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# Enhancing Crop Productivity and Quality through Mutation by Speed Breeding in the Asia Pacific Region (RAS5088, 2021-2024)


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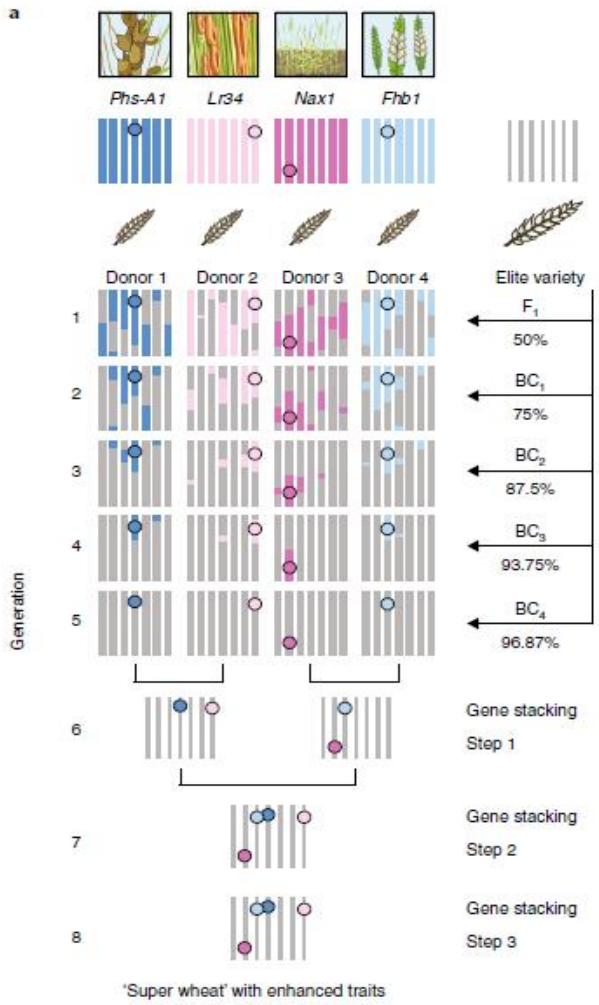
# Background

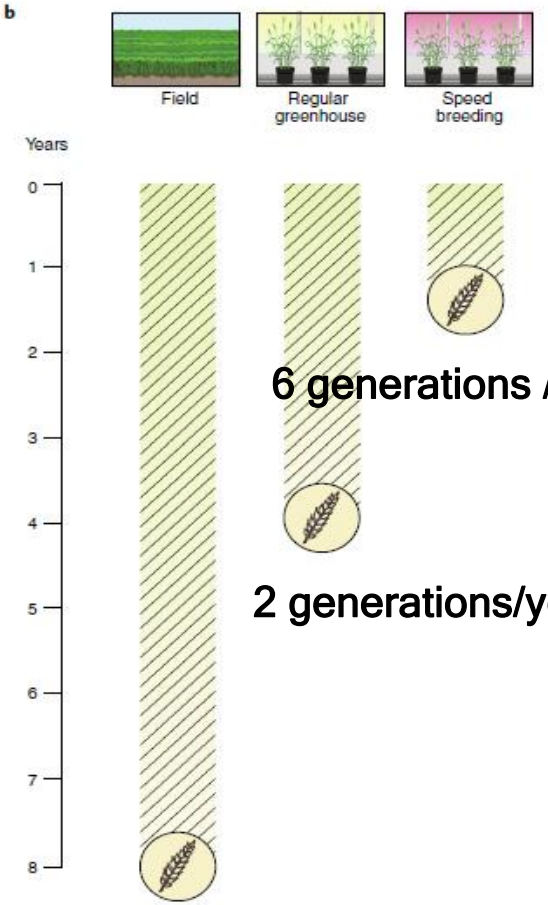
## Improved Crop Varieties Are Necessary for International Food Security

- Hunger remains a serious problem especially in Asia and Africa
- The UN Sustainable Development Goal 2 focuses on ending hunger, achieving food security and improved nutrition and promote sustainable agriculture.
- Meeting the future basic demand for main agricultural products in the Asia Pacific region will ultimately depend on the sustainable development of new crop cultivars adapted to ever-changing environments

# Speed Breeding Accelerate Crop Variety Development

- **Annual breeding cycles:**
  - **1-2 generations/year**
  - **Minimum of 4-6 generations for stable lines**
- **Speed breeding methods:**
  - **Shorten to 1-2 years for homozygous lines**

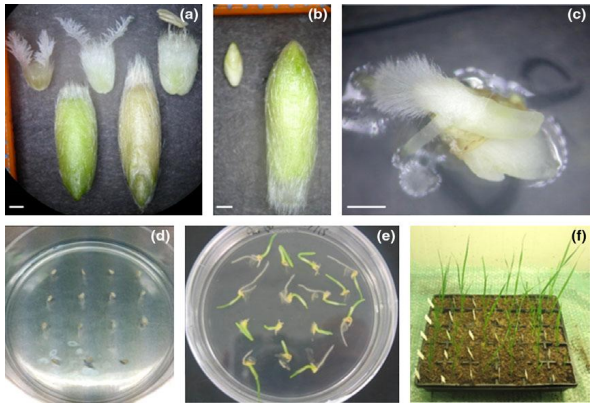


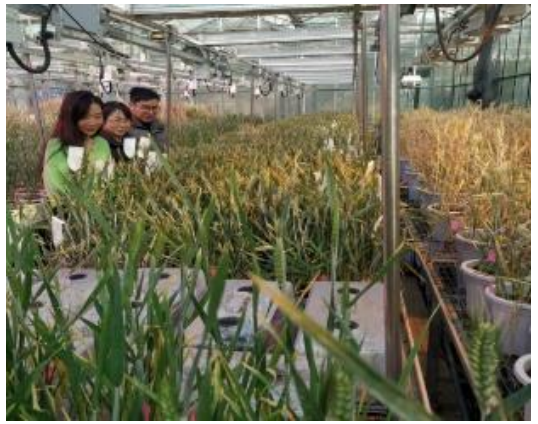



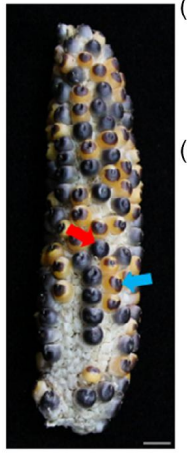

Nature Biotechnology, 2019, 37: 744-754

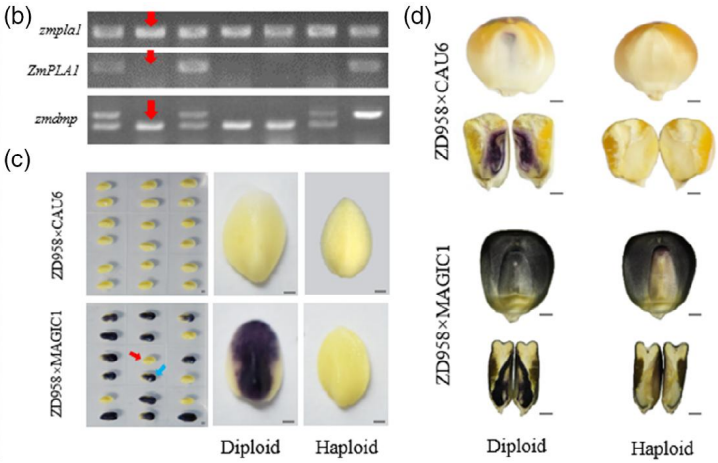
# Ways for Speed Breeding

- **MAS**: Increased selection efficiency and accurate marker assisted selection result in much shorter time to obtain desirable genotypes
- **DH**: speeding via double haploid process to reduce the time required to get homozygous individuals
- **Rapid cycling**: promoted growth and/or controlled chamber to manage more generations per year
- ……








The Plant Journal (2022) 111, 1296-1307; Plant Breeding (2016) 135, 574-579

# Project RAS5088 design

## Overall Objective

- To improve food security in the Asia Pacific region through faster release of mutant varieties with improved crop productivity and quality.
- In line with the UN SDGs and RCA MTS 2018-2023 Strategic Priorities

# Outcome

**Established Mutation by Speed breeding (MbyS) approach in the RCA GPs for faster development of promising mutant lines with improved performance**

**Mutation induction + speed breeding = Mutation by Speed breeding (MbyS)**

**By MbyS, elite/promising mutation lines be bred within 5 years**

# Expected outputs and Performance Indicators

1. **Capacity established for MbyS in GPs institutions: 6 researchers per GP to be trained on MbyS by end of the project, in case each GPs nominate 2 appropriate trainees for each training course, and the trainees willing to be trained.**
2. **MbyS protocols developed for application in GPs: At least 4 protocols based on local facilities and adopted to local environments to be developed by the efforts of all participating GPs by the end of project**
3. **Promising mutant lines developed through MbyS protocols by GPs: At least 5 mutant lines developed by MbyS approach by the end of project**

# Participating countries (GPs, 20)

Australia
Bangladesh
China
Cambodia
Fiji
India
Indonesia
Japan
Korea
Laos
Malaysia
Mongolia
Myanmar
Nepal
Pakistan
Palau
Philippines
Sri Lanka
Thailand
Vietnam

# Crop species and techniques

## Working Crop Species

Rice, wheat, soybean, mungbean, barley, chickpea, urdbean, Lentil, tomato, fingrmillet, watermelon, ground nut, blackgram

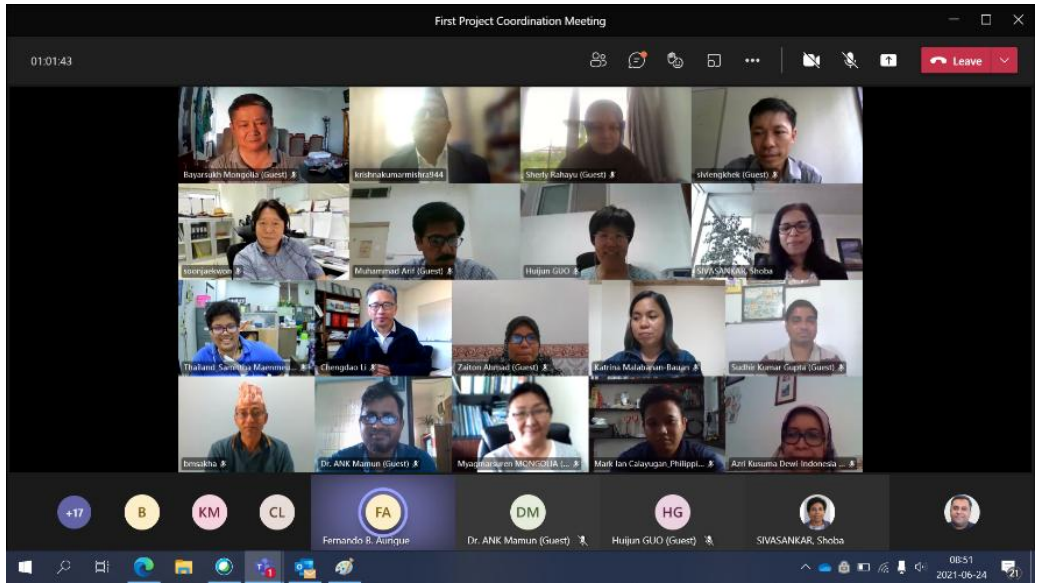
## Mutation and speed breeding

Heavy ion beams
Gama rays irradiation
*in vitro* mutagenesis
Electron beam
Double haploid
Molecular marker-assisted selection
Rapid cycling
TILLING
…

# Regional Activities: Meeting

## *First Project Coordination Meeting, Virtual, 21-25 June 2021*

- 17 NPCs attended the Meeting
- Regional project work plan was fine-tuned with specific time frames
- National work plans were developed and work teams were identified
- A draft of project document




# Regional Activities: Meeting

## *Mid-Term Review Meeting, Beijing, 16-20 October 2023*

- 17 NPCs/Senior Scientists attended the Meeting
- Reviewed and discussed the implementation of the project activities and evaluated the results achieved
- Identified gaps and needs of MbyS approaches and techniques to develop new crop mutants and varieties with improved yield and quality
- Refined/adjusted country workplans as well as the RAS5088


# Regional Activities: Workshop

## *Regional Workshop, Hanoi, April 15-19, 2024*

- 15 NPCs/Senior Scientists attended the Meeting
- In-depth presentations showcasing the implementation and impact of mutation by speed breeding protocols in different countries
- An exchange of valuable information and knowledge among participants to foster collaborative learning
- Presentations highlighting the tangible impact of mutation by speed breeding on crop improvement


# Regional Activities: Training course

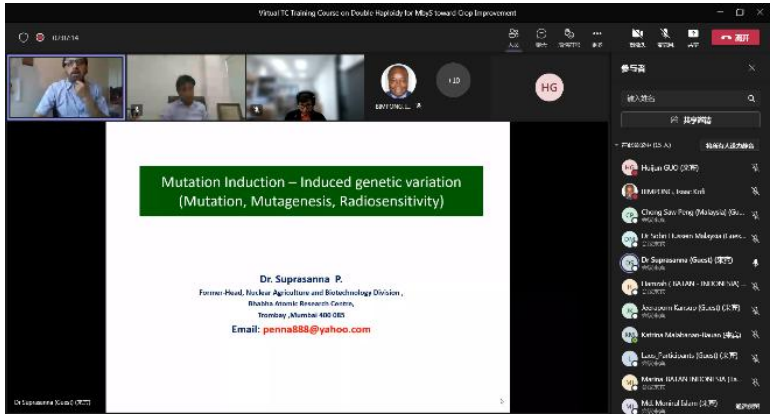
## *RTC on Digital Breeding Management Systems and Field Experimental Data Analysis, 2021.11.22-12.03, virtual*

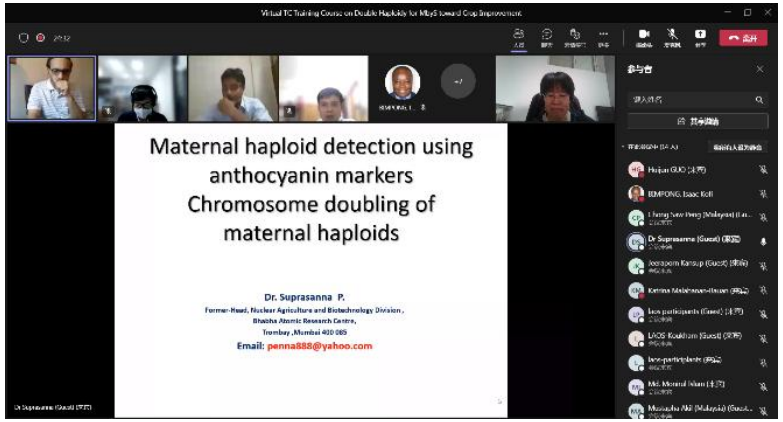
- **28 participants from 10 different RCA countries**
  **Bangladesh, Indonesia, Korea, Malaysia, Mongolia, Nepal, Pakistan, Philippines, Thailand, and Viet Nam**
- **Lectures**


# Regional Activities: Training course

## *RTC on Double Haploidy for MbyS toward Crop Improvement, 2022.03.15-16, virtual*

- **15 participants from 10 different RCA countries**
  **Bangladesh, Cambodia, Indonesia, Lao P.D.R., Philippines, Malaysia, Mongolia, Pakistan, Thailand, and Viet Nam**
- **Lectures**



# Regional Activities: Training course

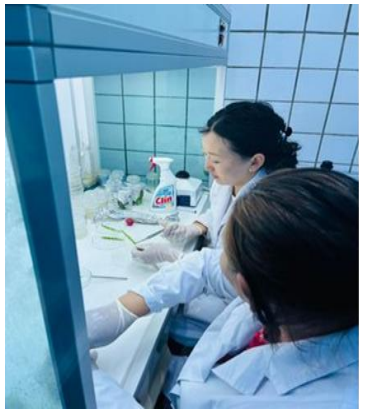
## *RTC on Mutation by Speed Breeding (MbyS) for Abiotic Stress Tolerance, 7 to 18, August, 2023, Jakarta, Indonesia*

- **24 participants from 14 different RCA countries**
  **Bangladesh, Cambodia, China, Fiji, Indonesia, Lao P.D.R., Philippines, Malaysia, Mongolia, Myanmar, Pakistan, Sri Lanka, Thailand, and Viet Nam**
- **Lectures and lab practice.**
- **Visits to irradiation facility and field**


# Main achievements: Enhanced Capability on MbyS in GPs

- Speed breeding using LED light combinations: established facilities and collected data on the effect of LED light photo-period on the growth and reproduction of tomato in Malaysia [Protocol]
- Speed breeding under controlled environments: get 2 generations within one year in Mongolia
- Protocol on double haploid:  induction media, regeneration medium, sampling stage



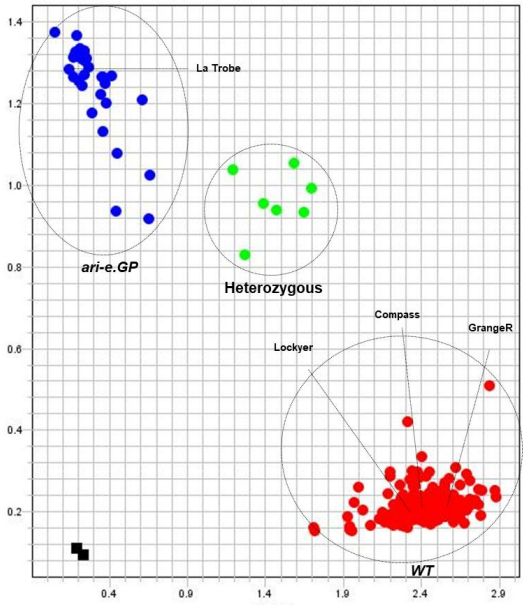


# Main achievements: Enhanced Capability on MbyS in GPs

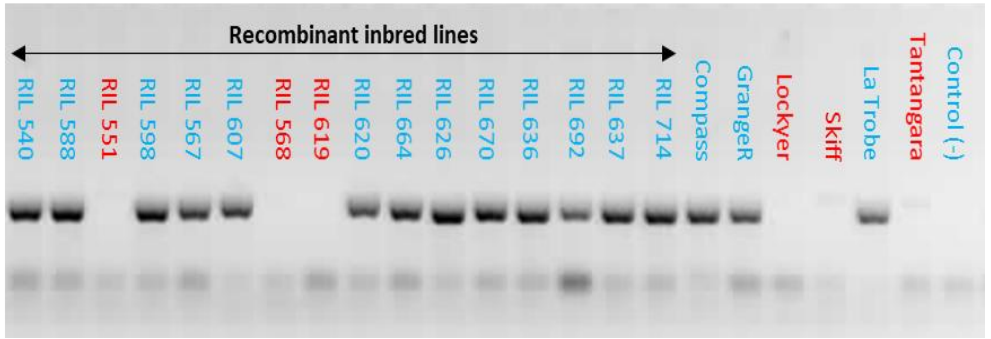
- **Marker Assisted Selection**

  **Molecular markers on various traits/crops: barley, wheat, groundnut……**

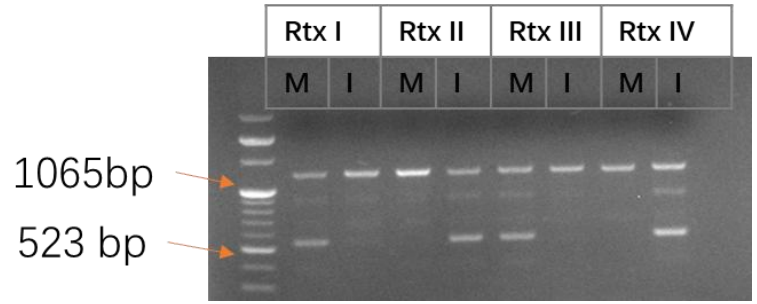
  **KASP/SNP, CASP, SSR,**




**Dense and erect panicle 1 (DEP1) gene**



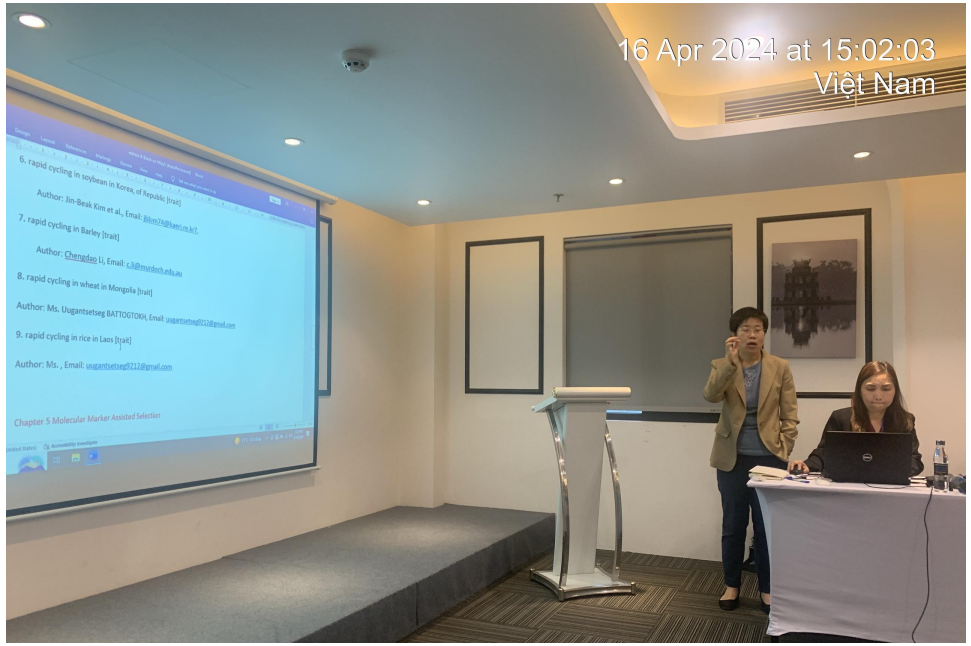

**Allelic variation of sdw1 gene**




**SNP markers for high oleic acid content**

# A Book on Mutation by Speed Breeding

- In preparation
- 7 to 9 Chapters
- Protocols on MbyS and their applications in MSs




**Book Title**

Accelerating Plant Breeding: Advanced Techniques in Plant Mutation Breeding for Crop Improvement

**Chapter 1 Introduction**

- → Brief overview of the importance of plant breeding for global food security and agricultural sustainability.
- → Historical context of traditional plant breeding methods and their limitations in meeting the increasing demand for improved crops.
- → Introduction to the concept of speed breeding and its potential to revolutionize plant breeding.
- → Zaiton AHMAD (zaitonahmad@nm.gov.my) can contribute to this part on MAS

**Chapter 2 Fundamentals of MbyS**

Accelerated plant mutation breeding using double haploid (double inducers), rapid cycling, MAS, high-throughput phenotyping, reverse and forward genetics,

**Chapter 3 Doubled Haploid Technology**

[Example]:

Mutation: mutagen, dosage, explant, original variety/wild type
Trait, objective
Methodology and Facility: flow-chart [As detail as possible]
Achievement: indicated by data, pictures, figures, tables.....
Conclusion:
References:

1. Title: Salt tolerant mutant selection by double haploid in rice in Bangladesh
   Author: A.N.K. Mamun et al., Email: ankmamun@yahoo.com
2. Title: Optimization of double haploid method for improvement of Sweet pepper for yield and fruit quality traits in Nepal
   Author: Tika Karki et al., Email: tbkarki2003@gmail.com
3. Standardization for DH methods on rice mutation breeding in Indonesia.
   Author: Azri Ksuma DEWI et al., Email: azridewi@yahoo.com
4. Wheat DH method in Pakistan [trait]
   Author: Muhammad Arif et al., Email: marif_nibge@yahoo.com
5. Barley DH method in Australia [trait]
   Author: Chengdao Li et al., Email: c.li@murdoch.edu.au
6. in vitro anther mutagenesis for salt tolerance in wheat
   Author: Huijun Guo et al., Email: guohuijun@caas.cn
7. contributions from Sri Lanka, Fiji, Myanmar, Japan,?
   → Author: ??, Email: ??

**Chapter 4 Rapid Generation Cycling**

# Main achievements: Mutant variety/line under RAS5088 since 2021

| Country | Crop | Mutant variety officially released since 2021 | | |
|---|---|---|---|---|
| | | Year of release | Variety Name | Main trait(s) improved by mutation techniques |
| China | wheat | 2021 | Hangmai3290 | Drought tolerance |
| | | 2021 | Hangmai802 | High yield and wide adaptability |
| | | 2022 | Hangmai106 | High yield |
| | | 2023 | Hangmai818 | Harmonious on 3-factor |
| | soybean | 2021 | Heike85 | Early maturity |
| India | | | | |
| Indonesia | | | | |
| | | 2023 | Pikatan | high yield, early maturity, plant type, tillering number |
| | soybean | 2021 | Sugentan 1 | early maturity (68 days) |
| | | 2021 | Sugentan 2 | early maturity (67 days), |
| | | 2022 | Detara | high yield, black soybean and big seed size |
| Lao | Rice | 2022 | Saphart 1 and Houykod 2 | reduced plant height, lodging resistance, early maturity |
| Malaysia | Rice | 2021 | Hibiscus rosa sinensis Peach | Peach petal as compared to pink of the parent |
| Pakistan | Rice | 2023 | NIBGE-9 | Yield, BLB resistance, earliness |
| | mungbean | 2023 | NIAB Pari | High yield, earliness, disease resistance |
| Sri Lanka | Bean | 2022 | HORDI Bean 3 | Yield, quality, yellow mosaic virus resistance |
| Vietnam | Groundnut | 2023 | LDT3 | The yield higher than original variety 21%), almost 3-seeded fruits (original variety only 2-seeded fruits), |
| | soybean | 2022 | DT215 | Black seeds, high yield and quality, good resistance (original variety with yellow seeds) |
| | | 2021 | DT2010 | Wide adaptation, earnly maturity, high yield |
| | | 2021 | DT218 | Good resistance to lodging and desease, high yield and high protein content (41.12%) |

24 mutant varieties in 8 MSs

>140 promising mutant lines & >3500 mutants in pipelines

# Improved mutant varieties released in crops

- ***BINA dhan 25***: Rice variety. Developed through 40 Gy carbon ion beam irradiation, officially released in 2022. Early mature, day neutral, higher yield (7.14 to 8.50 t/ha) and long grain fine Boro rice (Bangladesh)
- ***Saphart 1***: Rice variety. Developed through 300 Gy ɣ-rays irradiation, 25-30 days earlier maturity, short plant (110cm) and lodging resistant, higher yield (5 to 5,9 t/ha) (Laos)
- ***Hangmai 106***: Wheat variety. Yield potential 12 t/ha with high dietary fiber (China)

BINA Dhan 25

Hangmai 106

# Risk Management

- **Covid-19 on training and meeting activities:** virtual trainings & meetings
- **Less nominated trainees than expected:** recommend NPCs/GPs to nominate young researchers and relevant

# Workplan in 2024

| MT/RTC | Title of Event | Proposed Country | Date |
|---|---|---|---|
| MT | Mutation breeding network meeting | IAEA | July 22 to 26 |
| RTC | RTC on Genomics; Genotyping; Phenotyping; Genetics, Handling of mutants to speed up. | Faislabad, Pakistan<br>Dr. Muhammad Arif | Oct. 28 to Nov. 8 |
| MT | Final review meeting | Vientiane Capital, Laos<br>Mr. Siviengkhek Phommalath | 18 to 22 Nov |


Wheat Mutant Resource with Broad Spectrum Variations
Institute of Crop Sciences, Chinese Academy of Agricultural Sciences
Thank you!