Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Plant Breeding & Genetics Newsletter

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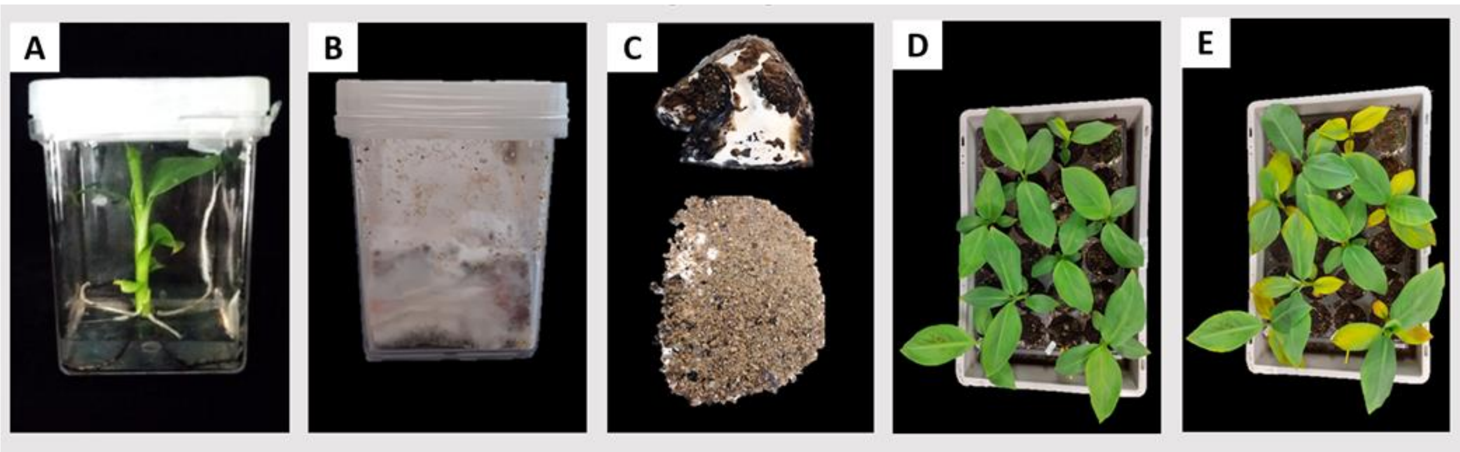
Contents

To Our Readers



Lab-based screening for resistance to Fusarium wilt (TR4) in Cavendish banana at the PBG Laboratory in 2020. Photo: A. Gennett.

Dear Colleagues,

I hope that you continue to be safe and well during these difficult times. As 2020 comes to a close and the pandemic situation remains unabated, Plant Breeding and Genetics (PBG) technical support to Member States and research and development through Technical Cooperation (TC) and Coordinated Research Projects (CRP) continue as best as practically possible.

PBG provided technical support for the development and release of 25 mutant varieties during the year, most of these in the Asia Pacific Region. An informal virtual meeting of the **Mutation Breeding Network of the Asia Pacific Region** was held in Nov 2020 where PBG led discussions with participant Member States on (a) the development of improved mutant lines, populations and new mutant varieties; b) the use and implications of heavy ion beam for DNA modification and faster development of new varieties; and (c) the use of genomics technologies to understand the molecular variants underlying mutations. The meeting was attended, and technical presentations made, by representatives of 14 of the current 16 participant Member States.

PBG received approval for a **new CRP** on 'Development of Integrated Techniques for Induced Genetic Diversity and Improvement of Vegetatively Propagated and Horticultural Tree Crops (D24014)'. The CRP aims to develop new genetic resources and technologies for accelerated breeding in cassava, other roots and tubers, and olive through induced genetic diversity, chimera-free regeneration and functional genomics. The CRP was the result of discussions during a virtual Consultation Meeting and subsequent feedback received during the presentation of the concept note for approval. Call for proposals for the CRP is currently open, with the expectation of having contracts signed by April 2021, and the first Research Coordination Meeting to be held soon thereafter.

R&D activities implemented by contract holders in the **five ongoing CRPs** have been on track in most instances, although in a few cases, delays imposed by the pandemic were experienced. First-year activities of a two-year, single-contract CRP on impact assessment of mutant rice varieties released by the Bangladesh Institute of Nuclear Agriculture were completed successfully. Research Coordination Meetings of two CRPs have been postponed to 2021. PBG provided technical support to the **implementation of 47 Technical Cooperation Projects** (TCPs), of which 35 began in 2020, and to the **design of 35 new TCPs** planned for the 2022–23 cycle. Emphasis was placed on procurement during this pandemic year, while two planned group training courses at the PBG Laboratory (PBGL) have been postponed to 2021. Similarly, most capacity building activities of ongoing TCPs have been delayed, including regional training courses, fellowships and scientific visits.

The PBGL adapted a protocol for the verification and screening for resistance to the disease, Fusarium Wilt TR4 in Cavendish banana, which enables the screening of mutant populations and verification of putative mutants of banana with resistance to TR4. The disease has been devastating banana plantations in Asia, and its appearance in Africa was reported in 2013 and in Latin America in 2019. The protocol was optimized using a TR4 susceptible Cavendish banana under contained, environmentally controlled conditions, and will now be applied to known TR4 resistant cultivars and for verification purposes.

Further, a new pilot project was initiated under the Functional Genomics for Trait Utilisation initiative for the **targeted selection of mutations** in specific genes in sorghum. A first batch of 6 000 M_1 seed was irradiated, planted and M_2 seed is now harvested. Also, to address the need for user-friendly bioinformatics tools to analyse large volumes of DNA sequence data, **a software workflow** has been developed to simplify the handling and primary analysis of Illumina sequence data, including streamlined quality control and identification of DNA sequence variants from whole genome sequence data. Finally, the PBGL has recently acquired and operationalized a robotics station for automated molecular biology protocols to support genomics research. Additional equipment investments were also made in specialized polymerase chain reaction technologies for higher throughput marker-assisted breeding and for targeted, genotypic selection of mutations in large-scale mutation breeding programmes.

Most importantly, I want to announce the **call for nominations for Outstanding Achievement Awards, Women in Plant Mutation Breeding Awards, and Young Scientist Awards**, in the science, application and impact of induced genetic variation and plant mutation breeding (page 31). The Awards will take the form of a certificate and will be officially announced during the 65th regular session of the IAEA General Conference, which will be held at the IAEA Headquarters in Vienna, Austria, from 20 to 24 September 2021.

I thank you for all your support and efforts during these difficult times and look forward to continuing strong collaborations in the coming year, and beyond.

Shoba Sivasankar
Head
Plant Breeding and Genetics Section

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[1] Separated in November 2020
[2] Joined in December 2020
[3] Joined in September 2020
[4] Joined in October 2020
[5] Joined in December 2020

Staff News

Welcome

Ms Ksenija Ajvazi (Austria) joined the Plant Breeding and Genetics (PBG) Laboratory in Seibersdorf on 1 December 2020 as Team Assistant. Ksenija was previously working for the Soil and Water Management & Crop Nutrition Section providing administrative support for many years in her capacity as Team Assistant. We welcome Ksenija and wish her all the best for her new assignment.

Ms Alkier Susu (Austria) joined the PBG Laboratory in October 2020 as an intern. Susu obtained a BSc in agricultural sciences at BOKU University, Vienna and is currently finalizing her MSc in agricultural and food economy at the same university. Her MSc project simulates a public payment to Austrian farmers that aims to incentivize low N2O-emission farming practices. Through this internship, Susu wants to strengthen her practical skills and knowledge in plant breeding and genetics. Her internship programme combines field, glasshouse and laboratory experiments for phenotyping, mutant characterization and marker development for agronomically useful mutants in cereals. We welcome Susu to the PBG team!

Mr Anibal E. Morales Zambrana (USA) joined the PBG Laboratory as an intern in September 2020. He recently graduated with two BSc degrees in Biomedical and Electrical Engineering from Florida International University, Miami, FL, USA. As an undergraduate, he worked in academia (MIT, BU, and FIU), government (NASA and DOE), and industry (Ford, TissueTech, and Northrop Grumman). Under the supervision of Norman Warthmann, he will assist in computer programming by developing computational workflows to analyze genomic datasets and automating the laboratory's liquid-handling robot. This internship will help him prepare for a Master's degree in Artificial Intelligence to build decision-making in robots. Welcome on board, Anibal!

Ms Faith Luvai joined the PBG Laboratory in December 2020. In 2019, she graduated from Kenyatta University in Nairobi, Kenya with a BSc in Molecular and Cellular biology. Faith briefly worked in parasitology techniques involving culturing *Leishmania* and malaria parasites, Kato techniques for diagnosis of schistosomiasis (*S. mansoni*), filtration techniques for diagnosis of *S. haematobium* and PCR-based detection of point mutation in *P. Falciparum* that are associated with resistance, at the Kenya Medical Research Institute (KEMRI). She has an interest in learning and gaining practical working and research experience to advance her career, which this internship program offers. She will be working with biotechnology and molecular tools related to plant pathology and the selection of mutant traits across different crops such as sorghum and banana, including *in vitro* tissue, basic and advanced molecular biology techniques and related activities in the greenhouse or field, while contributing to the drafting of laboratory protocols. She has already joined ongoing activities for banana *in vitro* tissue culture.

Farewell

We are sad to say goodbye to **Ms Caroline Wafula** (Kenya) who left the PBG Laboratory on 30 November 2020 after serving for six months. Caroline took over the Team Assistant duties from Ms Joanna Mletzko on a temporary assignment. While her duration with PBG was brief, we have greatly enjoyed the support and good services that Caroline provided to the team. We wish her all the best for the future!

From October 2019 until July 2020 PBG Laboratory had the pleasure of hosting **Mr Anza Ghaffar** from Pakistan as Data Science intern. He came to us from Finland with a Master's degree in industrial automation and previous working experience as data analyst in the private telecommunication, energy service, and finance sector. This internship was his first exposure to biology and genetics, but it did not take him long to make solid contributions. With his programming skills, particularly in R and python, he contributed visualization tools (R) and a mutation catalogue dashboard (python). Both are solid projects, which we will further develop and bring to service for our Member States. Even during the challenging COVID-19 lock-down, he kept up his motivation far from home. Good luck for the future, Anza, it was great to have you as part of the team!

Forthcoming Events

Research Coordination Meetings (RCMs) of FAO/IAEA Coordinated Research Projects (CRPs)

Third Research Coordination Meeting (RCM) on Improving Resilience to Drought in Rice and Sorghum through Mutation Breeding, D23031, *(Virtual Meeting)*, 12–16 April 2021*. (More information on Page 8)

Second Research Coordination Meeting (RCM) on Disease Resistance in Rice and Wheat for Better Adaptation to Climate Change, D23032, *(Virtual Meeting)*, 26–30 April 2021*. (More information on Page 8)

Fourth Research Coordination Meeting (RCM) on Mutation Breeding for Resistance to *Striga* Parasitic Weeds in Cereals for Food Security, D25005, *(Virtual Meeting)* April–May 2021 *(Date to be finalised)*. (More information on Page 8)

Second Research Coordination Meeting (RCM) on Enhanced Biotic-stress Tolerance of Pulses Towards Sustainable Intensification of Cropping Systems for Climate-change Adaptation, D22006, *(Virtual Meeting)*, 17–21 May 2021*. (More information on Page 8)

First Research Coordination Meeting (RCM) on Development of Integrated Techniques for Induced Genetic Diversity and Improvement of Vegetatively Propagated and Horticultural Tree Crops, D24014, *(Virtual Meeting)*, 21–25 June 2021*. (More information on Page 9)

Other Meetings

First Project Coordination Meeting on Enhancing Productivity and Resilience to Climate Change of Major Food Crops in Europe and Central Asia, RER5024, Ankara, Turkey, 8–12 February 2021*. (More information on Page 16)

Past Events

Consultants Meeting

Consultants Meeting on Integrated Breeding of Major Mutant Traits for Food Security and Climate-Smart Agriculture, Vienna, Austria *(Virtual Meeting)*, 12–16 October 2020. (More information on Page 9)

Other Meetings

Coordination Meeting on Promoting the application of Mutation Techniques and Related Biotechnologies for the Development of Green Crop Varieties, IAEA/RCA, RAS5077, Vienna, Austria *(Virtual Meeting)*, 5–9 October 2020. (More information on Page 16)

First Coordination Meeting on Enhancing Crop Productivity through Climate Smart Crop Varieties with Improved Resource Use Efficiency (AFRA) RAF5083, Vienna, Austria *(Virtual Meeting)*, 19–23 October 2020. (More information on Page 16)

Informal *Virtual Meeting* on Mutation Breeding Network (MBN) for Asia Pacific Region, 12–13 November 2020. (More information on Page 30)

*Dates tentative at present.

Coordinated Research Projects (CRPs)

Project Number	Ongoing CRPs	Project Officers
D22005	Efficient Screening Techniques to Identify Mutants with Disease Resistance for Coffee and Banana (2015–2020)	I. Ingelbrecht S. Sivasankar
D25005	Mutation Breeding for Resistance to *Striga* Parasitic Weeds in Cereals for Food Security (2016–2022)	A.M.A. Ghanim L. Jankuloski
D23031	Improving Resilience to Drought in Rice and Sorghum through Mutation Breeding (2017–2021)	F. Sarsu A.M.A. Ghanim
D23032	Disease Resistance in Rice and Wheat for Better Adaptation to Climate Change (2018–2023)	L. Jankuloski I.K. Bimpong
D22006	Enhanced Biotic-stress Tolerance of Pulses Towards Sustainable Intensification of Cropping Systems for Climate-change Adaptation (2019–2024)	S. Sivasankar N. Warthmann
D24014 **(New)**	Development of Integrated Techniques for Induced Genetic Diversity and Improvement of Vegetatively Propagated and Horticultural Tree Crops (2021–2025)	I.K. Bimpong S. Sivasankar
D20003	Impact Assessment of Mutant Crop Varieties Developed by BINA, Bangladesh (Single-contract project)	S. Sivasankar
D20004	Impact Assessment of Cotton Mutant Varieties Developed by NIAB, Pakistan (Single-contract project)	L. Jankuloski

Efficient Screening Techniques to Identify Mutants with Disease Resistance for Coffee and Banana, D22005

Project Officers: I. Ingelbrecht; S. Sivasankar

This CRP focuses on major transboundary plant diseases caused by fungal pathogens that affect coffee and banana production globally. Coffee Leaf Rust is caused by the fungal pathogen *Hemileia vastatrix* and has created recent epidemics in several countries in Central and Southern America where coffee is a major source of income for small scale farmers. Fusarium wilt is caused by the fungus *Fusarium oxysporum* Tropical Race 4 which is devastating banana production globally. The disease first affected Cavendish banana plantations in South and East Asia, including China and the Philippines, and spread to Northern Australia, the Middle East and Mozambique. In 2019 Foc TR4 was detected for the first time in South America (Colombia), a major banana exporting region. This CRP set out to develop innovative mutation induction and screening protocols to improve banana and coffee for resistance to Fusarium Wilt TR4 and Leaf Rust, respectively. Under this CRP, efficient TR4 screening protocols have been developed and a new TR4-resistant banana variety was released in China. In case of coffee, new methodologies for mutation induction have been developed and large mutant populations are now available. During this reporting period, this CRP was closed on 31 October 2020 after a one year no-cost extension following a duration of five years. The final reports from the 10 CRP contract holders have all been positively evaluated. The CRP has been a tremendous success for both coffee and banana. Two protocol books, one each for coffee and banana, are being compiled describing innovative mutation induction and screening protocols for wider dissemination to Member States. A description of the Book on 'Advanced Mutation Induction and Screening Technologies to Identify Mutants with **Resistance to Fusarium Wilt Tropical Race 4 in Banana**' is detailed on page 26.

Mutation Breeding for Resistance to *Striga* Parasitic Weeds in Cereals for Food Security, D25005

Project Officers: A.M.A. Ghanim; L. Jankuloski

The parasitic weeds *Striga* are major biological constraints to cereal production in most of sub-Saharan Africa and semi-arid tropical regions of Asia. The main objective of CRP (D25005) was to develop laboratory, screenhouse and field screening protocols for mutant populations of sorghum and upland rice for resistance to *Striga asiatica* and *S. hermonthica*. In addition, the CRP focuses on molecular marker discovery and doubled haploidy to enhance efficiency of mutant identification and to accelerate the delivery of resistant varieties to Member States. Tangible progress has been made during the reporting period despite the challenge created by the COVID-19 pandemic. Screening protocols for mutant populations of the targeted cereals are completed and the previously drafted protocols are in their final phase of revision. These protocols will be compiled and published for wider distribution to Member States. Mutant lines with *Striga* resistance have been verified and confirmed.

Improving Resilience to Drought in Rice and Sorghum through Mutation Breeding, D23031

Project Officers: F. Sarsu; A.M.A. Ghanim

The CRP officially started in October 2017 and its main objectives were to improve drought resilience of rice and sorghum through induced genetic variation and the development/adaptation of screening techniques for stable or increased yields under drought stress. The project seeks to simplify the identification of drought tolerant lines of rice and sorghum in breeding populations in glasshouse and controlled-environment conditions using a screening method at the flowering stage when the two plant species are most vulnerable to drought stress.

At the end of the fourth year of this project, considerable progress has been achieved in the development of effective pre-field screening of mutant rice for drought stress tolerance. Plans are in progress to prepare and publish protocols for use by plant breeders who need practical and rapid screens to process large mutant populations, including segregating populations, advanced generations, and rice and sorghum germplasm collections.

Disease Resistance in Rice and Wheat for Better Adaptation to Climate Change, D23032

Project Officers: L. Jankuloski; I.K. Bimpong

This CRP aims to improve disease resistance in rice and wheat through induced genetic variation and mutation breeding and the development of screening techniques for disease resistance. Specific research objectives are: (1) to generate genetic diversity and develop rice lines resistant to important diseases (blast, sheath blight, bacterial blight, and false smut); (2) to develop protocols for the screening of rice mutants resistant to the target diseases; (3) to develop molecular markers for disease resistance using available mutant germplasm; and (4) to generate mutant wheat populations and develop screening methods for resistance to wheat blast.

The CRP officially started in September 2018 and had its first Research Coordination Meeting (RCM) from 10–14 December 2018 in Vienna, Austria. The second RCM is tentatively planned to take place virtually during 26–30 April 2021.

Enhanced Biotic-stress Tolerance of Pulses Towards Sustainable Intensification of Cropping Systems for Climate-change Adaptation, D22006

Project Officers: S. Sivasankar; N. Warthmann

In this CRP, induced genetic variation and genomics technologies will be used for productivity improvement of three pulses, namely, chickpea, cowpea and lentil, which together account for 40% of global pulses' production. The research focus is on enhancing the tolerance of: (1) chickpea to the pod borer, *Helicoverpa armigera*; (2) cowpea to the bod borer, *Maruca vitrata*, and (3) lentil to the disease, *Stemphylium* blight.

Specific research objectives are (1) to generate genetic diversity in chickpea, cowpea and lentil through mutagenesis for resistance to *Helicoverpa armigera*, *Maruca vitrata* and *Stemphylium botryosum*, respectively; (2) to develop and/or refine phenotyping tools to facilitate precise and efficient selection of biotic-stress resistance in selected pulse crops; and (3) to develop genomic tools for accelerated variety development for the selected pulse crops and associated traits of interest.

The CRP which started in 2019 had its first RCM in September 2019 in Vienna, Austria. The second RCM is tentatively planned to be held virtually in May 2021.

Impact Assessment of Mutant Crop Varieties Developed by BINA, Bangladesh, D20003

Project Officer: S. Sivasankar

This is a single-contract CRP with the overall objective of estimating the economic impacts of promising mutant rice varieties developed by the Bangladesh Institute of Nuclear Agriculture (BINA).

The specific objectives are (1) to estimate the aggregate economic benefits associated with BINA-developed mutant rice varieties; (2) to determine the annual production and profitability trends of BINA-developed mutant rice varieties by location and variety; (3) to assess the adoption level of BINA-developed mutant rice varieties in all areas; (4) to identify farmers' preferences and constraints for cultivation of mutant rice varieties; and (5) to suggest policy guidelines/ recommendations.

Good progress has been made during its first year (2020) despite the difficulties of the pandemic situation. The CRP is planned to be completed in 2021 with a full report of the results achieved.

Impact Assessment of Cotton Mutant Varieties Developed by NIAB, Pakistan, D20004

Project Officer: L. Jankuloski

A new individual CRP on Impact Assessment of Cotton Mutant Varieties Developed by NIAB, Pakistan, was initiated this year.

The overall objective of this single-contract CRP is to evaluate the economic impact of the cotton mutant varieties developed by Nuclear Institute for Agriculture and Biology.

The specific objectives of this CRP are (1) to evaluate economic returns from mutant cotton varieties; (2) to assess adoption of mutant cotton varieties in different cotton growing areas of the country; (3) to identify the constraints to adoption of mutant cotton varieties in Pakistan; (4) to assess and determine annual production of NIAB cotton mutant varieties; (5) to evaluate the total area covered with cotton mutant varieties, their yield and economic benefits in total and of each mutant variety; and (6) to suggest policy recommendations for promotion of mutant cotton varieties.

The CRP is planned to be completed by the end of 2021.

Forthcoming Events

Third Research Coordination Meeting (RCM)

Improving Crops Resilience to Drought in Rice and Sorghum through Mutation Breeding, D23031

Virtual Meeting. 12–16 April 2021

Project Officer: F. Sarsu

The purpose of this event is to review progress made under the CRP, summarize the outputs, assess the outcome, verify areas to be further investigated and recommend additional actions to be taken by the Joint FAO/IAEA Centre and the participating Member States. The participants are expected to report on the developed/adapted and validated screening protocols for tolerance to drought in rice and sorghum in the field, green house and laboratory conditions, on mutant populations developed and lines identified for drought tolerance. During the RCM, individual project progress will be reviewed and performance data of mutant lines with improved drought tolerance will be evaluated. The overall activities and results of the CRP will be reviewed and evaluated, and decisions will be made on experiments to be elaborated, if any, and the development of possible publications.

Second Research Coordination Meeting (RCM)

Disease Resistance in Rice and Wheat for Better Adaptation to Climate Change, D23032

Virtual Meeting. 26–30 April 2021

Project Officer: L. Jankuloski

The second RCM of the CRP will be held in Vienna, Austria from 26–30 April 2021. Twelve participants from Bangladesh, Brazil, China, India, Indonesia, Malaysia, Pakistan, United republic of Tanzania, USA and FAO will be attending this RCM. All participants will present progress and achievements since the initiation of the project, and future work plans and activities will be fine-tuned for the remaining duration of the project.

The CRP has three working groups 1) Wheat group (with the objective of developing wheat blast resistant lines); 2) Rice blast group (with the objective of developing molecular marker/s for blast resistance); 3) Rice BLB group (with the objective of developing molecular marker/s for BLB resistance).

Fourth Research Coordination Meeting (RCM)

Mutation Breeding for Resistance to the Parasitic Weed (*Striga spp.*) in Cereal Crops for Food Security, D25005

Virtual Meeting. April–May 2021 *(Exact date to be discussed)*

Project Officer: A.M.A. Ghanim

The project has held three of the planned four RCMs to date. Two were organized in Vienna and the third RCM was in Kenya in 2019. The final RCM was originally planned for the fourth quarter of 2020 but revised during the CCRA meeting in October 2019 to be conducted in the second Quarter of 2021. The fourth RCM is now planned for April-May 2021 with the objectives of sharing progress and challenges in the remaining portion of the CRP, review of outputs and achievements, and preparations for the closure of the CRP. The meeting was originally planned to be hosted by Turkey but given the current situation of the pandemic it is possible that this meeting will be conducted virtually. It is expected to be attended by seven research contract holders, two technical contract holders and two to three agreement holders.

Second Research Coordination Meeting (RCM)

Enhanced Biotic-stress Tolerance of Pulses Towards Sustainable Intensification of Cropping Systems for Climate-change Adaptation, D22006

Virtual Meeting. 17–21 May 2021

Project Officer: S. Sivasankar

The CRP held its first RCM during 23–27 September 2019 with primary focus on discussing and finalizing first-year workplans in preparation for the achievement of intended objectives during the subsequent duration of the CRP. The second RCM will discuss results generated since the start of the project, provide course-corrections where necessary, and finalize the next stages in the workplans for individual contracts. While this meeting was previously planned to be held in Tunisia, due to the pandemic situation it is likely that it will be held virtually.

First Research Coordination Meeting (RCM)

Development of Integrated Techniques for Induced Genetic Diversity and Improvement of Vegetatively Propagated and Horticultural Tree Crops, D24014

Virtual Meeting. 21–25 June 2021

Project Officer: K. Bimpong

The first Research Coordination Meeting (RCM) of the new CRP developed through a Consultation Meeting in October 2020 is planned to take place in Vienna, Austria from 21 to 25 June 2021. This CRP will focus on developing novel genetic resources, methodologies and tools for accelerated breeding for productivity improvement in vegetatively propagated crops (mainly cassava along with other root and tuber crops) and horticultural tree crops (olive) by using mutation induction and associated biotechnologies. The main objective of this RCM is to discuss and finalize workplans in individual contracts.

Past Events

Consultants Meeting

Development of Integrated Techniques for Induced Genetic Diversity and Improvement of Vegetatively Propagated and Horticultural Tree Crops

Virtual Meeting. 12–16 October 2020

Project Officer: I.K. Bimpong

The objective of the meeting was to develop a concept note on research to address exiting bottlenecks in the improvement of vegetatively propagated and horticultural tree crops through induced genetic variation, and the development of optimal *in vitro* mutation induction techniques.

The Consultants Meeting brought together six external experts covering the fields of micropropagation, mutation induction and advanced genomic screening techniques for vegetatively propagated and tree crops, along with one FAO observer and PBG Technical Officers. Due to the COVID-19 pandemic, the meeting was held virtually.

A 10-page concept note was prepared that has subsequently been approved for launch as CRP D24014 by the Committee for Coordinated Research Activities (CCRA) of the IAEA. For more information on the new CRP, please see page 32.

Technical Cooperation Field Projects

Project Number	Country/Region	Title	Technical Officer(s)
ANG5015	Angola	Achieving Drought Tolerant Plants by Inducing Mutation with Gamma Rays	I.K. Bimpong
AZB5002	Azerbaijan	Developing Mutant Cotton Breeding Lines Tolerant to Diseases, Drought and Salinity through Mutation Breeding	F. Sarsu
BDI5001	Burundi	Improving Cassava Productivity through Mutation Breeding and Better Water and Nutrient Management Practices Using Nuclear Techniques	I.K. Bimpong *(Participating)* in collaboration with SWMCN *(Leading)*
BKF5019	Burkina Faso	Improving Food Crop Genotypes for Enhancing Yield and Adaptation to Climate Change Using Mutation Breeding and Isotopic Techniques	L. Jankuloski *(Leading)* in collaboration with SWMCN *(Participating)*
BOT5019	Botswana	Improving Selected Legumes and Cereals against Biotic and Abiotic Stresses to Improve Food Production and Security	I.K. Bimpong
BUL5015	Bulgaria	Increasing Productivity and Quality of Basic Food Crops	F. Sarsu
BUL5016	Bulgaria	Improving the Productivity and Quality of Economically Important Crops through Mutation Breeding and Biotechnology	F. Sarsu
CAF5013	Central African Republic	Improving Productivity of Maize and Developing Resistant Armyworm Maize Varieties Using Radio-Mutagenesis Techniques	S. Sivasankar
CHI5052	Chile	Using Nuclear Techniques to Improve the Adaptation and Productivity of Forest Species Facing Climate Change	S. Sivasankar
COL5026	Colombia	Enhancing Crop Productivity of Creole Potato Using Nuclear and Related Techniques	I.K. Bimpong *(Leading)* in collaboration with SWMCN *(Participating)*
CPR5024	China, People’s Republic of	Enhancing the Accelerated Application of Mutant Germplasm and High-Efficiency Breeding in Crops	N. Warthmann
CUB5023	Cuba	Strengthening National Capacities for the Development of New Varieties of Crops through Induced Mutation to Improve Food Security While Minimizing the Environmental Footprint	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*
ERI5011	Eritrea	Developing Improved Banana and Maize Varieties through Mutagenic Nuclear Techniques	A.M.A. Ghanim

Project Number	Country/Region	Title	Technical Officer(s)
GHA5037	Ghana	Using Irradiated Pollen for the Development of Provitamin A Rich, Drought Tolerant and Cassava Mosaic Disease Resistant Cassava Mutants	I. Ingelbrecht
GHA5038	Ghana	Using Irradiated Pollen for the Development of Provitamin A Rich, Drought Tolerant and Cassava Mosaic Disease Resistant Cassava Mutants	F. Sarsu
HON5009	Honduras	Improving Genetic Resistance of Coffee to Coffee Leaf Rust through Mutation Breeding	L. Jankuloski
INS5043	Indonesia	Intensifying Quality Soybean Production to Achieve Self-Sufficiency	A.M.A. Ghanim/L. Jankuloski *(Leading)* in collaboration with SWMCN *(Participating)*
INS5044	Indonesia	Using Nuclear Technology to Support the National Food Security Programme	S. Sivasankar *(Leading)* in collaboration with SWMCN *(Participating)*
IRA5014	Iran, Islamic Republic of	Improving Wheat Yield and Stress Tolerance for Sustainable Production	L. Jankuloski
IRA5015	Iran, Islamic Republic of	Enhancing Capacity of National Producers to Achieve Higher Levels of Self-Sufficiency in Key Staple Crops	I.K. Bimpong *(Participating)* in collaboration with FEP *(Leading)* and SWMCN *(Participating)*
IRQ5023	Iraq	Utilizing Nuclear Technology to Improve Key Legume Crops for Climate Change Adaptation	I.K. Bimpong
IVC5039	Cote d'Ivoire	Improving Maize Production in Savannah Areas with Severe Pedoclimatic Degradation in the North of Cote d'Ivoire through the Cultivation of Induced Mutants Adapted to these Areas	L. Jankuloski/I. Ingelbrecht/K. Bimpong/F. Sarsu *(Leading)* in collaboration with APH *(Participating)*
IVC5040	Cote d'Ivoire	Improving Agricultural Production of Maize, Rice and Cassava through Cultivation of Induced Mutant Adaptable to Climatic Changes	I.K. Bimpong
JAM5013	Jamaica	Improving Crops by Using Experimental Mutagenesis and Diagnostic Technologies	S. Sivasankar
JAM5014	Jamaica	Establishing a Self-Contained Gamma Irradiation Facility for the Introduction of Sterile Insect Technique and Experimental Mutagenesis and Diagnostic Technologies	S. Sivasankar *(Participating)* in collaboration with IPC *(Leading)*
KAZ5004	Kazakhstan	Developing Drought Tolerant and Disease Resistant Wheat Varieties with Enhanced Nutritional Content Using Mutation Breeding	F. Sarsu

Project Number	Country/Region	Title	Technical Officer(s)
KEN5038	Kenya	Using Nuclear Techniques to Evaluate and Improve the Impact of Mutated Forages on the Performance of Smallholder Dairy Cows	I.K. Bimpong *(Leading)* in collaboration with APH *(Participating)*
KUW5003	Kuwait	Implementing Mutation Induction to Improve Barley Production under Harsh Environmental Conditions – Phase II	L. Jankuloski
KUW5005	Kuwait	Implementing Mutation Induction to Improve Barley Production under Harsh Environmental Conditions – Phase III	L. Jankuloski
MAG5025	Madagascar	Enhancing Biocontrol of *Striga asiatica* (L.) Kuntze through the Development of Tolerant Rice and Maize Lines and its Links with Microbiological and Ecological Functioning of Soil	L. Jankuloski *(Leading)* in collaboration with SWMCN *(Participating)*
MAG5026	Madagascar	Enhancing Rice and Maize Productivity through the Use of Improved Lines and Agricultural Practices to Ensure Food Security and Increase Rural Livelihoods	S. Sivasankar/L. Jankuloski *(Participating)* in collaboration with SWMCN *(Leading) and IHS (Participating)*
MAL5031	Malaysia	Establishing an Environmentally Sustainable Food and Fodder Crop Production System	L. Jankuloski *(Participating)* in collaboration with SWMCN *(Leading)*
MAL5032	Malaysia	Strengthening National Capacity in Improving the Production of Rice and Fodder Crops and Authenticity of Local Honey Using Nuclear and Related Technologies	F. Sarsu *(Leading)* in collaboration with FEP *(Participating)* and SWMCN *(Participating)*
MAR5023	Mauritius	Improving Landraces of Crucifers (Cauliflower and Cabbage) and Carrot through the Use of Nuclear Techniques for Mutation Breeding and Biotechnology	F. Sarsu
MAU5006	Mauritania	Contributing to the Improvement of Rice Crop Yields through the Application of Nuclear Techniques to Water Management and Soil Fertility	L. Jankuloski *(Leading)* in collaboration with SWMCN *(Participating)*
MLW5003	Malawi	Developing Drought Tolerant, High Yielding and Nutritious Crops to Combat the Adverse Effects of Climate Change	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*
NAM5016	Namibia	Developing Drought Tolerant Mutant Crop Varieties with Enhanced Nutritional Content	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*
NAM5017	Namibia	Improving Crops for Drought Resilience and Nutritional Quality	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*

Project Number	Country/Region	Title	Technical Officer(s)
NEP5006	Nepal	Enhancing Productivity of Corps and Fruit Employing Nuclear and Molecular Techniques	I.K. Bimpong
NER5024	Niger	Improving Key Staple Crops towards Food Security	S. Sivasankar
NHE5001	Vanuatu	Enhancing the Productivity and Quality of Crops through the Application of Mutation Breeding Techniques	L. Jankuloski
NIC5011	Nicaragua	Broadening the Genetic Variation of Vegetative Propagated Crops Using Nuclear Techniques	I.K. Bimpong/F. Sarsu
OMA5005	Oman	Enhancing the Application of Mutation Breeding and Supporting Biotechnology Techniques for the Improvement of Important Strategic Crops	A.M.A. Ghanim
PAL5009	Palestine	Enhancing the Performance of Durum Wheat Landraces by Induced Mutation (Phase II)	L. Jankuloski
PAR1005	Paraguay	Establishing National Capabilities in Irradiation Technologies for the Treatment of Patients with Burns and the Introduction of Mutation Breeding for Enhanced Quality and Productivity of Crops	S. Sivasankar *(Participating)* in collaboration with RPRT *(Leading)* and ARBR *(Participating)*
PER5034	Peru	Improving Yellow Potato and Coffee Crops through Mutation Breeding Techniques	L. Jankuloski
PRC5002	Congo, Republic of the	Developing Disease-Resistant Varieties of Cassava and Banana	I.K. Bimpong
QAT5008	Qatar	Developing Best Soil, Nutrient, Water and Plant Practices for Increased Production of Forages under Saline Conditions and Vegetables under Glasshouse Using Nuclear and Related Techniques	A.M.A. Ghanim *(Participating)* in collaboration with SWMCN *(Leading)*
RAF5076	Regional Africa	Improving Crops by Using Mutation Induction and Biotechnology through a Farmer Participatory Approach (AFRA)	F. Sarsu
RAF5083	Regional Africa	Enhancing Crop Productivity through Climate Smart Crop Varieties with Improved Resource Use Efficiency (AFRA)	S. Sivasankar/F. Sarsu
RAS0080	Regional Asia	Promoting Self-Reliance and Sustainability of National Nuclear Institutions	S. Sivasankar *(Participating)* in collaboration with PCG *(Leading)*, RPRT *(Participating)* and PHY *(Participating)*
RAS5073	Regional Asia	Supporting Climate-proofing Rice Production Systems (CriPS) Based on Nuclear Applications-Phase II	L. Jankuloski *(Leading)* in collaboration with SWMCN *(Participating)*

Project Number	Country/Region	Title	Technical Officer(s)
RAS5075	Regional Asia	Improving Sustainable Cotton Production through Enhanced Resilience to Climate Change	L. Jankuloski *(Leading)* in collaboration with SWMCN *(Participating)*
RAS5077	Regional Asia	Promoting the Application of Mutation Techniques and Related Biotechnologies for the Development of Green Crop Varieties (RCA)	I.K. Bimpong
RAS5079	Regional Asia	Improving Crop Resilience to Climate Change through Mutation Breeding in Pacific Islands	F. Sarsu
RAS5088	Regional Asia	Enhancing Crop Productivity and Quality through Mutation by Speed Breeding (RCA)	S. Sivasankar/I.K. Bimpong
RER5024	Regional Europe	Enhancing Productivity and Resilience to Climate Change of Major Food Crops in Europe and Central Asia	F. Sarsu
RLA5068	Regional Latin America	Improving Yield and Commercial Potential of Crops of Economic Importance (ARCAL CL)	F. Sarsu
RLA5084	Regional Latin America	Developing Human Resources and Building Capacity of Member States in the Application of Nuclear Technology to Agriculture	S. Sivasankar *(Leading)* in collaboration with SWMCN *(Participating)* and APH *(Participating)*
RWA5001	Rwanda	Improving Cassava Resilience to Drought and Waterlogging Stress through Mutation Breeding and Nutrient, Soil and Water Management Techniques	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*
SAF5016	South Africa	Promoting Mutation Breeding of Vegetables to Improve Rural Livelihoods — Phase I	N. Warthmann
SIL5020	Sierra Leone	Enhancing the Concurrent Selection and Evaluation of Biofortified and Bio-enriched Varieties Derived from Mutant Rice, Cassava and other Crops	I.K. Bimpong
SIL5021	Sierra Leone	Improving Productivity of Rice and Cassava to Contribute to Food Security	I.K. Bimpong *(Leading)* in collaboration with SWMCN *(Participating)*
SRL5050	Sri Lanka	Supporting Genetic Improvement of Tea	S. Sivasankar
SUD5037	Sudan	Applying Nuclear Techniques to Improve Crop Productivity and Livelihood of Small-scale Farmers in Drought Prone Areas	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*
SWA5002	Eswatini, Kingdom of	Improving Adaptability of Cowpea to Climate Change through Mutation Breeding	L. Jankuloski
SYR5026	Syrian Arab Republic	Using Accelerated Mutation Breeding of Staple Crops for Enhanced Resilience to Climate Change through Speed Breeding, Phenotyping and Genotyping	L. Jankuloski

Project Number	Country/Region	Title	Technical Officer(s)
THA5056	Thailand	Strengthening Food Safety Laboratory Capacities	F. Sarsu *(Participating)* in collaboration for FEP *(Leading)*
TOG5002	Togo	Improving Crop Productivity and Agricultural Practices through Radiation Induced Mutation Techniques	I.K. Bimpong *(Participating)* in collaboration with SWMCN *(Leading)*
TUN5029	Tunisia	Developing Barley and durum Wheat Resilience to Drought and Heat Tolerance through Mutation Breeding	F. Sarsu
UGA5041	Uganda	Developing Disease Resistant High Yielding Farmer Preferred Cassava Varieties in Uganda through Induced Mutation Breeding	I.K. Bimpong/L. Jankuloski
URT5030	Tanzania, United Rep. of	Improving Rice and Barley Production through Application of Mutation Breeding with Marker Assisted Selection	F. Sarsu/L. Jankuloski
URT5032	Tanzania, United Rep. of	Developing Maize Cultivars for Improved Yield and Resistance to Viral Disease	F. Sarsu
URT5037	Tanzania, United Rep. of	Developing Rice Varieties with Resistance to Rice Blast and Salinity Tolerant Using Mutation Breeding and Biotechnology Techniques	L. Jankuloski
YEM5015	Yemen	Enhancing Sorghum and Legume Crop Productivity through Induced Mutations with Supportive Breeding and Biotechnologies	L. Jankuloski
ZAI5029	Congo, Democratic Republic of the	Enhancing Crop Productivity of Soybean and Maize through Improved Mutant Varieties and Lines	I.K. Bimpong
ZAM5031	Zambia	Improving the Yield of Selected Crops to Combat Climate Change	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*

APH: Animal Production and Health, NAFA; FEP: Food and Environmental Protection, NAFA; IPC: Insect Pest Control, NAFA; SWMCN: Soil and Water Management and Crop Nutrition, NAFA; RPRT: Radioisotope Products and Radiation Technology, NAPC; ARBR: Applied Radiation Biology and Radiotherapy, NAHU; PHY: Physics, NAPC; PCG: Programme Coordinator, NA; HIS: Isotope Hydrology Section, NAPC

Forthcoming Events

First Project Coordination Meeting

Enhancing Productivity and Resilience to Climate Change on Major Food Crops in Europe and Central Asia, RER5024

Ankara, Turkey. 8–12 February 2021

Project Officer: F. Sarsu

An increased production of the main crops (legumes, cereals and other important food crops) in Europe and Central Asia is being addressed under the TC regional project with technical support from the Joint FAO/IAEA Division. Nuclear technology is used to generate new beneficial mutations followed by mutation breeding to develop improved lines and varieties. The overall objective of the project is to support the production of major food crops with higher yields, improved quality, and better resilience to climate change through mutation breeding and combined biotechnologies in order to contribute to food security in Europe and Central Asia.

The purpose of this first coordination meeting are to review the workplan of this new regional TC project RER5024 (2020–2024); to establish national workplans of the participating countries to be implemented during 2020–2024; and to provide technical feedback to strengthen crop improvement efforts in participating countries.

This meeting will be open to designated counterparts of the project RER5024.

Past Events

Coordination Meeting

Promoting the application of Mutation Techniques and Related Biotechnologies for the Development of Green Crop Varieties, IAEA/RCA, RAS5077

Virtual Meeting. 8–9 October 2020

Project Officer: K. Bimpong

Due to the COVID-19 pandemic, the project review meeting was held virtually to assess progress of the project. The meeting offered the opportunity to (i) review results achieved on implementation of individual country workplans, and regional outputs and outcomes since the beginning of the project in 2017, and (ii) adjust/modify the proposed regional workplan for 2020 to ensure efficient implementation of the project objective.

Seventeen National Project Coordinators (NPCs) from Government Parties (GPs) in Asian and Pacific countries participated in the meeting.

Progress on national project activities as well as the workplans were discussed and aligned with the overall objective of the project. Participants agreed to develop success stories achieved in order to show the impact of the project. Two regional trainings and one final technical meeting earmarked for the 2020 workplan could not be carried out due to the COVID-19 pandemic. The regional workplan for 2020 was updated and recommendation was made to hold the final review meeting in person by the end of the first quarter of 2021.

The year under review saw the release of 19 new mutant varieties. In addition, a large number of advanced mutant lines and mutant populations are continuously being developed for further selection under the project.

First Coordination Meeting

Enhancing Crop Productivity through Climate Smart Crop Varieties with Improved Resource Use Efficiency (AFRA) RAF5083

Virtual Meeting. 19–23 October 2020

Project Officer: S. Sivasankar

This project builds upon previous initiatives and redirects regional attention towards neglected and underutilized food crops that are indigenous to Africa, while progressing the current efforts in all crops towards upscaling. It is intended to enhance human capacities in both seed and vegetative crops, and to contribute to the improvement of process efficiencies and statistical rigor in field-testing for the selection of improved varieties; advance modalities for informal and formal seed systems for the multiplication and dissemination of seed for upscaling and cultivation; and develop capacities for the use of newly developed varieties for molecular characterization towards process efficiencies in future selection.

The first Coordination Meeting was held virtually, and researchers from participating Member States presented the current status of their research in mutation breeding, which is the starting point for this project. Technical workplans for the year and for the entire project duration were discussed and feedback was provided by the Technical Officer. Also discussed were procurement needs and status, and planned training courses.

Feature Articles

Industry-Grade Pilot on Precision Phenotyping for Improved Drought Tolerance in Botswana for the African Continent

Isaac K. Bimpong[1], Jeffrey R. Schussler[2], Odireleng O. Molosiwa[3], Chipo Nkomazana[3], Benny A. Keotshabe[4], and Shoba Sivasankar[1]

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[4]Bobonong Horticultural Research Station, Ministry of Agricultural Development and Food Security, Francistown, Botswana

Project Background

Drought is the primary cause of yield loss in agriculture throughout the world and is currently the most common reason for global food shortages and food insecurity. The estimated cost of drought across Africa over the period of 2014 to 2017 totalled USD$ 372 billion. Climate change is expected to increase drought severity and its negative effect. The impact of drought is particularly severe in Sub-Saharan Africa (SSA) where rainfed subsistence farming dominates food production and the social and economic disaster management systems are usually inadequate. An increase in crop yields is required to meet the needs of a growing population.

The agricultural sector in Botswana has experienced a steady decline in its contribution to GDP over the past 50 years. This creates a huge challenge in the fight against poverty since about 70% of the rural households derive their livelihoods from agriculture. Crop production, that is mainly based on rain-fed farming, has been the most vulnerable part of the agricultural sector in Botswana due to low and erratic rainfall (600 mm in the north to less than 250 mm in the southwest), poor soils, pests and diseases and lack of improved varieties.

Recurring drought conditions have had significant and devastating impacts on Botswana's food security. The worst drought in recent years in the country occurred during 1981 to 1987, and 1990 to 1995. Droughts were also experienced during the 1998/99 season, from 2002 to 2006 and from 2011 to 2013. Drought adversely affects the already fragile food and agricultural situation and seriously impairs the rural economy and socio-cultural structures in Botswana.

Project Implementation

The leading counterpart of the project is the Department of Agricultural Research. The Technical Cooperation Project (TCP) BOT5019 on 'Improving Selected Legumes and Cereals Against Biotic and Abiotic Stresses to Improve Food Production and Security' (20202021) funded by the International Atomic Energy Agency (IAEA), builds on the past project (BOT5009) where radiation technology was used to develop novel genetic variation in cowpea to stabilize yields under drought stress.

The aim of the project is to use induced genetic variation for mutation breeding with the use of optimal phenotyping systems to improve cowpea adaptation to drought. It is expected to lead to the release of high-yielding cowpea varieties tolerant to drought stress.

Output

The project intends to establish a precise managed-stress environment (MSE) for drought phenotyping in three different locations in Botswana, and the incorporation of a robust statistical design to enable the detection of yield differences as low as 2% among cowpea mutant lines. These testing locations represent a defined target population of environments (TPE) that have been classified based on daily weather data from the past five years (temperature, relative humidity and rainfall), data on soil type, cropping season and cropping systems, especially as it applies to the cropping window for the target crop (e.g. cowpea).

Cowpea mutant lines at the flowering stage. Photo: O.O. Molosiwa.

Towards defining the TPE and identifying the testing locations, a review was conducted of all five sites/regions in Botswana where the Department of Agricultural Research has research stations. The review led to the selection of the three best sites across the country for the pilot precision drought phenotyping trials, namely, 1) Impala Agricultural Research Station in Francistown; 2) Mmamanaka Agricultural Research Station in Bobonong; and 3) Sebele Agricultural Research Station in Gaborone.

At the Impala Agricultural Research Station (21° 10' S and 27° 30' 45' E), the months of April to October are usually rain-free, resulting in a dependable dry season. Also, the average annual temperature of 30°C (87°F) is suitable for growing cowpea.

The Mmamanaka Agricultural Research Station (21º57' S and 28º26'E altitude 728 m), which lies within the central district in the eastern part of the country, is a typical semi-arid area, where drought is common in most growing seasons (April to October), with an average temperature of > 33°C.

The third site, the Sebele Agricultural Research Station (24º 35' S and 25º56' E altitude of 993 m), located in the south eastern part of the country, has average temperatures ranging between 19.7°C (67.5°F) to 32.7°C (87°F) with January as the warmest month. In 2019, rainfall occurred on 41 days throughout the year with a total precipitation of 189.7 mm (7.5 inches). The month of July is the driest month (precipitation rate of 0.4 mm (0 inches) per day), while December has the most rainfall (six days, with a total of 32.9 mm (1.3 inches)).

Cowpea mutant lines at maturity. Photo: O.O. Molosiwa.

The three identified sites are suitable locations for drought phenotyping where planting can be done during the last week of April using medium-maturity cowpea mutants. These mutant lines will reach peak flowering in early July, and the critical pod filling stage will occur from late July through August. At each site, drought stress will be imposed at the desired intensity, duration and timing based on crop stage. Good uniformity of the drought stress will be achieved by managing irrigation schedules during the dry season.

The national counterpart team has successfully increased seeds of the advanced M_4 cowpea lines developed from the previous IAEA project (BOT5009). In addition, the team has completed the characterization of the M_4 lines based on phenology (flowering date) and growth type (determinate or indeterminate) at two of the three selected sites in May 2020. Large variation in flowering time among the mutants may complicate interpretation of the effect of drought on yield. To manage this complication, mutant lines will be grouped together in blocks for testing, based on maturity. It is generally recommended that all mutant lines in a trial should be within a 23-day maturity range.

Harvesting of mutant lines in the field. Photo: O.O. Molosiwa.

The counterpart team observed flowering dates ranging between 57 to 89 days (average of 71 days) among the 86 M_4 mutant lines at the Sebele Agricultural Research Station; whilst at the Mmamanaka Agricultural Research Station in Bobonong, variation in flowering dates ranged between 57 to 84 days with a mean of 68 days. Establishment of testing groups of similar maturity is critical for the timing of the managed drought stress and therefore for reliable selection of improved genotypes. Only one mutant line was identified as indeterminate at all three testing locations. To initiate the screening experiments, 73 mutant lines with increased seeds have been identified.

Procurement

Equipment for meteorological data collection (weather station) including sensors for rainfall, relative humidity, temperature, PAR and windspeed have been purchased for all three sites. Other critical phenotyping equipment including soil moisture probes to document soil water extraction patterns for moisture management, pressure compensated drip tape to provide uniform water applications as necessary to the trials, weighing scales, seed counters, cowpea threshers, barcoding, printers and data collection devices are planned to be purchased shortly.

The project is also providing technical support for capacity development through the upgradation of breeding facilities and laboratories, and the training of research personnel through expert missions, scientific visits and training at advanced research institutes.

Deliverables

The project will lead to the establishment of pilot precision phenotyping locations for drought tolerance research in cowpea in Botswana, the application of industry-grade precision phenotyping technology for drought tolerance across all row crops in Botswana as prototypes for the rest of Africa and the development of new improved mutant varieties of cowpea with tolerance to drought.

Long-term Future Impact

The expected long-term impact of the project will be technology transfer of precision phenotyping for drought stress tolerance in Botswana and the rest of Africa, resulting in increased yield stability for staple crops, combining induced genetic variation and mutation breeding with speed-breeding methodologies.

New Breakthroughs in Plant Mutation Breeding Prominent Among the Top Ten Scientific Research Advances in China in 2019

Luxiang Liu

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On 7 August 2020, the Chinese Society of Nuclear Agriculture Sciences released new developments during 2019 in China, including the wide cultivation of the new mutant wheat variety *Luyuan 502*, release of the new mutant rice variety with low cadmium accumulation, hosting of the first workshop of the Mutation Breeding Network for the Asia Pacific Region, and the award of the CAAS-IAEA Collaboration Center. These were among ten final achievements nominated for award to fully represent the main progress of agricultural application of nuclear technology in China in 2019. Nominations were made after a process of preliminary selection, academic review and recommendation.

*The wheat mutant variety, **Luyuan 502**. Photo: L. Liu.*

China has long been the leading country for plant mutation breeding projects supported by the International Atomic Energy Agency (IAEA) in the Asia Pacific Region, and has made remarkable achievements in the development of new and improved crop mutant germplasm resources, and the large-area cultivation of new mutant varieties.

Large-scale application of the new wheat mutant variety *Luyuan 502* with wide adaptability, high productivity and stable yield. Through a combination of space mutagenesis and conventional breeding, *Luyuan 502*, was bred by the Institute of Atomic Energy Agricultural Application, Shandong Academy of Agricultural Sciences and the Institute of Crop Sciences, Chinese Academy of Agricultural Sciences. It solved the practical problem of heavy lodging encountered during the cultivation of wheat varieties with heavy spikes. With a yield potential of more than 12 t/ha, it was officially released by the national as well as four provincial committees and has been planted on more than 5.13 million hectares by 2019. It is now the second largest cultivated wheat variety in China. It has been awarded the First Award of Shandong Provincial Science and Technology Progress in 2018 and the Second Award of National Science and Technology Progress in 2019.

The *Yangfumai* series mutant wheats contribute to the replacement of high-yielding soft wheat varieties. This series of wheat varieties have been bred by the Lixiahe Regional Institute of Agricultural Sciences in Jiangsu Province. It integrates mutation induction, conventional breeding, and marker-assisted selection, and establishes a high-efficient wheat breeding method. New wheat germplasm resistant to fusarium head blight and yellow mosaic virus were developed using the innovative approach, and new mutant varieties of *Yangfumai No. 3*, *No. 4*, and *No. 5* have been bred and officially released. The varieties have been planted on over two million hectares in the Middle and Low Yangtze Valleys in the Winter Wheat Region of China. It was awarded the Second Award of Jiangsu Science and Technology Progress in 2019.

*The wheat mutant variety, **Yangumai No.3.** Photo: L. Liu.*

*The wheat mutant variety, **Yangfumai No. 4**. Photo: L. Liu.*

Combined utilization of radiation-induced mutagenesis and heterosis between *indica* and *japonica* rice makes new progress. The Sichuan Institute of Atomic Energy has developed a new approach which combines radiation-induced mutagenesis and heterosis between *indica* and *japonica* rice to develop improved germplasm. By using this approach, a new rice germplasm, *D069*, with high restoring and combining ability and good disease resistance, has been created, and three new varieties including *IIyouD069* have been bred. The three new inter-subspecies hybrid rice varieties with high yield and disease resistance have been planted in southwest China over nearly one million hectares. This achievement was awarded the Second Award of Sichuan Science and Technology Progress in 2019.

*Three-line hybrid rice variety, **IIyouD069**. Photo: L. Liu.*

Mutation breeding makes a breakthrough in the development of new rice varieties with lower cadmium accumulation. The Institute of Nuclear Agriculture Sciences and Space Mutagenesis Breeding of Hunan Academy of Agricultural Sciences has recently established a platform for the use of high-energy electron accelerator for mutagenesis and radiation-induced mutation breeding in rice. This led to the development of 22 new and improved mutant lines and a new two-line hybrid rice variety *C Liangyou 266* with low cadmium accumulation. The variety has been planted on more than 0.31 million hectares. It was awarded the Second Award of Hunan Science and Technology Progress in 2019.

*Two-line hybrid rice variety, **C Liangyou 266**. Photo: L. Liu.*

The Plant Mutation Breeding Network for the Asia Pacific Region was launched. The First Meeting of the Plant Mutation Breeding Network for the Asia Pacific Region was held in Jingzhou, Hubei, China from 22 to 25 July 2019. Representatives from 13 different countries including Bangladesh, China, India, Indonesia, Lao P.D.R., Malaysia, Mongolia, Myanmar, Pakistan, the Philippines, Sri Lanka, Thailand, Viet Nam, two observers from Cuba and Senegal, the international organizations, FAO/IAEA and ICRISAT, and several domestic breeders and researchers attended the workshop. The workshop formed a 'Jingzhou Proposal' for the Mutation Breeding Network for the Asia Pacific Region. It is agreed that three countries including China, Indonesia and India plus the FAO/IAEA Joint Division would steer the Network with two-year rotations of the national representatives. The current Chair is China.

Opening session of the First Workshop of the Mutation Breeding Network for the Asia Pacific Region. Photo: L. Li.

CAAS-IAEA Collaborating Center was officially started. The Center was set up in the Chinese Academy of Agricultural Sciences (CAAS) and its institutions in December 2019, with the aim to promote international cooperation and enhance capabilities of the utilization of nuclear techniques in Agriculture. It consists of five centers hosted by different institutions - the Collaborating Center for Nuclear Techniques in Plant Mutation Breeding, the Collaborating Center for Nuclear Techniques in Land and Water Management, the Collaborating Center for Nuclear Emergency Preparedness and Response in Agriculture, the Collaborating Center for Nuclear Techniques in Food Safety and Quality, and the Collaborating Center for Nuclear Techniques in Diagnosis and Control of Animal and Zoonotic Diseases.

Award ceremony for the CAAS-IAEA Collaborating Centre.

Mutation Breeding in India: Accomplishments and Socio-Economic Impact

Souframanien Jagadeesan and Ganapathi Thumballi Ramabhatta

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Indian agriculture in the past has witnessed events such as the Green Revolution which transformed the country's status from a food importing nation to a self-sufficient nation. The ushering in of the Green Revolution in the 1960s had ensued a phenomenal increase in the production of agricultural crops especially food-grains, in India. The crucial accomplishment of the Green Revolution was the dramatic augmentation in the production of two major cereals viz. wheat and rice.

The impetus to the Green Revolution emanated from the introduction of the spontaneous mutant dwarfing genes of 'Norin-10' wheat and 'Dee-Gee-Woo-Gen' rice into breeding programs culminating in the development of non-lodging and fertilizer-responsive wheat and rice varieties. Currently, Indian agriculture is facing the mammoth challenge of producing adequate food to meet the increasing demands of a burgeoning population, for which dwindling natural resources and unpredictable climatic events are emerging as major challenges. Genetic diversity and plant breeding are definitive elements in tackling the repercussions of climate change on agriculture, and strategic integration of plant breeding into climate-smart agriculture is one of the best initiatives for sustainable food production.

Nuclear technology through mutation breeding has played a significant role in broadening the genetic diversity and augmenting crop productivity by developing mutants with desirable agronomic traits. In India, concerted efforts for crop improvement through induced mutations were initiated during the second half of the 1950s, although the world's very first mutant cotton variety , MA-9 induced by X-rays, and endowed with drought tolerance, was released by India way back in 1948. Mumbai-based Bhabha Atomic Research Center (BARC), New Delhi-based Indian Agricultural Research Institute (IARI), Lucknow-based National Botanical Research Institute (NBRI) and various State Agricultural Universities are some of the major research centers, apart from others, that are actively engaged in mutation breeding in several crops and have contributed substantially to the development and release of a large number of mutant varieties in the country. India has developed about 386 mutant varieties in 62 crops through direct mutagenesis. Major varieties have been developed in rice, groundnut, mungbean, barley, cowpea, blackgram, sugarcane, chickpea, soybean, *Chrysanthemum*, bougainvillea, *Portulaca*, and *Dahlia*. In total, 82 mutant varieties have been released in cereals followed by pulses (63) and oilseed crops (55)**.** Among horticultural crops, the maximum number of mutant varieties were released in ornamentals (112) followed by other horticultural (21) and vegetable crops (15). India, distinctly, is first in the world to have released radiation induced mutant crop varieties in cotton ('MA-9'), wheat ('NP-836'), sugarcane ('Co-6608'), castor ('Aruna'), blackgram ('Co-4'), mungbean ('TAP-7'), chickpea ('Pusa-408'), pearlmillet ('NHB-5'), pigeonpea ('Co-3'), cowpea ('V-16') , lablab ('Co-10'), okra ('MDU-5'), turmeric ('Co-1'), bitter gourd ('MDU-1') and ridged gourd ('PKM-1'). Many of the mutants released in India are very popular among farming communities and have contributed substantially in elevating their economic status. Among the several gamma radiation-induced rice mutant varieties released in India, two early maturing and aromatic mutant rice varieties, 'PNR_381' and 'PNR_102', are very popular among farmers, with annual production worth 1748 million US dollars. Mutant varieties like 'TAG24', 'TG37A', 'TG38', 'TPG41', 'TG51' of groundnut; 'Pusa 408' (Ajay), 'Pusa-413' (Atul), 'Pusa-417' (Girnar) of chickpea; 'TAU-1', 'Co-4', 'TU40' of blackgram; 'TT401', 'TJT501', 'PKV-TARA' of pigeonpea; 'TMB37', 'TJM3' of mungbean; 'MaruMoth-1' of mothbean are among the important varieties of economic significance released in India.

*Trombay groundnut variety '**TG 38'** in Karnataka, India: Breeder seed multiplication. Photo: BARC.*

Under the peaceful applications of atomic energy, BARC had initiated radiation-based mutation techniques in agriculture for genetic enhancement of crops more than six decades ago. At present, BARC is concentrating on major cereals, pulses and oilseeds of country's interest like rice, wheat, sorghum, groundnut, mustard, soybean, sunflower, linseed, pigeonpea, mungbean, blackgram, chickpea and cowpea. In most of these crops, the major objectives have been to develop high-yielding varieties with early maturity, large seed size, high oil (oilseed crops) and protein (pulses) contents, moderate seed dormancy, ideal plant type, tolerance to biotic and abiotic stresses, and improved seed quality traits. The varieties released in these crops comprise direct mutants or mutant derivatives through inter-mutant or cultivar-mutant hybridizations. BARC has contributed substantially to the development and release of a large number of mutant varieties that have been in cultivation widely. These include, among many others, 43 mutant varieties of oilseed and legume crops (out of a total 118 mutant varieties developed nationwide), and the recent high yielding mutant rice varieties 'TCDM-1' (Trombay Chhattisgarh Dubraj Mutant-1) and 'TKR Kolam' (Trombay Karjat Rice Kolam) released for cultivation in Chhattishgarh and Konkan region of Maharashtra state.

*Trombay blackgram variety **'TAU-1'**. Photo: BARC.*

In blackgram, large seed mutants, 'UM-196' (dark green leaf mutant) and 'UM-201' were hybridized with an elite cultivar 'T-9' resulting in the development of high yielding varieties 'TAU-1', 'TAU-2' and 'TPU-4'. Likewise, in pigeonpea, a fast neutron induced large seed size mutant variety 'TT-6' was hybridized with 'ICPL 84008' and three early maturing and high yielding varieties ('TT-401', 'TJT-501' and 'PKV-TARA') have been developed. In mungbean, crosses involving 'Kopergaon' and 'TARM-2' have resulted in the development of an early maturing variety 'TMB-37' for North East Plain zone. This variety has recently been readopted by the state of Punjab owing to its earliness and yield superiority. The major thrust of BARC in induced mutations of pulse crops has been in the field of disease resistance. The first powdery mildew (PM) resistant mungbean mutant variety (TARM-2) in the whole of Asia was developed from BARC through induced mutagenesis and subsequently, a series of PM resistant mungbean varieties were evolved by utilizing the PM resistant mutant. BARC is also acclaimed for developing yellow mosaic virus (YMV) resistant mutants in blackgram and mungbean. These mutants have been successfully used in hybridization leading to the development of YMV resistant varieties. Mutants with resistance to cowpea aphid-borne mosaic virus and leaf crinkle diseases have also been identified in cowpea. Mutants with reduced phytic acid content in mungbean, reduced flatulence factors viz., raffinose family oligosaccharides in blackgram and increased iron content in chickpea have been developed.

Mutation breeding has been successfully applied in the traditional rice improvement programme which has resulted in improvement of aromatic rice varieties viz., Dubraj, Jawaphool etc. Two high yielding mutant rice varieties i.e., 'TCDM-1' (Trombay Chhattisgarh Dubraj Mutant-1) and 'TKR Kolam' (Trombay Karjat Rice Kolam) have been recently released for cultivation in Chhattishgarh and Konkan region of Maharashtra states, respectively. Improvement of other traditional rice varieties are underway in collaboration with the Indira Gandhi Krishi Viswa Vidyalaya, Chhattisgarh, which will bring these varieties back into cultivation and help in improving the livelihoods of tribal and marginal farmers.

For dissemination of research efforts of BARC to farmers, effective linkages have been established with the Indian Council of Agricultural Research (ICAR), State Agricultural Departments, State Agriculture Universities, National and State Seed Corporations, NGOs, National Institutes, Krishi Vigyan Kendras, progressive farmers etc. Most released mutant varieties have not only benefited the Indian farming community, but are also being used as genetic resource materials in national and state breeding programs. Among the groundnut varieties, 'TAG 24', 'TG 26', 'TG 37A' in the normal seed class and 'TKG 19A' and 'TPG 41' in the large seed class, became popular among the farming communities in India. These are being used as check varieties in the respective national and state varietal trials. By cultivating these mutant varieties, groundnut productivities in major groundnut growing states like Gujarat, Andhra Pradesh, Maharashtra, Karnataka, Odhisa and Rajasthan have almost doubled. With the introduction of recently released mutant groundnut varieties in these states, hundreds of farmers harvested significantly higher yields up to even seven tonnes/ha, and earned net profits up to 1,200 US dollars/ha.

*Trombay rice variety **'TKR Kolam'**. Photo: BARC.*

Trombay cowpea mutant variety ***'TC-901'****. Photo: BARC.*

The mutant variety 'TAU-1' in blackgram (developed in collaboration with Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola) released way back in 1985 is still very popular among Maharashtra farmers. This variety is extensively grown throughout Maharashtra and occupies more than 50% of the area under blackgram. The recently released high yielding blackgram variety 'TU-40' is now gaining popularity in the southern states. The pigeonpea mutant variety 'TJT-501' (developed in collaboration with the Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur) occupies almost 60% of the area under pigeonpea in Madhya Pradesh and is one of the topmost varieties receiving an average national breeder seed indent of 12%. The introduction of this variety in Madhya Pradesh has completely changed the pigeonpea farming scenario in the last decade. The area and productivity of pigeonpea almost doubled in this State and the seed replacement rate increased almost five times from 10.48% to 48.11% in the last decade. In mungbean, the mutant variety 'TMB-37' is widely preferred by farmers throughout the country for its earliness and suitability for summer cultivation though it was originally released for the North East Plain Zone.

In addition to direct traditional phenotyping, the emerging fields of genomics and phenomics offer opportunities for more precise breeding and large gains in efficiencies, while reducing the time for recovery of desired variants. Mutational genomics is becoming a valuable tool to differentiate mutants improved via mutation breeding programs. Induced mutations will continue to play an increasing role in creating crop varieties with traits such as improved oil quality, protein and starch quality, enhanced uptake of nutrients, deeper rooting system, and resistance to drought, diseases and salinity as a major component of environmentally sustainable agriculture.

Acknowledgements: We acknowledge the cooperation from the Indian Council of Agricultural Research and State Agricultural Universities in popularizing the released mutant crop varieties among farmers. We are also thankful to the International Atomic Energy Agency (IAEA) for giving us opportunities to participate in the RCA and CRP projects.

Trombay mungbean variety ***'TM-96-2'*** *in rice fallows in Andhra Pradesh, India. Photo: BARC.*

Developments at the Plant Breeding and Genetics Laboratory (PBGL)

Screening Protocols for Gamma-ray Irradiation Induced Resistance to the Parasitic Weed *Striga* in Cereals

The parasitic weeds *Striga* are major biological constraints to cereal production in most of sub-Saharan Africa and semi-arid tropical regions of Asia. The main objective of CRP D25005 'Mutation Breeding for Resistance to the Parasitic Weed (*Striga spp.*) in Cereal Crops for Food Security' has been to develop laboratory, screenhouse and field screening protocols of mutant populations of sorghum and upland rice for resistance to *Striga asiatica* and *S. hermonthica,* and the development of germplasm resources for resistance. In addition, the CRP focuses on doubled haploid techniques and molecular markers to enhance the efficiency of mutant identification and to accelerate the delivery of resistant varieties.

Tangible progress was made during the reporting period despite the challenges imposed by the COVID-19 pandemic. Screening protocols for mutant populations of the targeted cereals were developed and seven protocols are in their final phase of revision. These protocols will be published for wider distribution to Member States. The protocols were optimized for field, screenhouse and laboratory screening of mutant populations of cereals, mainly upland rice, maize and sorghum for resistance to the most common *Striga* weeds: *S. hermonthica* and *S. asiatica*.

In the validation process of these protocols, several outstanding mutants identified by the participating contract holders from field-screening were further verified and confirmed by the screening protocols established at the PBGL. Substantial achievements were produced from the CRP in terms of efficient protocols, and generation of new germplasm of resistant mutants in rice, maize and sorghum for *S. hermonthica* and *S. asiatica* in farmer-preferred varieties from participating *Striga*-prone Member States in Africa. Furthermore, through this CRP, the scope of the *Striga* resistance mechanism has been widened for the first time. A foundational paper describing the gamma-ray irradiation induced resistance to *S. hermonthica* in sorghum was published during this reporting period: Induced Resistance to *Striga hermonthica* in Sorghum by Gamma Irradiation. American Journal of Plant Sciences, 2020, 11, 1545-1561. https://www.scirp.org/journal/ajps ISSN Online: 2158-2750

Striga screening at the PBGL.

Book on 'Advanced Mutation Induction and Screening Technologies to Identify Mutants with **Resistance to Fusarium Wilt Tropical Race 4 in Banana**'

Since the 1970's, a new fungal strain causing Fusarium Wilt in banana, called *Fusarium oxysporum* Tropical Race 4 (TR4), is devastating banana production in South East Asia. From there it spread to other banana growing regions in the Middle East, Australia and Africa. Since 2019, the disease has spread to Colombia where it is now threatening the livelihoods of farmers and allied sectors involved in banana cultivation, consumption and export in Latin America. This alarming issue has triggered banana researchers to develop efficient and fast technologies for the production and selection of TR4 resistant and tolerant banana cultivars.

To help address the TR4 global threat to banana producers and consumers, PBG initiated the CRP D22005 'Efficient Screening Techniques to Identify Mutants with Disease Resistance for Coffee and Banana' in 2015. The CRP brought together banana researchers from the public and private sectors from Austria, China, the Philippines, Malaysia, South Africa, Mauritius, Iran, and France, together with the PBG team to develop efficient mutation induction and screening technologies of Cavendish banana (AAA) for resistance to TR4. Substantial achievements resulted from this CRP in terms of innovative R&D protocols and advanced mutant banana lines showing resistance/tolerance to TR4. China has officially released a

TR4 resistant banana variety generated using a combination of *in vitro* techniques and mutagenesis. During this reporting period, the CRP was closed, and some 12 protocols have been drafted and compiled in a protocol book jointly by the CRP contract holders and the PBG team. The objective is to share the advances and new technologies developed under this CRP with all FAO/IAEA Member States. The book describes improved methods and technologies that cover every stage of the banana mutation breeding process from the induction of mutations to efficient screening techniques for TR4 resistance. Topics include methods for low-cost *in vitro* techniques especially suited for developing countries, efficient mutation induction techniques, mutant population development, detection of mutants *via* phenotypic screening *in vitro* as well as *ex vitro*. Advanced genotypic techniques for mutation discovery and mutant characterization are also described.

The technical innovations and improvements described in this book are intended to help Member States address the banana Fusarium Wilt TR4 pandemic, as the disease is further spreading globally. Several countries in Latin America and Africa, including Ecuador, Tanzania and Uganda have already taken steps to initiate mutation breeding programs to address the TR4 threat in their countries with support from PBG (see below, new PUI project).

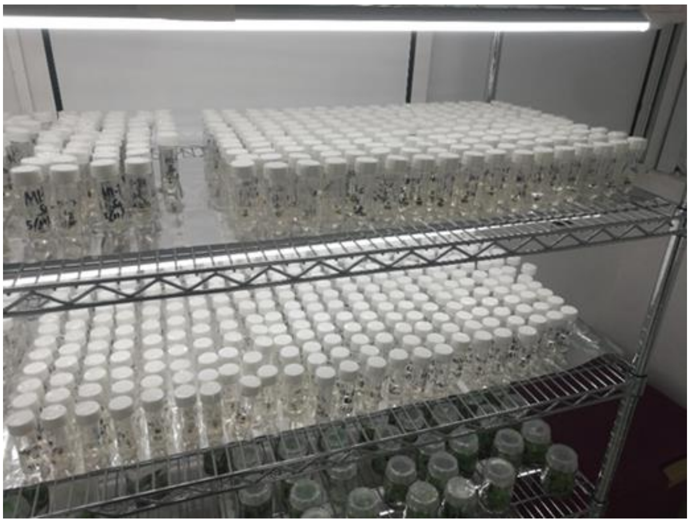
Progress on the Peaceful Use Initiative 'Enhancing Climate Change Adaptation and Disease Resilience in Banana-Coffee Cropping Systems in East Africa'

Banana and coffee are major cash and staple crops in Central and East Africa. Climate change, coupled with the accelerated spread of plant diseases, is impacting the livelihood of small-holder farmer communities in this region if no adaptation measures are taken.

Banana (*Musa* spp.) is an important crop in the African Great Lakes region in terms of income and food security, with the highest per capita consumption worldwide. The so-called Mchare varieties are of special interest in view of their high market value and commercial potential to improve the livelihoods of small holder farmers who typically grow them. In addition, Mchare are diploid (AA) banana and considered the progenitors of the triploid (AAA) dessert bananas.

The present project involves an international partnership between IITA, Arusha, Tanzania; the KUL, Belgium; Stellenbosch University, South Africa; and the FAO/IAEA. It focuses on the development of mutant populations for field or greenhouse testing and the development of protocols for targeted trait utilization and selection in Mchare. Focal traits include Fusarium wilt resistance and dwarfism, two key constraints for Mchare production.

At this time, four popular Mchare varieties have been multiplied *in vitro* to ca 8 000 plantlets in total at two of the partner institutions (see Fig and Table 1). Their multiplication rates have been determined with germplasm partially shipped to the PBGL for mutation induction experiments.



In vitro Mchare banana at IITA, Arusha, Tanzania for mutation induction.

Table 1. *In Vitro* Multiplication of Mchare Banana for Mutation Breeding

Variety Name	# Plants	Institution, Location	Characteristics
Huti Green Bell	1368 + 200	KUL, Belgium + FAO/IAEA	
Mshale	1836 + 200	KUL, Belgium + FAO/IAEA	
Huti white	2000 + 200	IITA, Arusha, Tanzania + FAO/IAEA	Higher seed set among Mchare; greater proportion of viable pollen
Mchare Laini	2000 + 200	IITA, Arusha, Tanzania + FAO/IAEA	Most preferred by consumers in this region

A Mutation Detection Software Workflow Has Been Developed

PBG strives to enable Member States to fully participate in the genomics revolution and thus enhance their Mutation Breeding projects. Whole genome re-sequencing with Next Generation short read sequencing technology (NGS) is very cost-effective and DNA sequencing capacity is readily accessible around the world. These sequencing machines turn out hundreds of millions of sequencing reads per run, which allow for in-depth views of crop genomes. However, handling such large amounts of data is challenging. In fact, PBG has identified the challenges of genome data analysis as one major obstacle for adoption of genomic approaches by Member States.

PBG has been using NGS-enabled genomics approaches for several years now. We understand the challenges to efficiently find genetic variants/mutations. For our in-house analyses, we have automated large parts of the analysis process by building computational workflows, where we chain together state-of-the-art open source analysis tools into a coherent pipeline.

The PBGL has now developed the pipeline in the workflow language *Snakemake* and have written a detailed documentation.

The workflow will perform an entire genome -resequencing analysis automatically: starting from raw sequence reads (fastq) it will align those reads against one or several reference genome(s), call variants (SNPs and Indels), annotate those variants with a genome annotation, and return a list of variants in the universal vcf file format. After running the workflow, the user will have a list of all detected variants along with their predicted impacts on annotated genes.

Since the challenges are different in every crop, the user has the choice between different alignment programs and variant callers and can use multiple reference genomes simultaneously. The workflow is a great time saver, and in addition, it abstracts much of the complexity of the analysis from the user, empowering non-experts to embrace genomics projects.

PBGL is planning to host training courses for researchers from Member States on genomics approaches including the use of our workflow. Stay tuned!

Functional Genomics for Trait Utilization: A New Pilot Project in Sorghum

Success in mutation breeding is largely influenced by the precision of the screening method for the targeted trait and the ability to grow the largest mutant population to increase the chance of inducing the targeted mutants. Traditionally most of the induced mutants, so far, were selected using the forward approach of screening for the phenotypes. However, with the fast development in molecular techniques and the availability of sequence information for agronomically important genes, it is becoming increasingly possible to screen mutant populations in the reverse direction; for sequence variation in the targeted genes, pick variants and further verify these variants by phenotyping for the targeted trait. Towards integration of these advances, the PBGL has initiated a pilot project on genotypic screening in sorghum. This project is being implemented under the overall Functional Genomics for Trait Utilization initiative which has as goal to use advances in genomics technologies for improved mutant trait discovery and selection. An M_1 population of about 6 000 individuals was grown in the field from which M_2 seeds were harvested and stored for each plant. A subset of pooled M_2 seeds of equal amount will be pooled to generate a bulked sample for molecular screening. Pools (s) with positive variation in the target genes will be disassembled to track individuals with the respective mutation. In the context of this research, innovative technologies applied in the medical sector to detect rare mutations underlying human disease will be adapted to plant mutation breeding.

Sorghum M_1 population in the experimental farm at Seibersdorf, Austria at grain maturity stage (left); M_2 seed collection (right).

Data Science Internships

2020 saw the next round of Computer Science Interns at PBGL. 'Big Data' has truly arrived in our lives, and it is highly relevant for plant mutation breeding, which has a large data science component by now. There is a global shortage of much needed experts and PBGL is committed to help train the next generation of data scientists by providing the opportunity of data science internships with us. During 2020, PBGL hosted two such interns. Anza Ghaffar (Pakistan) was with us until July 2020 and Anibal E. Morales Zambrana (USA) joined in August and will stay with us until July 2021. If you are a recent graduate in a computer science, statistics, or engineering, we would like to hear from you, and you could be our next intern and assist in genome data analysis and learn about plant breeding.

Crop Irradiation Services Provided to Member States

Due to the COVID-19 pandemic with related travel and shipment restrictions imposed by governments worldwide, a reduced number of requests were received by the PBGL in 2020. After the COVID-19 lockdown earlier in the year, the number of requests for irradiation has steadily increased from July 2020 onwards. At this time of writing (30 Nov 2020), the PBGL has received 24 requests for irradiations of crops and crop varieties as summarized in Table 2.

Table 2. Crop Irradiation Services

Request Number	Country	Request Type	Crop
1623	Ireland	Other	Eucalyptus
1624	Germany	Other	Ornamental
1625	Hungary	Other	Ornamental
1626	The Netherlands	Other	Ornamental
1627	Zambia	CRP	Cowpea, Groundnut
1628	Tanzania	TC	Rice
1629	Eswatini (Swaziland)	TC	Cowpea
1630	Niger	TC	Rice
1631	Zambia	CRP	Cowpea, Soybean
1632	Serbia	TC	Wheat, Barley
1633	PBGL	Other	Coffee
1634	Germany	Other	Ornamental
1635	Namibia	CRP	Cowpea
1636	Kenya	CRP	Cowpea
1637	Senegal	CRP	Cowpea
1638	Uruguay	Other	Rice
1639	The Netherlands	Other	Ornamental
1640	Croatia	TC	Wheat
1641	Germany	Other	Ornamental
1642	Nigeria	Other	Yam
1643	Cameroon	TC	Cowpea, Maize, Watermelon
1644	Togo	TC	Rice
1645	Cyprus	TC	Barley
1646	Zambia	CRP	Cowpea

Individual Training

After the COVID-19 lockdown in the first half of 2020, the international travel restrictions have somewhat eased and PBGLs intern and individual fellow training programme has picked up again. The PBGL welcomed two new fellows (Burkina Faso and Tunisia) and three interns (Austria, Kenya and USA) as summarized in Table 3.

Table 3. Individual Training Activities at the PBGL

Name	Country	Status	Topic	Period
Ms Susu ALKIERS	Austria	Intern	Plant breeding and genetics	2 months
Mr Anibal E. MORALES ZAMBRANA	USA	Intern	Data science	3 months
Ms Faith LUVAI	Kenya	Intern	Plant molecular biology/biotechnology	1 month
Mr Phillipe NIKIEMA	Burkina Faso	Fellow	Screening protocols for resistance to the parasitic weed *Striga*	4 months
Mr Mokhtar BARAKET	Tunisia	Fellow	Genotyping protocol for Marker-Assisted Selection for barley feed quality	3 months

Mutation Breeding Network (MBN) Updates

The Mutation Breeding Network currently operating in pilot mode for the Asia-Pacific Region held an informal virtual meeting in November 2020 to bring national representatives together to discuss updates on mutation breeding research and technologies since the First MBN Workshop held during 22–25 July 2019 in Jingzhou, China. It also provided an opportunity to touch upon the effects of the pandemic on research in the institutions of the MBN participants.

The meeting was successful in sharing recent updates in most cases and in discussing success stories and emerging technologies.

The Meeting:

1. Acknowledged that the Asia Pacific region remains at the forefront of mutation breeding research and development globally, with almost 2 000 reported mutant varieties from the region in the FAO/IAEA Mutant Variety Database;
2. Emphasized that while mutation breeding has been useful in crop improvement for several decades now, the significance of its potential to develop novel genetic diversity attains immense proportions in present times. This is because genomics technologies are becoming more cost- and time-efficient, and they can now, together with bioinformatics, seamlessly support the identification of molecular variants underlying mutations which can be developed into molecular markers for marker-assisted breeding and/or used as candidate genes for gene editing;
3. Emphasized that while technology exchange is an important benefit of the MBN, germplasm exchange shall be done with bilateral agreements between respective Ministries of the countries involved;
4. Urged that MBN presentations ideally provides (a) brief overview of mutation breeding research in each country; and (b) detailed information on new research and development addressed/achieved since the previous meeting;
5. Pointed out that it is ideal that representatives of countries in the MBN have an overall idea of national research and development in the field of plant mutation breeding, in addition to information from just one institution;
6. Recognized that the use of the heavy ion beam for induced genetic diversity is gradually becoming more prevalent;
7. Highlighted the need to have one additional, alternative representative from among young researchers for each country, citing impending retirements of some senior researchers or transfer to other institutions;
8. Received potential offers to host the next meeting from Bangladesh and Malaysia, provisional to financial support from the IAEA.

During the meeting, it was indicated that Superior Achievement Awards in plant mutation breeding (including Outstanding Achievement, Women in Plant Mutation Breeding, and Young Scientist Awards) are planned for 2021 by the Joint FAO/IAEA Division, with Note Verbale in process, and announcement planned for the January Newsletter of NAFA-PBG.

While the Mutation Breeding Network launched in 2019 continues as a pilot with current focus in the Asia Pacific Region, the team of Latin American and Caribbean researchers in mutation breeding has expressed strong interest for similar networking. At the meeting of the Regional Technical Cooperation project, RLA5068, held in March 2020, a professional network for the region was established under the name Latin American Network for the Application of Nuclear Technology in Agriculture (ATENA). Eventual combining of the two regional networks is foreseen once the pilot network for the Asia Pacific region establishes functionally.

Announcements

Outstanding Achievement, Women in Plant Mutation Breeding and Young Scientist Awards

Introduction

Six years have elapsed since researchers in plant mutation breeding were last recognized for their contributions to the field with Superior and Outstanding Achievement Awards at the IAEA 58th General Conference, on the 50th Anniversary of the Joint FAO/IAEA Division. The event, in 2014, was very successful, received excellent feedback, and was picked up by the national media in many member countries. Much progress in the field of plant mutation breeding has been achieved in the six years since then, which has prompted recommendations from member countries to hold a similar recognition event to promote further application of the science and its impact. Thus, the Sponsoring Organizations are once again seeking nominations for one or more individuals, teams or institutes in the following categories:

1. Outstanding Achievement Award;
2. Women in Plant Mutation Breeding Award; and
3. Young Scientist Award.

Nominations must be based on the following criteria:

1. Outstanding progress in developing and releasing mutant varieties in terms of the number of released mutant varieties with improved traits in important crops since 2010;
2. Mutant varieties with the strongest socio-economic impact in the last ten years in terms of yield gains and increased income to local farmers and the contribution to the economy of the respective member country;
3. Acceptance by farmers of the released mutant varieties including steps to involve farmers in speeding up the cultivation and expansion of improved mutant varieties;
4. Significant contribution to the advancement of agricultural productivity through research in plant breeding and genetics;
5. Efficient implementation of a plant breeding programme; and
6. Exceptional scientific work of young researchers in the field of plant mutation breeding.

The Awards will take the form of a certificate and they will be officially announced during the 65th regular session of the IAEA General Conference, which will be held at the IAEA's Headquarters in Vienna, Austria, from 20 to 24 September 2021.

Selection Panel

A Selection Panel will review all submitted nominations and make recommendations for awards. The Selection Panel will be chaired by the Director of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and will include staff members of the Joint Division's Plant Breeding and Genetics Section, selected FAO staff members and internationally acknowledged experts in the application of nuclear techniques in plant breeding.

Submission of Nominations

Nominations must be submitted using the Nomination Form or by request to the Joint Division (Email: NAFA.Contact-Point@iaea.org). The form provides a means of listing measurable achievements. Completed forms should be endorsed by governmental authorities, including the Permanent Missions to the IAEA or FAO. They must be received by the Joint Division no later than **1 March 2021**. Nominations received after that date or submissions not containing the completed Nomination Form cannot be considered. The Selection Panel will collect and distribute appropriately all documentation concerned.

Background Information and Nomination Form in .pdf can be found here.

New CRP: Development of Integrated Techniques for Induced Genetic Diversity and Improvement of Vegetatively Propagated and Horticultural Tree Crops (D24014)

Isaac Kofi Bimpong, IAEA Department of Nuclear Sciences and Applications

Vegetatively propagated crops (VPCs) and horticultural tree crops (HTCs) play an important role in food security and income and represent significant agricultural opportunities in most countries of the globe. However, due to limited genetic diversity, their improvement has been very slow as they cannot be easily self or cross-pollinated to produced seed or expand variation.

Climate change further worsens this situation by causing serious production losses from factors such as intensifying and transboundary spread of pests and pathogens. To date, very few VPCs and HTCs have been improved or developed through induced genetic variation and released for cultivation compared to seed-propagated crops. To meet the rising demands for food and nutrition without adverse environmental footprints, it is imperative to develop efficient methodologies and protocols capable of overcoming these limitations associated with plant mutation breeding in VPCs and HTCs.

The IAEA, in cooperation with the Food and Agriculture Organization of the United Nations (FAO), is launching this new Coordinated Research Project (CRP) with a time frame of five years to develop novel genetic resources, methodologies and tools for accelerated breeding for productivity improvement in VPCs (root and tuber crops) and HTCs (olive) by using mutation induction and associated biotechnologies.

By developing and/or optimizing these protocols for tissue culture-based induced mutagenesis, the CRP will provide outcomes that can guide National Agricultural Research Systems (NARS) in Member States to accelerate the development of new varieties of VPCs and HTCs through the use of efficient state-of-the-art technology packages.

The CRP will comprise ten participating countries from Member States where the crops are grown extensively, some advanced institutions and the CGIAR research centres with the respective mandates. Each country will bring together researchers covering the fields of micropropagation, advanced functional genomics for variant discovery and the use of nuclear techniques to induce genetic diversity at the cell or tissue level in select VPCs and HTCs to address the research objectives.

CRP Overall Objective

The CRP aims to develop new genetic resources and technologies for accelerated breeding in VPCs and HTCs through induced genetic diversity, chimera-free regeneration and functional genomics.

Specific Research Objectives

1. To develop or refine protocols for tissue culture, chimera-free regeneration and retention of induced mutation in root and tuber crops, primarily cassava, and in the perennial tree crop, olive.
2. To generate induced genetic diversity in cassava and olive through physical mutagenesis for tolerance to cassava brown streak virus, and olive quick decline syndrome, respectively or a major disease in a specific root and tuber crop.
3. To develop functional genomics tools and methodologies for the discovery of molecular markers and candidate genes in cassava, olive or a specific root and tuber crop.

Impact

The CRP will lead to the generation of (a) stable mutant clones that are free-of-chimeras and characterized at the genetic and molecular levels for traits of interest and (b) publication of protocols for phenotyping and genomic analyses for Member States.

Relevance

Genetic improvement of these important crops will help to directly meet some of the Sustainable Development Goals (SDGs), particularly those related to health and nutrition, and the reduction of poverty and hunger. For instance, more than 240 million tons of roots and tuber crops covering around 23 million hectares are produced annually in sub-Saharan Africa. But VPCs and HTCs are constrained compared to seed produced crops because of their reduced genetic diversity. Besides, the application of conventional breeding methods is also time-consuming due to the high degree of heterozygosity, long juvenility, large size, and sometimes self-incompatibility in most VPCs and HTCs, which often results in cultivars not accepted by consumers.

There is a high demand from Member States to improve VPCs and HTCs as reflected in many technical cooperation projects (TCPs); Recently, Member States in the Pacific Islands, such as Fiji, Vanuatu, Jamaica, etc. have also expressed an interest in the development of VPCs (taro, yam, banana, ginger and indigenous potatoes).

The use of mutagens such as gamma or X rays is particularly appealing for VPCs and HTCs, since unlike chemical mutagens they create structural mutations which involve many genes, increasing the overall probability of success in this CRP. Based on the predominance of the two crops in FAO/IAEA Member States, the CRP contracts will be distributed in a proportion of 70:30 between cassava (or root and tuber crops in general) and olive.

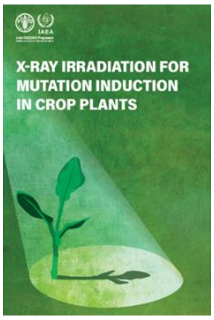
How to join the CRP

Please submit your Proposal for Research Contract or Agreement by email, no later than **30th January 2021**, to the IAEA's Research Contracts Administration Section, using the appropriate template on the CRA web portal. Note that the same template can be used for both research contract and technical contract.

For further information related to this CRP, potential applicants should use the contact form under the CRP.

Publications

Books



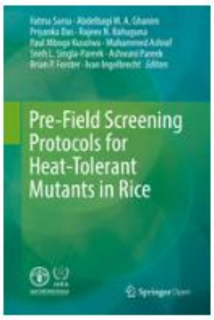
X-Ray Irradiation for Mutation Induction in Crop Plants *(in press, FAO)*

Ghanim, A.M.A., Bado, S., Ali, A.B., Sangwan, R.S., Forster, B.P., Ingelbrecht, I.L.

Manuel d'amélioration des plantes par mutation, Troisième édition

Édité par. M.M. Spencer-Lopes, B.P. Forster et L. Jankuloski, Sous-programme de Génétique et d'Amélioration des Plantes Division mixte FAO/IAEA des Techniques Nucléaires appliquées à l'Alimentation et à l'Agriculture.

http://www.fao.org/3/i9285fr/I9285FR.pdf
ISBN 978-92-5-132932-0

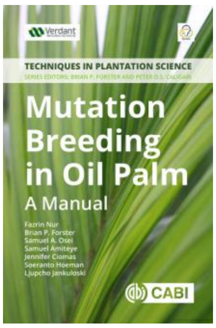


Pre-Field Screening Protocols for Heat-Tolerant Mutants in Rice

Sarsu, F., Ghanim, A.M.A., Das, P., Bahuguna, R.N., Kusolwa, P.M., Ashraf, M., Singla-Pareek, S.L., Pareek, A., Forster, B.P., Ingelbrecht, I.L.

Springer (2018)
ISBN 978-3-319-77338-4

https://www.springer.com/de/book/9783319773377



Mutation Breeding in Oil Palm: A Manual

Nur, F., Forster, B.P., Osei, S.A., Amiteye, S., Coimas, J., Hoeman, S., Jankuloski, L.

CABI Publishing (2018)

ISBN 9781786396235 (ePDF)
ISBN 9781786396228 (ePub)
ISBN 9781786396211 (pbk: alk. paper)

https://www.cabi.org/bookshop/book/9781786396211

Peer-reviewed Publications

2020

NIKIÈMA, M. P., OUÉDRAOGO, N., TRAORÉ, H., SAWADOGO, M., JANKULOSKI, L., ABDELBAGI, M. A. G., YONLI, D. (2020). Sorghum Mutation Breeding for Tolerance to Water Deficit Under Climate Change. Journal of Plant Breeding and Crop Science, 12(3), 192–199.

AHUMADA-FLORES, S., GÓMEZ PANDO, L.R., PARRA COTA, F.I., DE LA CRUZTORRES, E., SARSU, F., DE LOS SANTOS VILLALOBOS, S. (2020) Technical Note: Gamma Irradiation Induces Changes of Phenotypic and Agronomic Traits in Wheat (*Triticum turgidum* ssp. durum), Applied Radiation and Isotopes. https://doi.org/10.1016/j.apradiso.2020.109490

WANGA, M.A., SHIMELIS, H., HORN, L.N., SARSU, F. (2020) The Effect of Single and Combined Use of Gamma Radiation and Ethylmethane Sulfonate on Early Growth Parameters in Sorghum. Plants 2020, 9, 827. https://www.mdpi.com/2223-7747/9/7/827

SIVASANKAR, S., HENG, L.K, KANG, S.-Y. (2020) Agriculture: Improving Crop Production. Elsevier Encyclopedia of Nuclear Energy. https://doi.org/10.1016/B978-0-12-409548-9.12323-1

NIKIÈMA, M.P., YONLI, D., RABEFIRAISANA, H.J., ALI, A., OUÉDRAOGO,N., TRAORÉ, H., YANOGO, H.Y.A., DAO, K., SAWADOGO, M., JANKULOSKI, L., INGELBRECHT, I., GHANIM, A.M.A. Induced Resistance to *Striga hermonthica* in Sorghum by Gamma Irradiation. American Journal of Plant Sciences, 2020, 11, 1545–1561. https://doi.org/10.4236/ajps.2020.1110112

JANKOWICZ-CIESLAK, J., GOESSNITZER, F., INGELBRECHT, I., TILL, B.J. Physical mutagenesis and population development in Musa spp. In: Efficient Screening Techniques to Identify Mutants with TR4 Resistance in Banana. *(submitted)*

GENNETT, A., GOESSNITZER, F., JANKOWICZ-CIESLAK, J., INGELBRECHT, I., GHANIM, A.M.A. Reliable non-destructive phenotyping assay for evaluating Fusarium wilt tropical race 4 resistance screening of Cavendish banana. In: Efficient Screening Techniques to Identify Mutants with TR4 Resistance in Banana. *(submitted)*

JANKOWICZ-CIESLAK, J., INGELBRECHT, I., TILL, B.J. Mutation detection using Low Coverage Copy Number Variation. In: Efficient Screening Techniques to Identify Mutants with TR4 Resistance in Banana. *(submitted)*

CÉSPEDES, R., ARRIETA, N., BARQUERO, M., ABDELNOUR, A., NIELEN, S. and INGELBRECHT, I. (2020) Determination of Radiosensitivity of *Coffea arabica* var. Venecia Seeds to Gamma-ray Irradiation. Chapter 7, Section 3. Mutation Induction Techniques for Enhancing Genetic Variation. Proceedings of the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology. *(in press)*

HAWLICZEK, A., BOLIBOK, L., TOFIL, K., BORZĘCKA, E., JANKOWICZ-CIEŚLAK, J., GAWROŃSKI, P., KRAL, A., TILL, B.J. and BOLIBOK-BRĄGOSZEWSKA, H. Deep Sampling and Pooled Amplicon Sequencing Reveals Hidden Genic Variation in Heterogeneous Rye Accessions. *BMC Genomics* 21: Article number 845 (2020). https://bmcgenomics.biomedcentral.com/articles/10.1186/s12864-020-07240-3

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MBA, C., ABANG, M., DIULGHEROFF, S., HRUSHKA, A., HUGO, W., INGELBRECHT, I., JANKULOSKI, L., LESKIEN, D., LOPEZ, V., MUMINJANOV, H., MULILA MITTI, J., NERSISYAN, A., NOORANI, A., PIAO, Y. and SAGNIA, S. (2020). FAO Supports Countries in the Implementation of the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture. Acta Hortic. 1267, 197–208.
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RABEFIRAISANA, H.J., GHANIM, A.M.A., ANDRIANJAKA, A., RASOAMAMPIONONA, B., JANKULOSKI, L., RAZAFINDRASOA, M.A., RAVELONJANAHARY, N.H., RAKOTOARISOA, N.V. Impact of Mulch-Based Cropping Systems Using Green Mulch and Residues on the Performance of Advanced Mutants Lines of Maize (*Zea mays* (L.)) Under Infested Field with the Parasitic Weed *Striga asiatica* (L.) Kuntze in Madagascar. Chapter 18. Section 2. Mutation Breeding in Crop Improvement and Climate-Change Adaptation. Proceedings of the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology. *(in press)*

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WILSON, P.B., STREICH, J.C., MURRAY, K.D., EICHTEN, S.R., CHENG, R., AITKEN, N.C., SPOKAS, K., WARTHMANN, N., GORDON, S.P., VOGEL, J.P., and BOREVITZ, J.O. (2019). Global Diversity of the Brachypodium Species Complex as a Resource for Genome-Wide Association Studies Demonstrated for Agronomic Traits in Response to Climate. Genetics, 2019, 211(1), 317–331.

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TILL, B.J., DATTA, S., JANKOWICZ-CIESLAK. J. (2018) TILLING: The Next Generation. In: Advances in Biochemical Engineering/Biotechnology. Rajeev K. Varshney et al. (eds.), Springer.
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Gamma Irradiation and Low Coverage Whole Genome Sequencing. Plant Biotechnology Journal.
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DOI: 10.18466/cbayarfbe.430620

Conference Abstracts and Posters

2020

SARSU, F., SIVASANKAR, S., BIMPONG, I.K., JANKULOSKI, L. 2020. Induced Mutations for Food Security. Presented at the 2nd Latin American Symposium on Nuclear Applications in Agriculture, 5–6 March 2020, Ecuador.

WARTHMANN, N., GHANIM, A.M.A, ALI, A., and INGELBRECHT, I. (2020). Mutation Breeding Creates Desired Traits for African Sorghum –Semi-Dwarf and Early Maturing. PE0810. Plant and Animal Genome XXVIII, 11-15 January 2020, San Diego, USA.

WARTHMANN, N., GHANIM, A.M.A., ALI, A. and INGELBRECHT, I. (2020). Mutation Breeding Creates Desired Traits for African Sorghum – Semi-Dwarf and Early Maturing. International Symposium of the Society for Plant Breeding (GPZ), Digital Breeding, 11–13 February 2020, Tulln – Austria.

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RABEFIRAISANA, H.J., GHANIM, A.M.A., ANDRIANJAKA, A., ALI, A., RASOAMAMPIONONA, B., JANKULOSKI, L., INGELBRECHT, I., RAKOTOARISOA, N.V. (2019). Assessing the Reaction of Advanced *Striga asiatica*-resistant Mutants (M_5) of Rice (*Oryza sativa*) to Infestation of *Striga hermonthica*. WCPP June 2019, Amsterdam, the Netherlands.

News Highlights

- New CRP: Development of Integrated Techniques for Induced Genetic Diversity and Improvement of Vegetatively Propagated and Horticultural Tree Crops (D24014) **(16 December 2020)**
  Development of Integrated Techniques for Induced Genetic Diversity and Improvement of Vegetatively Propagated and Horticultural Tree Crops (D24014)

- New IAEA Publications Highlight Technical Cooperation Achievements in Asia and the Pacific **(2 December 2020)**
  https://www.iaea.org/newscenter/news/new-iaea-publications-highlight-technical-cooperation-achievements-in-asia-and-the-pacific

- World Food Day 2020: IAEA & FAO's Joint Work Benefits Farmers and Increases Food Security Worldwide **(16 October 2020)**
  https://www.iaea.org/newscenter/news/world-food-day-2020-iaea-faos-joint-work-benefits-farmers-and-increases-food-security-worldwide

- Homegrown Soybeans are Making a Comeback in Indonesia Thanks to New Varieties Developed Using Irradiation **(5 October 2020)**
  https://www.iaea.org/newscenter/news/homegrown-soybeans-are-making-a-comeback-in-indonesia-thanks-to-new-varieties-developed-using-irradiation

- Asian Cooperative Agreement Convenes 49th Annual Meeting to Discuss Regional Priorities, Challenges and Solutions **(23 September 2020)**
  https://www.iaea.org/newscenter/news/asian-cooperative-agreement-convenes-49th-annual-meeting-to-discuss-regional-priorities-challenges-and-solutions

- Double the Yield, Double the Harvest: Zanzibar Improves Rice Production Using Nuclear Techniques **(7 August 2020)**
  https://www.iaea.org/newscenter/multimedia/photoessays/double-the-yield-double-the-harvest-zanzibar-improves-rice-production-using-nuclear-techniques

- Tastier and More Nutritious Vegetables: Bulgaria Improves Food Quality with IAEA Support **(27 July 2020)**
  https://www.iaea.org/newscenter/news/tastier-and-more-nutritious-vegetables-bulgaria-improves-food-quality-with-iaea-support

- Nuclear Technology Helps to Develop Heat-Tolerant Tomato Varieties in Mauritius **(15 July 2020)**
  https://www.iaea.org/newscenter/news/nuclear-technology-helps-to-develop-heat-tolerant-tomato-varieties-in-mauritius

- World Environment Day 2020: How the IAEA Contributes to Soil, Plant and Animal Biodiversity **(4 June 2020)**
  https://www.iaea.org/newscenter/news/world-environment-day-2020-how-the-iaea-contributes-to-soil-plant-and-animal-biodiversity

- Drought Tolerant Crops: Zambia, IAEA and FAO Help Zambia Improve Production and Farmers' Income **(1 June 2020)**
  https://www.iaea.org/newscenter/news/drought-tolerant-crops-zambia-iaea-and-fao-help-zambia-improve-production-and-farmers-income

- Malaysia's Nuclear Agency and Partners Bring Improved Rice Variety to Country's Farmers **(6 April 2020)**
  https://www.iaea.org/newscenter/news/malaysias-nuclear-agency-and-partners-bring-improved-rice-variety-to-countrys-farmers

- IAEA and FAO Help Zanzibar Grow More Rice **(12 March 2020)**
  https://www.iaea.org/newscenter/news/iaea-and-fao-help-zanzibar-grow-more-rice

- Fighting Two Major Cassava Diseases in Burundi with Nuclear Technology **(18 February 2020)**
  https://www.iaea.org/newscenter/news/fighting-two-major-cassava-diseases-in-burundi-with-nuclear-technology

- Climate-Proof Crops: Capacity Building to Develop Resilient Crop Varieties in Small Island Developing States **(6 November 2019)**
  https://www.iaea.org/newscenter/news/climate-proof-crops-capacity-building-to-develop-resilient-crop-varieties-in-small-island-developing-states

- Ethiopian Plant Breeders Turn to a Nuclear Technique to Help Teff Farmers Adapt to Climate Change **(5 November 2019)**
  https://www.iaea.org/newscenter/news/ethiopian-plant-breeders-turn-to-a-nuclear-technique-to-help-teff-farmers-adapt-to-climate-change

- Targeting Hunger with Nuclear Techniques **(1 November 2019)**
  https://www.iaea.org/newscenter/multimedia/videos/targeting-hunger-with-nuclear-techniques

- From Field to Table: Nuclear Techniques Toward Zero Hunger **(16 October 2019)**
  https://www.iaea.org/newscenter/news/from-field-to-table-nuclear-techniques-toward-zero-hunger

- IAEA, FAO Help Develop Bananas Resistant to Major Fungal Disease **(30 September 2019)**
  https://www.iaea.org/newscenter/news/iaea-fao-help-develop-bananas-resistant-to-major-fungal-disease

- Nuclear Techniques Help Develop New Sorghum Lines Resistant to the Parasitic Weed *Striga* **(5 September 2019)**
  https://www.iaea.org/newscenter/news/nuclear-techniques-help-develop-new-sorghum-lines-resistant-to-the-parasitic-weed-striga

- Accelerating Growth: IAEA Launches Plant Mutation Breeding Network for Asia and the Pacific **(16 August 2019)**
  https://www.iaea.org/newscenter/news/accelerating-growth-iaea-launches-plant-mutation-breeding-network-for-asia-and-the-pacific

- From Lab to Field: Indonesian Scientists Develop New Crops for Farmers Using Nuclear Science **(24 April 2019)**
  https://www.iaea.org/newscenter/news/from-lab-to-field-indonesian-scientists-develop-new-crops-for-farmers-using-nuclear-science?fbclid=IwAR0AiQtFLTCQ5tKuIgf9UfdnBIAX-ExoXksMQyFmTnD4XFIwxhKrTTxLbt8

- How Nuclear Techniques Help Feed China **(4 April 2019)**
  https://www.iaea.org/newscenter/news/how-nuclear-techniques-help-feed-china

- Drought-tolerant Crops to Contribute to Food Security in Namibia **(13 March 2019)**
  https://www.iaea.org/newscenter/news/drought-tolerant-crops-to-contribute-to-food-security-in-namibia

- New CRP: Enhanced Biotic-stress Tolerance of Pulses Towards Sustainable Intensification of Cropping Systems for Climate-change Adaptation (D22006) **(27 February 2019)**
  https://www.iaea.org/newscenter/news/new-crp-enhanced-biotic-stress-tolerance-of-pulses-towards-sustainable-intensification-of-cropping-systems-for-climate-change-adaptation-d22006

- Sierra Leone to Tackle Hidden Hunger with Better Crops Through Nuclear Technology **(26 February 2019)**
  https://www.iaea.org/newscenter/news/sierra-leone-to-tackle-hidden-hunger-with-better-crops-through-nuclear-technology

- Barley in the Desert: Kuwait Progresses in the Development of a New Variety Using Nuclear Techniques **(18 February 2019)**
  https://www.iaea.org/newscenter/multimedia/photoessays/barley-in-the-desert-kuwait-progresses-in-the-development-of-a-new-variety-using-nuclear-techniques

- Nuclear Technology Helps Develop New Barley Variety in Kuwait **(18 February 2019)**
  https://www.iaea.org/newscenter/news/nuclear-technology-helps-develop-new-barley-variety-in-kuwait

- Bangladesh's Crop Scientists Find an Ally to Better Cope with Climate Change **(14 February 2019)**
  https://www.iaea.org/newscenter/news/bangladeshs-crop-scientists-find-an-ally-to-better-cope-with-climate-change

- Using Nuclear Science in Marker-Assisted Plant Breeding **(22 January 2019)**
  https://www.iaea.org/newscenter/multimedia/videos/using-nuclear-science-in-marker-assisted-plant-breeding

Websites and Links

- Plant Breeding and Genetics Section:
  http://www-naweb.iaea.org/nafa/pbg/index.html
- InfoGraphic on Mutation Breeding:
  http://www-naweb.iaea.org/nafa/resources-nafa/Plant-Mutation-breeding.mp4
- Mutant Variety Database:
  http://mvd.iaea.org
- Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture:
  http://www-naweb.iaea.org/nafa/index.html
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  http://www.fao.org/about/en/
- FAO Agriculture and Consumer Protection Department:
  http://www.fao.org/ag/portal/index_en/en/

Impressum

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