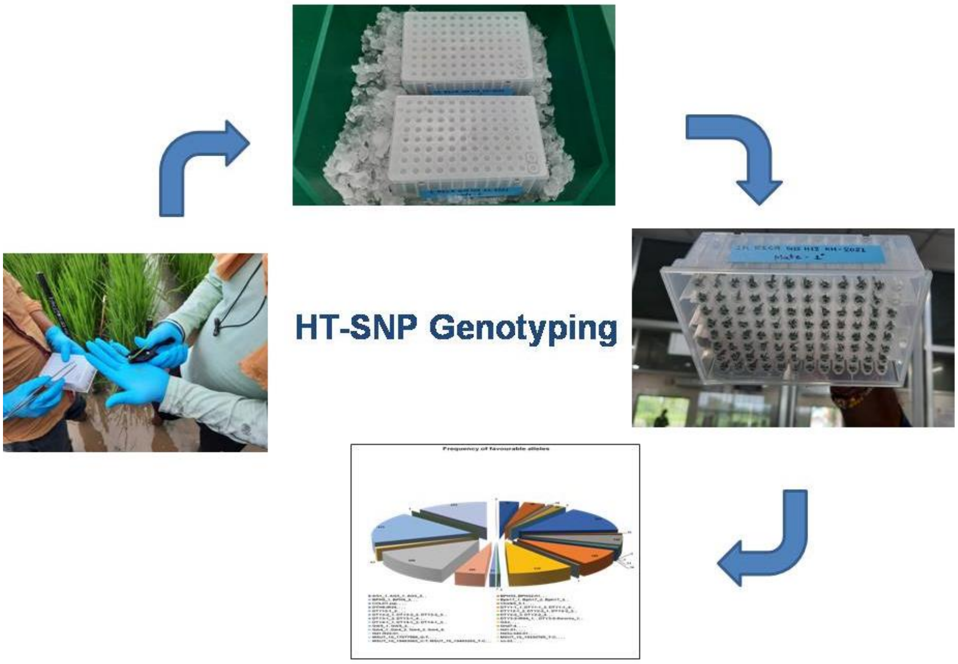
multilocation trials in 6 locations at State Preliminary Varietal Trials (SPVT). These initiatives will undoubtedly aid in the development of improved rice varieties that are better adapted to local conditions and have higher yields and better quality.



6) **Incorporation of Digitization, Electronic Data Capturing (EDC) and Breeding informatics:**

CGIAR-IRRI has played a key role in digitizing the operations of its NARES partners, including IGKV. This involved providing secure equipment such as hand-held devices, printers, and scanners, along with comprehensive on-site training and workshops. Through electronic data capture, the operational efficiency of breeding programs has been improved, with minimal human error. To this end, IGKV has implemented smart breeding tools and technologies on a massive scale, using the Breeding Management System (BMS) to digitize its historical data, particularly for its rice program.

Bar-coding, Automation & Digitization:

- Majority (85%) of 17000 field grown gene bank collections have been bar-coded.
- Majority (65%) of rice experiments/trials at IGKV, Raipur are bar-coded and Digitized.
- Complete 23,250 rice gene bank accessions are bar-coded; passport data & DUS traits digitized.

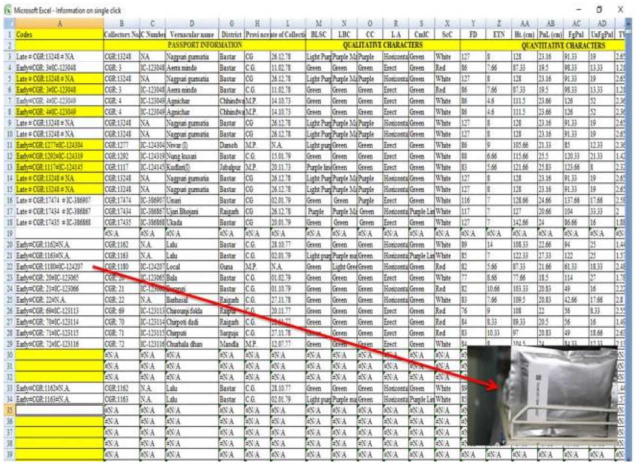
Electronic Data Capture of field experiments using Tablets & PB Apps:

- Use of tablets and "Field Book App" for capturing field observations electronically operationalized at large scale.
- Automation of post-harvest data recording – using Elane USB scale implemented.
- Use of manual field notebooks for data recording & Excel-minimized.

These statistics indicate that the use of bar-coding, automation and digitization technologies has been implemented to a significant extent in gene banks and field experiments related to rice at IGKV, Raipur. Bar-coding has been applied to a large proportion of the gene bank collections, while a majority of rice experiments and trials have also been bar-coded and digitized. The passport data and DUS traits of the rice gene bank accessions have also been digitized.

Overall, these technologies have the potential to improve data quality, reduce errors and increase efficiency in the management of gene banks and field experiments.

Digitization Gene bank collection



Automation and Digitization

Large scale Digitization of Experiments

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