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To Our Readers

The First Workshop on Plant Mutation Breeding Network for Asia Pacific, Jingzhou, Hubei, China, 22–25 July 2019.

Plant Breeding and Genetics (PBG) ended 2019 strongly with good progress in capacity building, partnerships and the development of innovative technologies.

An important event and highlight of the second half of the year was the **First Workshop of the Mutation Breeding Network (MBN)** held in Jingzhou, Hubei, China, during 22–25 July 2019. The workshop was jointly hosted by the Yangtze University, Jingzhou, and the Institute of Crop Sciences, Chinese Academy of Agricultural Sciences. It was attended by representatives from 17 countries, including the 13 signatories of the MBN (Bangladesh, China, India, Indonesia, Lao P.D.R., Malaysia, Mongolia, Myanmar, Pakistan, the Philippines, Sri Lanka, Thailand and Viet Nam), and one representative each from East Africa, West Africa, Latin America, and Australia. More than 100 scientists attended the first two days of expert presentations. The signatories of the MBN agreed on the **Jingzhou Proposal of 25 July 2019**, which identified important roles of the network in: (1) strengthening national and regional capacities, (2) enhancing germplasm resources, (3) enabling the use of speed-breeding technologies, (4) establishing functional genomics platforms, (5) establishing stress-screening locations, (6) early detection of transboundary pests and diseases, (7) conservation of mutant germplasm, and (8) joint resource mobilization, along with other minor topics of mutual interest. The MBN currently functions as a pilot involving just the Asia Pacific region, where the most success in mutation breeding has been reported to date. Wider extension is planned once the pilot is functionally established in the next two years.

The Workshop was preceded by a Consultation Meeting supported by Indonesia. Representatives from China, Indonesia and India participated to develop a concept note for discussions and deliberations at the Workshop.

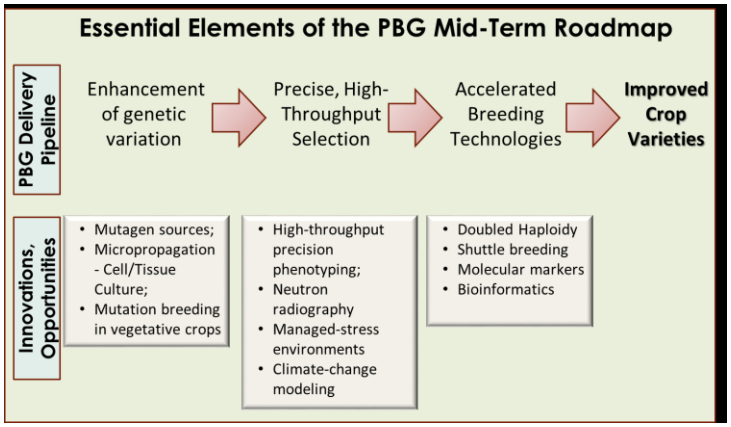
An important event in capacity building was the **Regional Training Course for Small Island Developing States** on Mutation Breeding and Efficiency-Enhancing Techniques for Crop Improvement organized during 14–24 October 2019 as part of the ongoing Technical Cooperation Project (TCP). It was attended by 12 scientists from Fiji, Marshall Islands, Palau, Papua New Guinea and Vanuatu, and a further 12 from other parts of the world including Africa and Latin America. The training course spanned the entire mutation breeding pipeline from induction and physiological selection to molecular techniques and computational biology and involved both lectures and hands-on practical experience. The agreement for the **new Collaboration Center, Gamma Greenhouse Facility of the Malaysian Nuclear Agency (MNA),** was formalized in September 2019 with a work plan centered on the use of chronic gamma radiation for mutation breeding for the region, and on molecular research to understand the chromosomal effects of acute and chronic radiation in plants.

Mr Qu Liang (Director, Joint FAO/IAEA Division) visiting gamma greenhouse at Malaysian Nuclear Agency, MNA, Selangor, Malaysia.

The Director of the Joint FAO/IAEA Division visited the gamma greenhouse at MNA in September 2019 and held discussions with the leadership and the staff. During the same week, the Director also visited the Bangladesh Institute of Nuclear Agriculture (BINA) and the Cotton Development Board of Bangladesh and held high-level discussion with their leadership and scientists. Bangladesh is one of the countries with significant success in mutation breeding. It has released several mutant varieties across crops including rice, groundnut, chickpea, lentil, rapeseed and others. These mutant varieties are currently in cultivation. Given BINA's success in the development of popular mutant crop varieties and its expertise in agricultural economics, a single-contract coordinated research project (CRP) was commissioned in November 2019 with BINA on **Impact Assessment of Mutant Rice Varieties Developed by BINA**.

Mr Qu Liang visiting Bangladesh Institute of Nuclear Agriculyure, BINA, Mymensingh, Bangladesh.

PBG also made good progress in research innovations in mutation breeding and associated biotechnologies. These technological advances are aligned with the PBG mid-term roadmap finalized at the PBG team meeting of 9 November 2018, during which innovations for accelerated genetic gain through mutation breeding were discussed and important mid-term research priorities were agreed:



Preliminary work was initiated on **ion-beam irradiation for mutation breeding** through three research contracts in a CRP involving China, Republic of Korea, Japan and Lao P.D.R. The work is expected to be completed by the end of 2019. In the area of **single-cell regeneration,** research at the PBG Laboratory (PBGL) succeeded in regenerating plants from single cells through somatic embryogenesis in **coffee**, variety Venecia, a technique that has significant value in mutation breeding for coffee improvement for a variety of traits, including resistance to the coffee leaf rust. The PBGL has also succeeded in establishing protocols for haploidy induction in rice through *in vitro* anther culture and has **developed doubled-haploid rice**.

As part of the CRP on *Efficient Screening Techniques to Identify Mutants with Disease Resistance for Coffee and Banana*, a combination of tissue culture and efficient disease

screening procedures has led to a **breakthrough in the identification of banana mutants with resistance to the Fusarium wilt (TR4)** by Chinese researchers at the Guangdong Academy of Agricultural Sciences, which holds a research contract with the CRP. At the PBGL, using recently developed lab- and greenhouse-based precision phenotyping protocols, scientists have now confirmed **rice mutant lines with resistance to the parasitic weed, *Striga hermonthica***.

Finally, PBG provided technical guidance for the development and/or release of **eight new crop varieties during the year**. These include one rice variety, Jiang79S, in China; one soybean variety in Cuba; two rice varieties, Rojolele Srinuk and Rojolele Srinar, in Indonesia; three tomato varieties, Summer King, Summer Star and Rising Star, in Mauritius; and one rice variety, Hom Rangsi, in Thailand.

I thank you for all your support, input and efforts, and look forward to continuing strong collaborations in the coming year and beyond to enhance wide scientific and practical utilization of mutations to generate novel genetic diversity for crop improvement and functional genomics studies. I wish you a wonderful 2020!

Sobhana Sivasankar
Head
Plant Breeding and Genetics Section

Participants of the Consultation Meeting held on 25–28 June 2019 in Vienna, Austria, for developing the concept note for the first Workshop of the Mutation Breeding Network.

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[1] Joined in October 2019
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[3] Separated in September 2019
[4] Joined in October 2019
[5] Separated in October 2019

Staff News

Interns

Welcome

Anza Ghaffar: A citizen of Pakistan, Mr Ghaffar joined the PBGL from Finland in October 2019 as a data science intern. He is involved in further improving a generic bioinformatics workflow that extracts relevant information from raw DNA sequences to support PBGL's trait discovery pipeline. Mr Ghaffar holds a master's degree in Wireless Industrial Automation from the University of Vaasa, Finland with majors in Machine Learning and a bachelor's in Electrical Engineering focusing on Telecommunication from the National University of Computer and Emerging Sciences, Pakistan. During his master's he represented his university in competitions in Innovation and Data Science. Anza previously worked as a Data Analyst/ Data Scientist for companies in Pakistan, Norway, Finland, and Hong Kong, in telecommunications service, the financial sector, and with energy system providers. During his previous jobs he developed multiple Minimum Viable Products and software prototypes. This is his first exposure to genomics, and biological data in general, and finds it very exciting.

Welcome and Farewell

Marcos Condo: From July until October 2019 PBGL was pleased to host Mr Conde from Spain as Data Science intern. Though he joined the PBGL without any prior experience in genetics or genomics, he quickly got up to speed with DNA sequence analysis. With his solid knowledge of the linux operating system, github, and particularly his programming skills in python, he greatly contributed to one of our data analysis workflows. It is written in the workflow language snakemake. Within two months, Marcos developed the workflow from an existing prototype to a usable tool. Marcos' main interest is computer vision. He will most likely return to this field but will certainly apply it to a biological problem. Good luck for the future, Marcos, it was great to have you!

Data Science at PBGL, from left to right; Marcos Conde, Norman Warthmann, Anza Ghaffar.

Farewell

Islam Tazirul: On 30 September 2019, we bid farewell to Islam who had joined the PBGL as Field & Greenhouse Worker on 3 September 2018. Throughout his stay, Islam provided excellent support to the PBGL field and greenhouse activities. He also supported the activities in glassware cleaning and sterilization, and related support services to the molecular activities. He will be sadly missed. Our very best wishes for the future, Islam!

Forthcoming Events

Consultants Meeting on Integrated Breeding of Major Mutant Traits for Food Security and Climate-Smart Agriculture, Vienna, Austria, 16–20 March 2020

Project Officer: K. Bimpong

Vegetatively propagated crops play an important role in food security and income and represent significant agricultural opportunity in (sub)tropical areas of sub-Saharan Africa, Asia and Latin America. Vegetatively propagated crops are constrained compared to seed crops due to their reduced genetic diversity, as they cannot be easily self or cross pollinated to produce seed or to enhance variation. This makes it difficult to apply conventional breeding methods. This has resulted in most vegetatively propagated crops having an extremely limited genetic pool. Further, disease-free planting materials may not always be available to farmers, hence diseases can accumulate over time when grown over multiple generations.

There is the need to develop new efficient and low-cost methods capable of overcoming the limitations associated with mutation induction in vegetatively propagated crops. Through the Consultants Meeting for the CRP planning, it is expected to develop a concept note that will be used to call for proposals to address the major bottlenecks of vegetatively propagated crops and perennials through the development of:

- Efficient and low-cost single-cell regeneration systems for mutant and clonal propagation;
- An efficient approach to monitor retention of mutation over generations; and
- Incorporation of genomic screening techniques for at least one trait in the developed system.

Participants will include six external experts covering the fields of micropropagation, genetics/genomics and mutation breeding of vegetatively propagated crops, including one FAO observer. PBG Technical Officers will also be present.

Second Research Coordination Meeting (RCM) on Disease Resistance in Rice and Wheat for better Adaptation to Climate change, D23032, Dhaka, Bangladesh, 2–6 March 2020

Project Officer: L. Jankusloski

Cereals are the main staple crops of food security for the population of the world, supplying around 42,5% of the global food calorie supply. Almost 50% of cereals consumed are rice and wheat and the predictions for 2017/18 being 703 and 503 million tonnes, respectively, to be consumed (FAO, 2017 http://www.fao.org/3/ai8278e.pdf). Rice is grown all over the world and is the main staple food of about 50% of the world population (IRRI, 2015; AfricaRice, 2015). The world today still has a high concentration of poverty and most of these concentrations are where rice is grown. Wheat is the staple food for hundreds of millions of poor people in developing countries while its production is mostly confined to temperate climate. Wheat provides around one-fifth of all calories and protein for people globally and in developing countries, wheat feeds around 1.2 billion people.

Diseases are among the major obstacles hindering yield improvements both in rice and wheat. Changing climatic conditions increase the spread of diseases to new destinations and exacerbate their impact. In addition to the already widely spread diseases of rice such as blast, sheath blight, false and bacterial leaf blight, threats of emerging diseases are becoming more serious such as in the case of false smut of rice and blast of wheat.

Mutations are a primary source of genetic variation in any organism, including plants. The use of mutation induction in generating new germplasm and developing new disease resistant varieties in rice and wheat is an efficient and valuable approach in crop improvement and has been very successful in rice and wheat breeding. More than 820 rice varieties and 255 wheat varieties have been developed by mutation breeding using mostly physical mutagens (https://mvd.iaea.org/#!Home).

The objectives of this Coordinated Research Project (CRP) are to improve disease resistance in rice and wheat through induced mutation/mutation breeding, to develop protocols for screening rice resistant mutants to diseases, to develop molecular markers for disease resistance using available mutant germplasm.

Twelve participants from Bangladesh, Brazil, China, India, Indonesia, Malaysia, Pakistan, United republic of Tanzania, USA and FAO will be attending this RCM.

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).

The major activities in the wheat group will be to develop and screen large number of (M_2) population in order to identify resistant mutants. The hot spot area in Bangladesh will be used for screening mutant populations.

The rice groups will focus on development of mapping population in order to map and develop molecular marker/s for rice blast and BLB.

The second RCM will be held in collaboration with the Bangabandhu Sheikh Mujibur Rahman Agricultural University in Dhaka, Bangladesh from 2–6 March 2020. All participant will present progress and achievements since initiation of the project and future work plans and activities will be fine-tuned for the following years.

Final Project Coordination Meeting on Improving Yield and Commercial Potential of Crops of Economic Importance, RLA5068, Quito, Ecuador, 2–6 March 2020

Project Officer: F. Sarsu

Many countries in Latin America and the Caribbean have a deficit in food production, leading to serious problems of poverty and malnutrition, especially in rural areas. This situation is further worsened by the effects of climate change and population growth. The productivity of small farmers is also affected by adverse weather conditions (drought, floods, extreme temperatures), soil impoverishment caused by inappropriate agricultural practices (salinization, acidification, loss of nutrients), inadequate technology and use of underperforming cultivars often susceptible to pests and diseases. The project focusses on the use of mutation induction, mutation detection and pre-breeding technologies to develop new crop varieties with improved characteristics.

The purpose of this coordination meeting is to review and discuss the details of the activities stated in the work plan to be implemented under the project RLA5068; to report on the progress made at national level by participating countries since the last RLA5068 meeting; to review the work plan of the project and agree on national plans for the activities to be implemented at the national level; and to identify and discuss measures to ensure sustainable continuation of work after completion of the project including exchange of material and information.

The meeting is open to participating Member States through their designated national project coordinators.

First Project Coordination Meeting on Enhancing Productivity and Resilience to Climate Change of Major Food Crops in Europe and Central Asia, RER5024, Ankara, Turkey-23–27 March 2020

Project Officer; F. Sarsu

A serious issue facing global efforts to ensure food security for the global population is the climate change that affects agricultural production in Europe and Central Asia. Overcoming the negative impact of drought on plant productivity and developing tolerant genotypes became a strategic goal in agriculture in the region. Drought, a combination of heat and water stress, results from climatic change that increases the percentage of arid, abandoned regions, which were formerly crop lands. This stress environmental stress seriously limits plant growth and crop yield. Increasing genetic diversity can play an important role in addressing the problems arising from unfavorable environmental conditions. Crop adaptation to environmental stress is particularly important for food security worldwide. An increased production of main crops (legumes, cereals and other important food crops) in Europe and Central Asia is being addressed under the TC regional project with the 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. Increasing drought and salt tolerance is the target, together with productivity and other traits available. 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 to contribute to food security in Europe and Central Asia. The expected outcome is the enhanced productivity and resilience to climate change of major food crops in the region.

The purposes of this first coordination meeting are to review workplan of the new TC project RER5024 on Enhancing Productivity and Resilience to Climate Change of Major Food Crops in Europe and Central and agree on regional activities to be implemented during 2020–2024; to establish national workplan of the participated countries to be implemented during 2020–2024; and to discuss and agree on work plans and strengthen the role of participating countries to achieve the project objectives.

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

Third Research Coordination Meeting (RCM) on Improving Resilience to Drought in Rice and Sorghum through Mutation Breeding, D23031, Jakarta, Indonesia, 22–26 June 2020

Project Officer: F. Sarsu

Drought is the most devastating abiotic stress factor worldwide affecting crop production and projected to worsen with anticipated climate change. It severely limits plant growth and development as well as agricultural characteristics resulting in reduction of crop yields. Improving drought tolerance in crops, to increase the efficiency of water use and to enhance agricultural water productivity under rain-fed conditions is among top priority for most countries. Among various agro-ecologies, Africa and South Asia are considered to be the most vulnerable to climate change and both have large numbers of poor populations constrained with meagre access to basic resources of water and productive land.

This CRP is focused on improving rice and sorghum to drought tolerance for current and future climate change scenarios. These two crops are essential staples in the diets of millions of impoverish and vulnerable populations, and therefore any attempt to increase their yields under drought stress could have a major and positive impact in terms of food security and income generation. It is expected that twelve participants including research agreements (2), technical contracts (2) and research contracts (8) will attend the meeting. The third RCM will be organized in collaboration with the Indonesia Government through Center for Isotopes and Radiation Application, BATAN National Nuclear Energy Agency.

The meeting objectives are to present progress made after the second meeting and to review and consolidate the work plan for the next cycle. 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, to enhance mutation breeding, to develop robust protocols for rapid advancement of generations, and to screen packages of mutant populations for drought tolerance efficiently. During the RCM individual project progress will be reviewed and data including mutant lines with improved drought tolerance will be evaluated.

Past Events

Second Research Coordination Meeting on Improving Crops Resilience to Drought in Rice and Sorghum through Mutation Breeding, D23031, Beijing, China, 10–14 June 2019

Project Officer: F. Sarsu

Drought is the most devastating abiotic stress factor affecting crop production worldwide and is projected to worsen with anticipated climate change. It severely limits plant growth and development as well as agricultural characteristics, resulting in a reduction of crop yields. Improving drought tolerance in crops to increase the efficiency of water use and to enhance agricultural water productivity under rain-fed conditions is among top priority for most countries. Among various agro-ecologies, Africa and South Asia are considered to be the most vulnerable to climate change and both have large numbers of poor populations constrained with meagre access to basic resources of water and productive land. To meet the increasing demands from countries for drought stress tolerant crops and to help address the effects of climate change on agricultural production, the Plant Breeding and Genetic Section of the Joint FAO/IAEA Division launched the CRP D23031 in 2017 with its first RCM held in the same year.

The second RCM was organized in collaboration with the Chinese Government through the Institute of Crop Sciences, Chinese Academy of Agricultural Sciences in Beijing, China. This CRP is focused on improving rice and sorghum to drought tolerance for current and future climate change scenarios. These two crops are essential staples in the diets of millions of impoverish and vulnerable populations, and therefore any attempt in increasing their yields under drought stress could have a major and positive impact in terms of food security and income generation.

Meeting participants.

The meeting was attended by 17 participants including research contracts (8), technical contracts (2), research agreements (4) and three observers (from FAO, Malaysia and India). In the first two days of the meeting, participants presented the progress on their planned activities during 2017–2019 and their work plans for 2019–2020. These were followed by discussions to assess progress made and challenges faced, and review of work plans. The participants reported on the development of phenotyping protocols to screen tolerance to drought in rice and sorghum in the field, green house and laboratory conditions to enhance mutation breeding and to develop robust protocols for rapid advancement of generations, and efficient screening packages of mutant populations for drought tolerance. During the meeting, the progress of individual projects and data including mutant lines with improved drought tolerance were reviewed and evaluated.

It was suggested to organize the third RCM in Jakarta, Indonesia at the National Nuclear Energy Agency (BATAN) facility. (For more details see page 18)

Regional Training Course on Methodologies and Mechanisms for Screening of Photosynthetic Efficiency in Crops, RAS5077, Philippine Nuclear Research Institute (PNRI), Quezon City, the Philippines, 17–21 June 2019

Project Officer: K. Bimpong
Course Director: A.M. Veluz

The training course was organized in collaboration with the Philippines Government through the Philippine Nuclear Research Institute (PNRI). The objectives of the course were to provide technical and practical knowledge on modern molecular technologies for mutation discovery and approaches for selection of desired green traits in crops for technicians directly involved in mutation breeding. Besides 11 local participants and 23 technicians from 14 member countries comprising of Bangladesh, Cambodia, China, India, Indonesia, Republic of Korea, Lao P.D.R., Malaysia, Mongolia, Myanmar, Pakistan, Sri Lanka, Thailand and Viet Nam attended the training course. Dr Fernando Aurigue, a scientist from the host country and Dr Mark Nas (an expert from Syngenta Asia Pacific) were the resource persons who gave lectures and practical sessions on:

- Importance of physiological traits and crop improvement;
- Theoretical concept of determination of physiological traits;
- Introduction to photosynthesis, C3 and C4 plants and importance of conversion of C3 to C4 plants;
- Phenotyping techniques for photosynthesis and component traits;
- Applications of modelling in physiological breeding;
- Biochemical measurement of photosynthesis and component traits (proteomics, metabolomics, transcriptomics);
- Molecular plant breeding for physiological traits (introduction to QTL mapping, marker assisted selection and genomic selection); and
- Experimental design for evaluation of physiological traits.

Training course participants.

The participant visited the Philippines Rice Research Institute (PhilRice) where drone technology for spreader, sprayer and imaging were demonstrated. The group also visited Central Luzon State University and visited their hydroponic facility for crop production.

Regional Training Course on Regional Training Course on Gene Expression Analysis Using RNA-Seq Technology for Genetic Improvement of Mutant Crops, RLA5068, Bogota, Colombia, 17-21 June 2019

Project Officer: F. Sarsu
Course Director: L.A. Quevedo Cárdenas

This training course was organized in collaboration with the Government of Colombia through Universidad Distrital Francisco José de Caldas. It was open to candidates and project partners in the project RLA5068 on Improving Yield and Commercial Potential of Crops of Economic Importance (ARCAL CL). Twenty participants from Argentina, Bolivia, Brazil, Chile, Colombia (3), Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Jamaica, Nicaragua (2), Mexico, Panama, Paraguay, and Peru attended the training course.

Training course participants.

The purpose of this course was to provide participants with theoretical as well as practical knowledge on the application of RNA-sequence technique, tools management, laboratory workflows and related bioinformatics (NGS). The course covered the following topics.

- Sample preparation for quantitative analysis NG;
- MiSeq Ilumina Platform – NGS;
- Primary sequential analysis;
- Bioinformatic analysis for RNA-Seq;
- Application of the techniques in plant mutation breeding programmes.

Practical session.

Molecular characterization of induced mutants is essential to identify the genetic locus involved, which can then be used in future. The course was well appreciated by the participants. Many questions were raised during the lectures and participants demonstrated satisfaction with the knowledge imparted. It was agreed to create a network for future collaborative research between participants. Participants added that such courses have a high impact on scientific growth of Latin American Countries and can further push technological and economic growth.

Regional Training Course on Farmer Participatory Variety Selection Approach in Plant Mutation Breeding, RLA5068, San Jose, Costa Rica, 15–19 July 2019

Project Officer: F. Sarsu
Course Director: R.S. Orozco Rodriquez

This training course was organized in collaboration with the Government of Costa Rica through Universidad Nacional de Costa Rica. It was open to candidates and project partners involved in the project RLA5068 on Improving Yield and Commercial Potential of Crops of Economic Importance (ARCAL CL). Fourteen participants from Argentina (2), Bolivia, Brazil, Chile (2), Colombia, Costa Rica (3), Dominican Republic (2), Ecuador (2), El Salvador, Guatemala, Mexico (2), Panama (2), Paraguay (2) and Peru attended the training course.

The purpose of this course was to provide participants with theoretical and practical knowledge on the application of farmer participatory approach on selection of mutant lines on important crops for the ARCAL CL region. The participants were given lectures and practical exercises in the field with farmer's participation. The training course provided lectures on the following areas:

- Handling mutant plant populations;
- Evaluation and selection of mutant varieties together with farmers in farmers' fields;
- Participatory plant breeding and participatory variety selection with farmers;
- Increasing the dissemination and adoption of released mutant varieties;
- Intellectual property rights;
- Efficient release of varieties;
- Dissemination of mutant lines/varieties using SMTA in the ARCAL region.

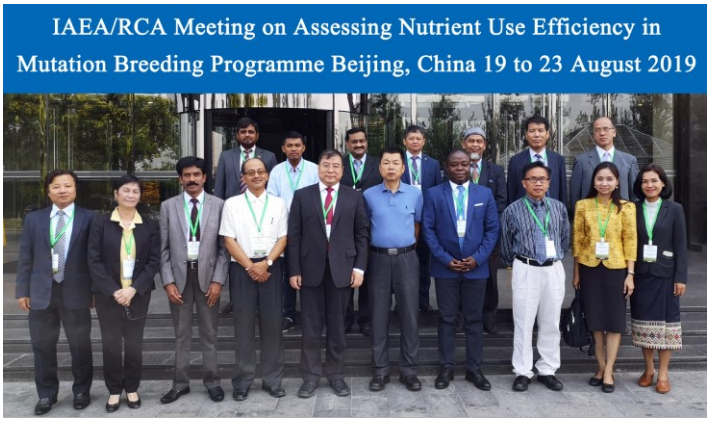
Training course participants.

The participants gained knowledge on the application of Farmer Participatory Variety Selection Approach. They emphasized that this training course will help them to properly link between breeders and farmers for variety selection to contribute towards food security in the region.

Practising participatory selection with farmers.

Regional Technical Meeting on Assessing Nutrient Use Efficiency in Mutation Breeding Programme (RCA), RAS5077, Beijing, China, 19–23 August 2019

Project Officer: K. Bimpong
Lead Country Coordinator (LCC): L. Liu



Meeting participants.

In collaboration with the Government of China through the Institute of Crop Sciences of Chinese Academy of Agricultural Sciences (CAAS), the technical meeting of this IAEA/RCA regional TC project was held at the Beijing Yulong International Hotel.

The meeting was attended by 17 National Project Coordinators (NPCs) from 17 Asia and Pacific countries (Australia, Bangladesh, Cambodia, China, India, Japan, Republic of Korea, Lao P.D.R., Malaysia, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Sri Lanka, Thailand and Viet Nam).

The objectives of the meeting were to review progress made regarding the implementation of the individual country work plans, regional project outcomes and outputs after the mid-term review meeting in December 2018 in Nepal; to review and discuss the main results of nutrient use efficiency improvement in national breeding programmes; and to discuss and finalize work plan for end of the project in 2020 in terms of key achievements (number of mutant varieties released, mutant lines and protocols with improvement of target green traits.

National project activities and achievements made in 2018 and 2019 were presented by each NPC.

The participants proposed a set-up of a journal for publications (MUTANT RESOURCES) to promote research on mutation breeding, which IAEA should assume the leadership role so that participants can publish/present preliminary results/findings of their research and share information amongst participants. It was suggested that the Plant Breeding and Genetics Section's website of the Joint FAO/IAEA Division should regularly provide information on Asia and Oceania Association of Plant Mutagenesis (AOAPM) including sharing the link to its website www.plantmutagenesis.net.

A protocol for Development of Mutant Germplasm and Varieties with Enhanced Nutrient Use Efficiency was prepared and shared with participants. The proposed four protocols during 2018 technical meeting in Pakistan were discussed and are expected to be completed in 2020.

A technical visit was paid to the China National Atomic Energy Institute in Beijing where participants were introduced to how ion beam is used as a mutation inducer in crop plants. Participants also visited the Institute of Crop Sciences at CAAS and their field research stations where Dr Luxiang Liu and his team briefed them on the ongoing activities.

Technical visit to the Institute of Crop Sciences at CAAS Field Research Stations.

The final review meeting of the project was agreed to be held in Malaysia or Lao P.D.R. in November 2020.

First Research Coordination Meeting (RCM) on Enhanced Biotic-stress Tolerance of Pulses Towards Sustainable Intensification of Cropping Systems for Climate-change Adaptation, D25006, Vienna, Austria, 23–27 September 2019

Project Officer: S. Sivasankar

Meeting participants.

The new CRP approved early this year, on Enhanced biotic-stress tolerance of pulses towards sustainable intensification of cropping systems for climate-change adaptation, had its first Research Coordination Meeting (RCM) during 23–27 September in Vienna, Austria. The CRP addresses crop improvement in pulse crops or grain legumes, with specific focus on the development of resistance in cowpea to the pod borer, *Maruca vitrata*; resistance in chickpea to the pod borer, Helicoverpa armigera; and resistance in lentil to the leaf blight caused by *Stemphylium botryosum*. The meeting was attended by the Chief Scientific Investigators (CSIs) for eight research/technical contracts (India, Kenya, Namibia, Pakistan, Senegal, Spain, Tunisia, and Zambia), and three research agreements (Canada, India and Nigeria). One more research contract from Ethiopia was signed after the meeting, and one research agreement is awaiting signatures. The FAO observer was also present at the meeting.

The meeting discussed current status of research on the CRP topic at each participating institute, and the selected research proposals. This was followed by detailed discussions to fine-tune the research work plans, specifically the plans for the first year.

Regional AFRA Training Course on Field Experimental Design and Data Analysis in Mutation Breeding, RAF5076, Quatre-Bornes, Mauritius, 9–20 September 2019

Project Officer: F. Sarsu
Course Director: M. Gungodaurdoss

This training course was organized in cooperation with the Government of Mauritius through the Food and Agricultural Research and Extension Institute (FAREI). Twenty-five scientist from Algeria, Benin, Burkina Faso, Burundi, Central Africa Republic, Egypt, Ethiopia, Ghana, Lesotho, Libya, Madagascar, Mali, Mauritius (5), Morocco, Niger, Senegal, Sierra Leona, Sudan, Tunisia, United Republic of Tanzania and Zimbabwe attended the training course.

Training course participants.

The purpose of the training course was to provide participants with theoretical as well as practical knowledge on (1) Learning the statistical methods used for designing field and laboratory trials and robust data analysis; (2) Improving breeding efficiency through application of appropriate experimental design and analysis models; (3) Application of mutation breeding for crop improvement; and (4) Consulting with experts in using efficient statistical methods and experimental designs to Member States.

The two-week training course consisted of theoretical lectures and computer-based practical sessions on:

A. Importance of Statistical Tests and Designs in Research

- Planning of experiments and considerations in running experiments;
- Importance of experimental designs;
- Correlations and regression and their use;

- Experimental designs:
  - Randomized Plots Design
  - Randomized Block Design
  - Latin Square Design
  - Experiments with two or more factors
- Combined analysis of data over years and locations;
- Genetic similarities and cluster analysis.

B. Application of Mutation Breeding

- Application of mutation breeding for crop improvement;
- Sampling in experimental plots;
- Interpretations of statistical data for crop improvement;
- Computer applications to agricultural experiments using statistical packages;
- Analysis of Variance for plant Breeding;
- Analysis of multi locational, multi-year data;
- Stability and its importance in plant breeding.

C. Using Molecular Markers

- Using Molecular marker data to detect mutations and use of markers in breeding
- Marker assisted breeding: MASB/MASR
- Characterization of mutagenized populations using molecular tools.

Participants practicing statistical tools on their computers.

Participants showed great interest in using statistical tools in mutation breeding which is essential to establish superiority of true breeding mutants in crop plants. They also showed interest in organizing similar training courses in their home countries.

Third Research Coordination Meeting (RCM) on Mutation Breeding for Resistance to *Striga* Parasitic Weeds in Cereals for Food Security, D25005, Nairobi, Kenya, 30 September–4 October 2019

Project Officer: A.M.A. Ghanim

Meeting participants.

The RCM was organized at the Biotechnology east and central Africa (BecA) facility, Nairobi, Kenya. The meeting objectives were to present the progress made in the planned activities of the project during 2018/2019, and to review and consolidate the work plan for the next cycle 2019/2020. The meeting was attended by nine participants (six research contracts, two technical contracts and one research agreement). They presented the developed/adapted and validated field, screen-house and laboratory screening protocols for resistance to *Striga asiatica* and *hermonthica* in sorghum and upland rice, and efficiency enhancing technologies mainly doubled haploid and genomics. In addition, the Technical Officer of this CRP presented the progress on the verified mutants at PBGL, Seibersdorf, Austria and the advances of doubled haploid in rice. Generally, the screening protocols are completed, and the drafts are prepared by the respective contract holders. The meeting agreed to submit a refined draft before the end of 2019 for compilation and edition towards publication during the next cycle. Cumulative progress showed that 252 putative mutants were evaluated under stringent pot-screening at PBGL of which 61 were confirmed: rice 24, sorghum 23 and maize 15 (for more details see pages 18 and 30). Following are general conclusions and recommendations reached at the third RCM:

- It was generally agreed that presented progress was satisfactory and even excellent in certain areas toward the goals set forth in the first RCM and the initial individual work plans;

- Individual work plans for the coming 2019/20 period were presented and revised;
- Field, pot and laboratory screening draft protocols should be improved and submitted by 15 December 2019 for compilation;
- The meeting identified tasks for all participants to advance mapping activities toward gene identification and marker development for promising mutants. The meeting requested that Research Contract Holders in Burkina Faso, Madagascar and Sudan choose the top three mutant genotypes from each crop they are targeting toward this goal;
- Specific recommendations were made for those producing mutagenized germplasm improving screening in the field (at least two sites) and pots for mutant verification;
- Advanced generations of top 10 mutants (including the above three top mutants) from Burkina Faso, Madagascar and Sudan will be shared with the PBGL to be distributed to laboratories of the Technical and Agreement holders for characterization and fine phenotyping to determine possible mechanisms of *Striga* resistance;
- The participants are encouraged by the verified mutants with confirmed resistance to *Striga hermonthica* in sorghum and rice and *Striga asiatica* in rice and maize. It was agreed that the 'best' materials should be released for further investigation in the collaborating laboratories of Japan, the Netherlands and the United States to begin the work of defining the stage of the parasitic relationship at which the gained resistance is expressed. From that, the possible mechanism by which the resistance in those mutants is achieved may be surmised. As the mapping populations from these mutants become available, the underlying genetic control of these resistance mechanisms can be determined, even to the extent of identifying the causal mutations and key genes determining resistance to *Striga*;
- There is some lag in generating the necessary backcrossed progeny of particular mutants with their wild parent lines that will be vital to identifying candidate causal mutations. Still the research contract holders in Burkina Faso, (rice and sorghum) Madagascar (maize and rice) and Sudan (rice and sorghum) either have or are planning to have in the coming cycle the necessary BCF2s that will become the 'mapping populations' that will reveal the key loci controlling host cereal resistance to *Striga*.

Regional Training Course on Mutation Breeding and Efficiency Enhancing Techniques for Crop Improvement, RAS5079, Seibersdorf, Austria, 14–24 October 2019

Project Officer: F. Sarsu
Course Director: I. Ingelbrecht

Training course participants.

The purpose of the training course was to provide participants with opportunities to familiarize themselves with basic and more advanced aspects of crop mutation breeding through lectures and practical sessions on (i) mutation induction; (ii) mutant population development and phenotyping methods; and, (iii) application of more advanced *in vitro* tissue culture and Next Generation Sequencing & genotyping methods. The training course was attended by 11 participants from the Pacific Islands (Fiji, Marshall Islands, Palau, Papua New Guinea and Vanuatu), one fellow from Iran and an additional 11 Scientific Visitors from seven different countries (Brazzaville, Democratic Republic of the Congo, Indonesia, Namibia, Oman, Nicaragua, Palestine, and Sudan). In addition to the PBGL staff providing lectures and practical sessions on mutation induction, case studies on marker-assisted selection, and advanced genomics technologies, two external resource persons Prof R. Swennen, banana breeder from the International Institute of Tropical Agriculture, Tanzania/KUL, Belgium and Prof S. Nishimura, Nara Institute of Science and Technology, Japan shared their expertise in banana breeding and in the use of advanced DNA sequencing techniques for genetic mapping, respectively. The course was very well received by all the participants receiving an overall rating of 4,5/5. The Section Head of the Regional TC Project RAS5079 also praised the course for its maturity and high-quality and proposed to organize it on a regular basis with support from the TC Department.

Regional Training Course on Molecular Approaches for Selection of Desired Green Traits in Crops (RCA), RAS5077, BATAN, Jakarta, Indonesia, 4–15 November 2019

Project Officer: K. Bimpong
Course Director: S. Human

The training course was organized in cooperation with the Government of Indonesia through the National Nuclear Energy Agency (BATAN); Centre for Application of Isotopes and Radiation Technology (PATIR); Department of Agriculture. The course is within the framework of the TC Project RAS5077 on Promoting the Application of Mutation Techniques and Related Biotechnologies for the Development of Green Crop Varieties (RCA).

Training course participants.

The objective of the training course is to provide technical and practical knowledge on modern molecular technologies for mutation discovery.

The training course consisted of lectures, demonstrations, and practical exercises in both the laboratory and field activities. Twenty-two participants, from 16 Member States (Bangladesh, Cambodia, China, India, Indonesia, Republic of Korea, Lao P.D.R., Malaysia, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Sri Lanka, Thailand and Viet Nam) attended the training course. Some local scientists from BATAN and one external expert from CIMMYT, China gave lectures and practical sessions on topics such as:

- Introduction to mutation breeding;
- Radiosensitivity study and estimating optimal irradiation doses for breeding purposes;
- Populations in genetics and breeding;
- Molecular breeding platforms and open-source breeding;
- Genotyping techniques and platforms and breeding informatics and decision support tools;
- Phenotyping and envirotyping;
- Mutation breeding of sorghum for drought tolerance using morphological markers;
- Experimental design, population development and data analysis.

Participants also had the opportunity to discuss their specific breeding activities and learned about the most suitable approaches in modern molecular technologies for mutation discovery. Participants visited some nuclear facilities at BATAN Serpong, Merah Putih Irradiator at BATAN Serpong and the Kebun Bunga Nusantara horticultural germplasm collection center.

Regional AFRA Training Course on Application of Marker Assisted Mutation Breeding and Basic Bioinformatics for Improvement of African Food Crops, RAF5076, Dakar, Senegal, 18–29 November 2019

Project Officer: F. Sarsu
Course Director: D. Diouf

The training was organized in cooperation with the Government of Senegal through Université Cheikh Anta Diop de Dakar (UCAD), Faculté des Sciences et Techniques; Département de biologie végétale; Laboratoire de biotechnologies végétale. It was open to candidates and project partners in the project RAF5076 on Improving Crops Using Mutation Induction and Biotechnology through a Farmer Participation Approach.

Twenty-five young scientist from Algeria, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Democratic Republic of the Congo, Egypt, Ethiopia, Ghana, Kenya, Libya, Madagascar, Mauritius, Namibia, Sierra Leone, Sudan, Tunisia, United Republic of Tanzania and Zambia. Prof Antonio Costa de Oliveira from Universidade Federal de Pelotas, Brazil, was resource person for the training.

The purpose of the event was to provide participants with the application of molecular techniques and bioinformatics for the identification of agricultural crops with characteristics of tolerance and/or resistance to various types of biotic and abiotic stress.

The course included lectures and practical sessions on:

- Induced mutation for crop improvement;
- Molecular techniques (extraction, quantification, and visualization of RNA, electrophoresis, RT-PCR in real time);
- Marker assisted breeding: MASB/MASR;

- Characterization of mutagenised populations using molecular tools;
- Bioinformatics (design of oligonucleotides, gene expression profiles of interest, basic concepts of transcriptomics);
- Identification of agricultural crops with characteristics of tolerance and/or resistance to various types of biotic and abiotic stress;
- Practical sessions on application of given techniques.

Participants showed strong interest in networking and sharing mutant varieties amongst countries in the region for research and breeding purposes. The final meeting of RAS5073 will be held in March 2020 in Indonesia.

Training course participants.

Coordinated Research Projects

Project Number	Ongoing CRPs	Project Officers
D22005	Efficient Screening Techniques to Identify Mutants with Disease Resistance for Coffee and Banana	I. Ingelbrecht
D25005	Mutation Breeding for Resistance to *Striga* Parasitic Weeds in Cereals for Food Security	A.M.A. Ghanim
D23031	Improving Resilience to Drought in Rice and Sorghum through Mutation Breeding	F. Sarsu
D23032	Disease Resistance in Rice and Wheat for Better Adaptation to Climate Change	L. Jankuloski
D22006	Enhanced Biotic-stress Tolerance of Pulses Towards Sustainable Intensification of Cropping Systems for Climate-change Adaptation	S. Sivasankar

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

Project Officer: S. Sivasankar

Pulses are important food crops in smallholder agriculture in Africa and Asia, and in several instances, they are also grown for fodder. Because of their vital role in human and soil health, farmers grow these crops with cereals to not only meet the diversified food needs but also for maintaining soil health. Leguminous crops are known to add nitrogen to the soil through biological nitrogen fixation and can be grown without added nitrogen fertilizers thus contributing to reduced carbon footprint. Among the pulse crops, chickpea, cowpea, and lentil are popular choices for the smallholder farmers in South Asia and sub-Saharan Africa as they thrive well even under limited external inputs. These crops are the mainstay of dryland farming systems.

The productivity of pulses is generally low in most developing countries, average yields ranging from about 0.5 to a little over one tonne per ha. Yields are reduced further by the incidence of several biotic and abiotic stresses. The fact that pulses are self-pollinated has led to a narrow genetic diversity in many of these crops.

In this CRP, mutation induction and associated 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 tolerances 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. Towards this end, the CRP, with the expected participation of the National Agricultural Research System of countries where the crops are grown extensively, shall over a period of four to five years, generate mutant populations, including advanced lines, and develop, validate and publish genotyping and phenotyping protocols.

Mutation induction is an established means to generate heritable variation in crops and therefore holds great promise to diversify further the genetic base of pulses, enhancing their adaptation to the pressures induced by the effects of climate change, especially the frequent emergence of new biotypes and strains of pests and diseases. The Mutant Variety Database of the IAEA identifies 23, 18 and 13 varieties, respectively, of chickpea, lentil and cowpea, released from past efforts in mutation breeding using irradiation (gamma rays) and chemical (EMS) mutations.

CRP Overall Objective

This CRP aims to develop genetic resources through induced mutations and associated genomic tools for accelerated adaptation of pulses-based cropping systems to climate change.

Specific Research Objectives

(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 (confident) 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.

Outputs

(1) Mutant population(s) generated for chickpea, cowpea and lentil; (2) Phenotyping tools developed for the identification of resistant germplasm; (3) Improved lines identified for traits of interest; (4) Molecular markers and associated protocols developed for variety development/improvement; (5) Scientific publications produced; and (6) Protocols and training manuals developed and disseminated.

The first Research Coordination Meeting (RCM) of this CRP was held in September in Vienna, Austria.

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

Project Officer: L. Jankuloski

A range of diseases are responsible for hindering yield improvements in both rice and wheat. Changing climatic conditions are helping diseases spread to new localities and exacerbating their impact. In addition to the already widespread diseases of rice, such as blast, sheath blight, false smut and bacterial leaf blight, emerging diseases like wheat blast are increasingly becoming serious threats.

To minimize the impact of such diseases, environment-friendly and cost-effective technologies are needed to help prevent and manage them. The use of mutation breeding techniques to develop disease resistant varieties is a viable tool in the development of appropriate germplasms and varieties.

Mutations are a primary source of genetic variation in any organism, including plants. The use of mutation induction in generating new germplasm and developing new disease resistant varieties in rice and wheat is an efficient and valuable approach in crop improvement and has been very successful in rice and wheat breeding. More than 820 rice varieties and 255 wheat varieties have been developed by mutation breeding using mostly physical mutagens (https://mvd.iaea.org/#!Home).

CRP Overall Objective

This CRP aims to improve disease resistance in rice and wheat through induced mutation/mutation breeding and development of screening techniques for sustainable food security.

Specific Research Objectives

(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 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.

Outputs

(1) Improved rice and wheat mutant germplasm as novel sources of disease resistance generated; (2) Efficient laboratory, screen-house or field-based screening protocols and techniques for identification of mutants with improved resistance to diseases developed; (3) Molecular marker(s) developed; and (4) Publications from the findings of the research activities generated.

This CRP officially started in September 2018 and had its first RCM from 10 to14 December 2018 in Vienna, Austria. The second RCM is planned to take place in Bangladesh in 2020.

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

Project Officer: F. Sarsu

The CRP officially started in October 2017 and had its first RCM from 9–13 October 2017 in Vienna, Austria. The second RCM was organized in collaboration with the Chinese Government through the Institute of Crop Sciences, Chinese Academy of Agricultural Sciences in Beijing, China (10–14 June 2019). The project started with 13 participating institutes from 10 countries (Bangladesh, China (2), India (2), Indonesia, Japan, Mali, Pakistan, Sudan and Viet Nam). Within the second year, two more agreement holders from Malaysia and India joined the project.

The main objective of the CRP is to improve drought resilience of rice and sorghum through induced mutations and the development/adaptation of screening techniques for sustainable food security. Since mutation breeding involves the screening of large mutant populations, effective protocols are required to reduce the cost and labour of selecting the rare, useful variants. The goal is to simplify the identification of drought tolerant lines of rice and sorghum in breeding populations in glasshouse and controlled-environment growth chambers using a screening method at the flowering stage as this is the development stage most vulnerable to drought stress.

Project participants agreed on a roadmap for genetic improvement of drought stress tolerance in rice using mutation breeding, molecular methodologies and screening techniques. In rice and sorghum, it was agreed to apply the drought stress as pre/post reproductive-stage to measure the effect. After phenotypical screening, biochemical markers such as MG and proline estimation will be tested. Any specific markers reported for drought responsive traits should be selected based on the literature and screened across progeny lines. Based on the phenotypic biochemical

and molecular analysis, selected mutants will be subjected to Multi location replicated yield trials under rainfed conditions. Based on the per se performance, 10% of the mutants should be shortlisted. Among them, best three mutant lines should be forwarded to National varietal testing trial and the remaining mutant lines should be deposited in the National Germplasm collection center. In addition, selected mutants can be used in the recombination breeding program developing varieties/ mapping population. Phenotypic and molecular results have to be compared and analyzed in order to identify true breeding stay green mutants. Such significant markers, which are tightly linked to the STAYGREEN QTL's will be validated in other populations

Improving grain yield under drought through selection on secondary traits such as root architecture, leaf water potential, panicle water potential, osmotic adjustment, and relative water content did not yield the expected results to improve grain yield under drought. Breeders and physiologists practiced selection for secondary traits as low selection efficiency for direct selection of grain yield under drought stress. These physiological traits rather could be used as the confirmation tools after selection in M3 stage based on phenotyping in the field at M3 stage. Similarly, at the molecular level, initial efforts in rice were devoted to mapping of QTLs for secondary drought-related traits such as root morphology and osmotic adjustment.

At the end of the third 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 develop 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.

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

Project Officer: A.M.A. Ghanim

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 this CRP is to develop laboratory, screen-house and field screening protocols of mutant population of sorghum and upland rice for resistance to *Striga asiatica* and *S. hermonthica*. In addition, the CRP focuses on technologies such as rapid cycling of generation of crop plants, doubled haploid techniques and molecular markers to enhance efficiency of mutant identification and accelerate delivery of resistant varieties.

The third RCM was organized during 30 September–4 October 2019 at the BecA facility in Nairobi, Kenya. Nine research and technical contract holders attended the meeting in addition to one agreement holder. The meeting was impressed by the encouraging results so far generated and the significant progress made in the planned activities during the last three years of the project Field and glass-house screening protocols of mutant populations for resistance to *Striga* were optimized and first draft is produced to be compiled as book of protocols developed by the CRP to be disseminate for use by Member States. A progress report was presented by the technical officer to the Committees for the Coordinated Research Activities (CCRA) on 5 November 2019. The meeting expressed satisfaction by the progress made and supported the proposal of extending the CRP until 2022. For more information, see past events and PBGL activities in this Newsletter.

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

Project Officer: I. Ingelbrecht

This CRP is focused on mutation breeding approaches to improve banana and coffee for resistance to Fusarium Wilt Tropical Race 4 (TR4) and Leaf Rust, respectively. Fusarium wilt in banana and coffee leaf rust are caused by fungal pathogens and have devastating effects on coffee and banana production in the affected countries. Coffee leaf rust has created recent epidemics in several countries in Central and Southern America while Fusarium wilt TR4 is threatening Cavendish banana production globally. The disease was initially confined to Asian countries such as China and the Philippines, from where it spread to Australia, and later to Africa (e.g. Mozambique), and most recently also to Colombia in Latin America, which is a major banana producing and exporting region globally. Under the CRP, the counterpart from China has recently produced TR4-resistant banana using mutagenesis techniques. See more under Information Dissemination for details on TR4 resistant banana and Developments at the PBGL for R&D progress on *in vitro* coffee single cell regeneration procedures at the PBGL.

Technical Cooperation Field Projects

Project Number	Country/Region	Title	Technical Officer(s)
ANG5015	Angola	Achieving Drought Tolerant Plants by Inducing Mutation with Gamma Rays	K. Bimpong
AZB5002	Azerbaijan	Developing Mutant Cotton Breeding Lines Tolerant to Diseases, Drought and Salinity through Mutation Breeding	F. Sarsu
BOT5019	Botswana	Improving Selected Legumes and Cereals against Biotic and Abiotic Stresses to Improve Food Production and Security	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
BKF5019	Burkina Faso	Improving Food Crop Genotypes for Enhancing Yield and Adaptation to Climate Change Using Mutation Breeding and Isotopic Techniques	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
BDI5001	Burundi	Improving Cassava Productivity through Mutation Breeding and Better Water and Nutrient Management Practices Using Nuclear Techniques	K. Bimpong in collaboration with Soil and Water Management and Crop Nutrition Section *(Leading)*
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
CPR5024	China, People's Republic of	Enhancing the Accelerated Application of Mutant Germplasm and High-Efficiency Breeding in Crops	N. Warthmann
COL5026	Colombia	Enhancing Crop Productivity of Creole Potato Using Nuclear and Related Techniques	K. Bimpong
ZAI5022	Congo, Democratic Republic of the	Improving Productivity and Quality of Crops (Soybean and Maize) Using Induced Mutation and Biotechnology	L. Jankuloski

Project Number	Country/Region	Title	Technical Officer(s)
ZAI5025	Congo, Democratic Republic of the	Increasing Genetic Variability in Cassava and Maize for Enhanced Tolerance to Biotic and Nitrogen Stresses	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
ZAI5026	Congo, Democratic Republic of the	Improving Productivity and Quality of Crops (Soybean and Maize) Using Induced Mutation and Biotechnology	K. Bimpong
ZAI5029	Congo, Democratic Republic of the	Enhancing Crop Productivity of Soybean and Maize through Improved Mutant Varieties and Lines	K. Bimpong
PRC5002	Congo, Republic of the	Developing Disease Resistant Varieties of Cassava and Banana	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	K. Bimpong
IVC5040	Cote d'Ivoire	Improving Agricultural Production of Maize, Rice and Cassava through Cultivation of Induced Mutant Adaptable to Climatic Changes	K. Bimpong
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
ERI5083	Eritrea	Developing Improved Banana and Maize Varieties through Mutagenic Nuclear Techniques	A.M.A. Ghanim
SWA5002	Eswatini, Kingdom of	Improving Adaptability of Cowpea to Climate Change through Mutation Breeding	L. Jankuloski
GHA5036	Ghana	Screening Oil Palm M2 Population for Useful Mutants	L. Jankuloski
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	I. Ingelbrecht
HON5009	Honduras	Improving Genetic Resistance of Coffee to Coffee Leaf Rust through Mutation Breeding	L. Jankuloski

Project Number	Country/Region	Title	Technical Officer(s)
INS5043	Indonesia	Intensifying Quality Soybean Production to Achieve Self-Sufficiency	A.M.A. Ghanim/L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
INS5044	Indonesia	Using Nuclear Technology to Support the National Food Security Programme	S. Sivasankar
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	K. Bimpong
IRQ5023	Iraq	Utilizing Nuclear Technology to Improve Key Legume Crops for Climate Change Adaptation	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
KAZ5004	Kazakhstan	Developing Drought Tolerant and Disease Resistant Wheat Varieties with Enhanced Nutritional Content Using Mutation Breeding	F. Sarsu
KEN5038	Kenya	Using Nuclear Techniques to Evaluate and Improve the Impact of Mutated Forages on the Performance of Smallholder Dairy Cows	K. Bimpong in collaboration with Animal Production and Health Section *(Participating)*
KUW5002	Kuwait	Implementing Mutation Induction to Improve Barley Production under Harsh Environmental Conditions	L. Jankuloski
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

Project Number	Country/Region	Title	Technical Officer(s)
LAO5002	Lao, P.D.R.	Improving Soil Fertility and Water Use Efficiency in the Cassava-Rice-Soybean Production System under Smallholder Farming Systems	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
LES5004	Lesotho	Using Nuclear Techniques for Improvement of Crop Yield, Quality and Stress Tolerance for Sustainable Crop Production (Continuation of the on-going project)	F. Sarsu
MAG5023	Madagascar	Promoting Climate Smart Agriculture to Face Food Insecurity and Climate Change with Regard to Basic National Foods (Rice and Maize)	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
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 in collaboration with Soil and Water Management and Crop Nutrition Section *(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	L. Jankuloski
MLW5003	Malawi	Developing Drought Tolerant, High Yielding and Nutritious Crops to Combat the Adverse Effects of Climate Change	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
MAL5031	Malaysia	Establishing an Environmentally Sustainable Food and Fodder Crop Production System	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section and Animal Production and Health Section *(Participating)*
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
MAU5006	Mauritania	Contributing to the Improvement of Rice Crop Yields through the Application of Nuclear Techniques to Water Management and Soil Fertility	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*

Project Number	Country/Region	Title	Technical Officer(s)
MAR5023	Mauritius	Improving Landraces of Crucifers (Cauliflower and Cabbage) and Carrot through the Use of Nuclear Techniques for Mutation Breeding and Biotechnology	F. Sarsu
NAM5016	Namibia	Developing Drought Tolerant Mutant Crop Varieties with Enhanced Nutritional Content	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
NAM5017	Namibia	Improving Crops for Drought Resilience and Nutritional Quality	F. Sarsu
NEP5003	Nepal	Improving Crop Yield for Food Security and Economic Growth by Using Nuclear and Molecular Techniques	L. Jankuloski
NEP5006	Nepal	Enhancing Productivity of Corps and Fruit Employing Nuclear and Molecular Techniques	K. Bimpong
NER5019	Niger	Improving Sesame Plant Productivity by Obtaining High-Yielding Induced Mutants Adapted to Semi-Arid Conditions	I. Ingelbrecht in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
NER5021	Niger	Using Microbial Biotechnology to Improve Productivity and Adapt Cowpea to Climate Change	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
NER5024	Niger	Improving Key Staple Crops towards Food Security	S. Sivasankar
NIC5011	Nicaragua	Broadening the Genetic Variation of Vegetative Propagated Crops Using Nuclear Techniques	F. Sarsu
OMA5004	Oman	Building Capacity for the Improvement of Major Crops through Induced Mutation Using Nuclear and Related Techniques	A.M.A. Ghanim/I. Ingelbrecht
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
PER1005	Peru	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

Project Number	Country/Region	Title	Technical Officer(s)
PER5034	Peru	Improving Yellow Potato and Coffee Crops through Mutation Breeding Techniques	L. Jankuloski
QAT5006	Qatar	Enriching Genetic Diversity and Conserving Plant Genetic Resources Using Nuclear Techniques and Related Technologies	A.M.A. Ghanim
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
RAF5066	Regional Africa	Improving Crops Using Mutation Induction and Biotechnology through a Farmer Participation Approach (AFRA)	F. Sarsu
RAF5076	Regional Africa	Improving Crops by Using Mutation Induction and Biotechnology through a Farmer Participatory Approach	F. Sarsu
RAF5083	Regional Africa	Enhancing Crop Productivity through Climate Smart Crop Varieties with Improved Resource Use Efficiency (AFRA)	S. Sivasankar
RAS5069	Regional Asia	Complementing Conventional Approaches with Nuclear Techniques towards Food Risk Mitigation and Post-Flood Rehabilitation Efforts in Asia	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section *(Leading)* and Animal Production and Health Section
RAS5070	Regional Asia	Developing Bioenergy Crops to Optimize Marginal Land Productivity through Mutation Breeding and Related Techniques (RCA)	L. Jankuloski/F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
RAS5073	Regional Asia	Supporting Climate-proofing Rice Production Systems (CriPS) Based on Nuclear Applications-Phase II	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
RAS5074	Regional Asia	Enhancing Wheat and Barley Productivity through Induced Mutation with Supportive Breeding and Related Biotechnology Techniques (Phase III)	F. Sarsu
RAS5075	Regional Asia	Improving Sustainable Cotton Production through Enhanced Resilience to Climate Change	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*

Project Number	Country/Region	Title	Technical Officer(s)
RAS5077	Regional Asia	Promoting the Application of Mutation Techniques and Related Biotechnologies for the Development of Green Crop Varieties (RCA)	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
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
RWA5001	Rwanda	Improving Cassava Resilience to Drought and Waterlogging Stress through Mutation Breeding and Nutrient, Soil and Water Management Techniques	F. Sarsu
SEN5034	Senegal	Using an Integrated Approach to Develop Sustainable Agriculture in a Context of Degrading Soil Fertility, Climate Change and Crop Diversification	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section *(Leading)*
SIL5017	Sierra Leone	Selecting and Analysing Bio-Enriched and Bio-Fortified Rice and Cassava Lines and their Efficient Postharvest Transformation to Popular Food Products	K. Bimpong
SIL5020	Sierra Leone	Enhancing the Concurrent Selection and Evaluation of Biofortified and Bio-enriched Varieties Derived from Mutant Rice, Cassava and other Crops	K. Bimpong
SIL5021	Sierra Leone	Improving Productivity of Rice and Cassava to Contribute to Food Security	K. Bimpong
SAF5016	South Africa	Promoting Mutation Breeding of Vegetables to Improve Rural Livelihoods — Phase I	N. Warthmann
SRL5045	Sri Lanka	Establishing a National Centre for Nuclear Agriculture	F. Sarsu in collaboration with Animal Production and Health Section and Soil and Water Management and Crop Nutrition Section *(Participating)*

Project Number	Country/Region	Title	Technical Officer(s)
SRL5050	Sri Lanka	Supporting Genetic Improvement of Tea	S. Sivasankar
SUD5033	Sudan	Enhancing Productivity of Major Food Crops (Sorghum, Wheat, Groundnut and Tomato) under Stress Environment Using Nuclear Techniques and Related Biotechnologies to Ensure Sustainable Food Security and Well-Being of Farmers	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
SUD5037	Sudan	Applying Nuclear Techniques to Improve Crop Productivity and Livelihood of Small-scale Farmers in Drought Prone Areas	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
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
TOG5002	Togo	Improving Crop Productivity and Agricultural Practices through Radiation Induced Mutation Techniques	K. Bimpong in collaboration with Soil and Water Management and Crop Nutrition Section *(Leading)*
TUN5029	Tunisia	Developing Barley and durum Wheat Resilience to Drought and Heat Tolerance through Mutation Breeding	F. Sarsu
URT5028	Tanzania, United Rep. of	Improving Crop Production and Productivity through the Use of Nuclear and Nuclear-Related Techniques	L. Jankuloski
URT5029	Tanzania, United Rep. of	Improving Rice and Barley Production through the Application of Mutation Breeding with Marker Assisted Selection	L. Jankuloski/F. Sarsu
URT5030	Tanzania, United Rep. of	Improving Rice and Barley Production through Application of Mutation Breeding with Marker Assisted Selection	L. Jankuloski/F. Sarsu
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
TUN5029	Tunisia	Developing Barley and Durum Wheat Resilience to Drought and Heat Tolerance through Mutation Breeding	F. Sarsu

Project Number	Country/Region	Title	Technical Officer(s)
UGA5041	Uganda	Developing Disease Resistant High Yielding Farmer Preferred Cassava Varieties in Uganda through Induced Mutation Breeding	L. Jankuloski
NHE5001	Vanuatu	Enhancing the Productivity and Quality of Crops through the Application of Mutation Breeding Techniques	L. Jankuloski
YEM5015	Yemen	Enhancing Sorghum and Legume Crop Productivity through Induced Mutations with Supportive Breeding and Bio-Technologies	L. Jankuloski
ZAM5031	Zambia	Improving the Yield of Selected Crops to Combat Climate Change	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section *(Participating)*
ZIM5021	Zimbabwe	Assessing and Promoting Sustainable Agricultural Production in Communal and Newly Resettled Farms	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section *(Leading)*

Success Stories

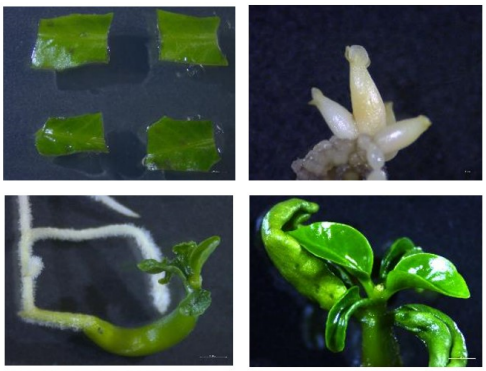
- Climate-Proof Crops: Capacity Building to Develop Resilient Crop Varieties in Small Island Developing States **(6 November 2019)** https://www.iaea.org/newscenter/news/climate-proof-crops-capacity-building-to-develop-resilient-crop-varieties-in-small-island-developing-states
- Ethiopian Plant Breeders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

Developments at the Plant Breeding and Genetics Laboratory (PBGL)

In Vitro Single-cell Regeneration Techniques to Improve Mutation Induction in Coffee and Banana Established at PBGL

In the context of the CRP on Disease Resistance in Banana and Coffee (D22005), the PBGL has initiated R&D on advanced *in vitro* plant cell and tissue culture techniques to improve existing methodologies for mutation induction in vegetative crops or trees. The presence of chimeric tissues harboring different mutations in mutagenised seed or *in vitro* explants presents a challenge for vegetative crops or for crops or trees with a long reproductive cycle such as coffee. Advances in *in vitro* single cell regeneration techniques now allow to grow an intact, fertile plant from individual somatic cells Therefore, mutation induction of single cells, followed by *in vitro* regeneration to plants is expected to solve the hurdle of chimeric tissues resulting in plants with more uniform and stable phenotypes. This year, the PBGL established for the first time, *in vitro* regeneration of plants from single cells, in a pilot study on coffee. Using *in vitro* somatic embryogenesis, arabica coffee plantlets could be regenerated from leaf discs (see photo for a summary of the somatic embryogenesis protocol). Further, in the context of the recently initiated Peaceful Use Initiative Project on 'Enhancing Climate Change Adaptation and Disease Resilience in Banana-Coffee Cropping Systems in East Africa', *in vitro* cell suspension cultures of the dessert Cavendish banana have been acquired through the KUL, Belgium. These cultures are now also being propagated at the PBGL with the objective to regenerate fertile banana plants through somatic embryogenesis. Such *in vitro* technologies not only offer great potential to significanlty shorten the mutation breeding cycle of crops such as coffee and banana but also offer new opportunities for lab-based selection schemes during the early *in vitro* tissue culture stages.



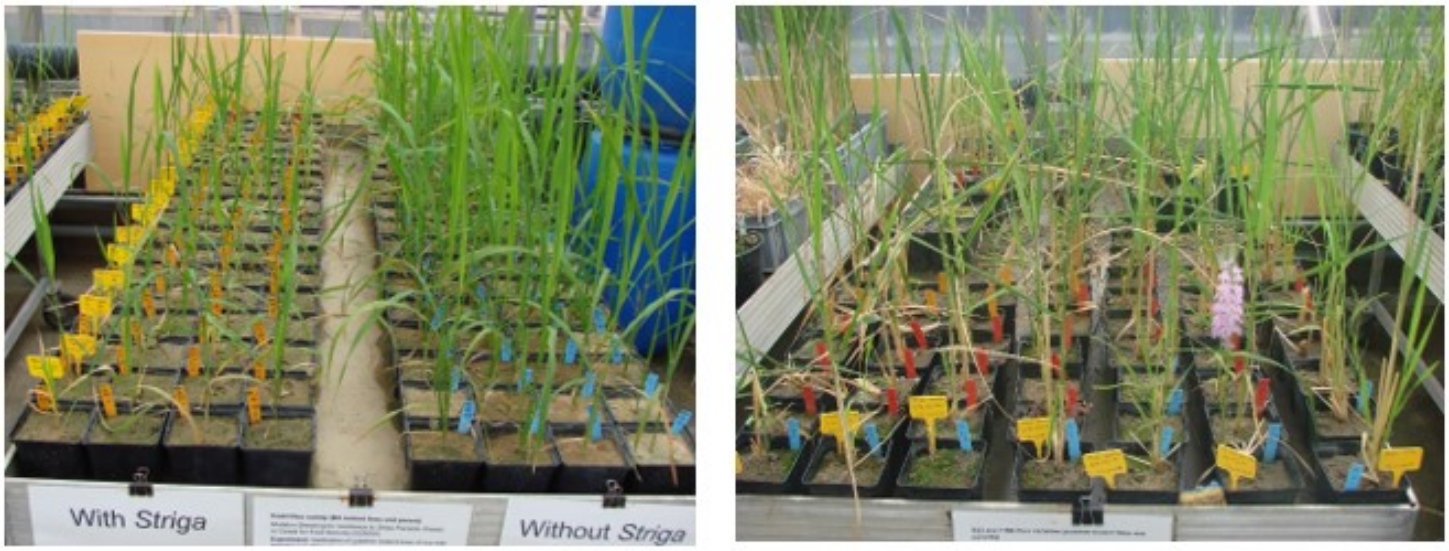
Overview of regeneration of coffee plants from single cells using *in vitro* somatic embryogenesis from *Coffea arabica* cv Venecia leaf tissues: leaf discs (top left); immature somatic embryos (top right); mature somatic embryo with root (bottom left); and, coffee plantlet (bottom right).

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

In the context of the ongoing R&D activities related to the CRP on *Striga* (D25005), the PBGL continued the verification experiments for putative mutants of rice and sorghum. During the reporting period, 30 and 36 putative rice mutants from Burkina Faso and Sudan, respectively, were evaluated using the established pot-screening protocol at the PBGL. The putative mutants from Sudan were at the M_3 generation while those from Burkina Faso were in advanced M_4/M_5 generation. Seeds were planted in medium-sized pots filled with soil mixture containing rice clay soil and sand in 2:1 ratio with pH = 6.5. Each putative mutant was tested in a set of four pots with uniformly mixed seeds of *Striga hermonthica* and four *Striga* seed-free pots. Wild parents and known positive *Striga* resistant checks were included. Plants were maintained in a glass-house at 25°C under natural light during June–November 2019 at the PBGL facility in Seibersdorf. Seedlings were irrigated 2–3 times a week until establishment and thereafter with 1–2 watering per week or as needed. No fertilizer was applied, and *Striga* plants started to emerge above the soil in about two months. After about three months, the damage due to *Striga* was scored on the pots containing *Striga* seeds as compared with the control (no *Striga* seeds). The number of *Striga* plants per pot, rice plant height and % damage (burned leaves/total leaves) were scored, and the tolerance/resistance index was calculated based on % reduction in growth due to *Striga* infection. There were significant differences in the damage due to *Striga* infection and the mutant lines were classified into susceptible (with all plants in the four pots damaged and $\leq$ 50% tolerance index), and resistant (with few or no *Striga* infection and tolerance index above 90%) (see photos). In total, four and seven resistant, and two and three tolerant mutants were confirmed from Sudan and Burkina Faso, respectively. The lines with confirmed resistance will be advanced to study the mechanisms of resistance and make intercrosses to test allelism and mapping populations to enable development of molecular markers for the verified resistance.

In the case of sorghum, an additional three resistant mutants were confirmed from Burkina Faso and 10 mutants from Sudan to make a total of 23 sorghum mutants in seven farmer-preferred sorghum varieties from Burkina Faso and Sudan. The initial analysis of the mechanism of resistance showed four possible mechanisms including low germination stimulant producer, inhibition of haustorium development, failure of attachment and reduced growth of

Striga. This indicates the great potential of pyramiding of induced resistance to produce more durable resistance combining different mechanisms. Development of mapping population is under way whereby the best three mutants with different mechanisms from each country were crossed with their wild parents to develop F_2 populations which will be phenotyped at the participating *Striga* affected countries. Tissue samples will be collected for DNA sequencing and further analysis is planned ultimately to lead to marker development for each of the induced mutants to facilitate pyramiding of the resistance genes.



General view (left) of the verification experiment for putative mutant lines of rice each replicated four times with Striga (yellow label) and without Striga seeds (blue label) at seedling stage (four weeks) using the established protocol at PBGL, and later view (right) 2–3 months of the verification experiment showing Striga at flowering stage.

View of representative verification experiments showing resistant mutant line three months after planting in striga infected soil (four pots in the middle), compared to a susceptible control (left), and a non-infected control (right).

In addition, the PBGL is conducting optimization experiments for doubled haploid production in rice and sorghum to be integrated in the process of mutant population development in the *Striga* CRP to enhance efficiency of selection and accelerate the delivery of *Striga*-resistant mutant varieties. Four rice varieties were tested (one from Burkina Faso, one from Madagascar and two from Sudan) together with their irradiated M_1 generation. Anther culture, shed pollen and microspore culture methods were tested for optimization to produce haploid plants. Haploids plants were produced, so far, from the anther cultured from the tested rice varieties and doubled haploid seeds were produced either spontaneously or following the established doubling procedure by colchicine treatment. The experiments are still ongoing and therefore a more detailed report will appear in the Newsletter, No. 45, July 2020 issue.

Data Science Internships at PBGL

Digitization is sweeping through all areas of our lives. Mutation Breeding, and Plant Breeding in general, is no exception. 'Big Data' has truly arrived, and it concerns the phenotype as well as the genotype. Fueled by new, highly parallel DNA sequencing technologies, we can now read the genetic code of individual plants with unprecedented speed and accuracy at an unprecedented low price. PBGL is harnessing this powerful technology to identify promising genetic variation for mutation breeding. However, wider adoption requires many more trained experts. PBGL has decided to help train the next generation of much needed data analysts and to offer Data Science internships.

2019 saw the first round of such interns. Marcos Conde (Spain) was with us from July until October, and Anza Ghaffar (Pakistan) joined in October and will stay until July 2020. Sharing our excitement about plant biology and plant breeding with enthusiastic recent computer science graduates is a very rewarding experience, and both Marcos and Anza, have made great contributions. You could be next. If you are skilled in computer science and interested in getting exposure to genome data analysis and improving food security, then please get in touch!

Information Dissemination

R&D progress under the CRP D25005 on *Striga* and the CRP D22005 Coffee and Banana Disease was widely disseminated through two IAEA web stories published ahead of the 2020 International Year of Plant Health. These stories highlight the contribution and achievements of crop mutation breeding to help address transboundary plant diseases and weeds such as *Striga* (witchweed) in cereals and Fusarium wilt TR4 in banana:

- https://www.iaea.org/newscenter/news/iaea-fao-help-develop-bananas-resistant-to-major-fungal-disease
- https://www.iaea.org/newscenter/news/nuclear-techniques-help-develop-new-sorghum-lines-resistant-to-the-parasitic-weed-striga

Crop Irradiation Services Provided to Member States

At this time of writing (3 December 2019), the PBGL has received 37 requests for crop irradiation from 31 Member States for 66 crops and multiple varieties.

Request Number	Country	Request Type	Crop
1583	Hungary		Ornamental
1584	United Arab Emirates	TC	Quinoa
1585	Togo	TC	Maize
1586	The Netherlands		Ornamental
1587	Zimbabwe	TC	Cowpea, Sorghum
1588	Cameroon	TC	Watermelon, Ochra, Cowpea, Maize
1589	Burkina Faso	TC	Cowpea
1590	Congo, Democratic Republic of	TC	Maize
1591	The Netherlands		Ornamental, Tomato
1592	PBGL		Arabidopsis
1593	Nigeria	TC	*Dioscorea rotundata*
1594	Mongolia	CRP	Pea, Soybean
1595	Austria		Maize
1596	Mali	TC	Rice
1597	USA		*Capsicum annuum*
1598	Malawi	TC	Maize, Groundnut
1599	Fiji		*Capsicum annuum*
1600	Namibia	TC	Pearl millet, Cowpea
1601	Ghana	CRP	Taro
1602	Kenya	TC	Brachiaria, Dolichos, *Mucuna pruriens*
1603	Sudan		Sesame, Peanut, Cowpea
1604	Senegal		Cowpea
1605	Burkina Faso	TC	Maize
1606	Germany		Ornamental
1607	Mali	CRP	Sorghum

Request Number	Country	Request Type	Crop
1608	Fiji	TC	Rice
1609	Germany		Ornamental
1610	Oman	TC	Date palm, Lime, Wheat
1611	Fiji	TC	Sweet potato, Yam, Breadfruit
1612	PBGL		Banana
1613	Namibia		Bambara groundnut
1614	Germany		Ornamental
1615	Ukraine		Wheat
1616	Palestine	TC	Cucumber, Zucchini
1617	Namibia	TC	Cowpea, Maize
1618	Spain	CRP/TC	Lentil
1619	Tanzania	CRP/TC	Rice
1620	Slovenia		Wheat, Millet, Sorghum, Buckwheat, Tomato, *Thinopyrum intermedium*
1621	Kuwait	TC	Barley, *Rhanterium epapposum, Calligonum polygonoides, Penisetum divisum, Farsetia aegyptia, Panicum turgidum*
1622	UK		Hosta

Individual Training Activities at the PBGL

Name	Country	Status	Topic	Period
Ms Luz GOMEZ PANDO	Peru	SV	Mutation beeding in Peruvian highlands	2 days
Mr Aimé NDOFUNSU	Congo, Democratic Republic of	SV	Mutation breeding and efficiency enhancing tools	10 days
Mr Abdallah ALIMARI	Palestine	SV	Mutation breeding and efficiency enhancing tools	10 days
Ms Yuliasti YULIASTI	Indonesia	SV	Mutation breeding and efficiency enhancing tools	10 days
Ms Lilik HARSANTI	Indonesia	SV	Mutation breeding and efficiency enhancing tools	10 days
Mr Luther CASCO HERRERA	Nicaragua	SV	Mutation breeding and efficiency enhancing tools	10 days
Mr Pio VALLECILLO RETES	Nicaragua	SV	Mutation breeding and efficiency enhancing tools	10 days
Mr Gerhard HAITEMBU	Namibia	SV	Mutation breeding and efficiency enhancing tools	10 days
Mr Kelvin KAMFWA	Zambia	SV	Mutation breeding and efficiency enhancing tools	10 days
Mr Elgailani ABDALLA	Sudan	SV	Mutation breeding and efficiency enhancing tools	10 days
Ms Wadhha AL-GHAFRI	Oman	SV	Mutation breeding and efficiency enhancing tools	10 days
Mr Sidi MENOUM	Mauritania	SV	Mutation breeding and efficiency enhancing tools	2 days
Mr. H. Jhonny RABEFIRAISANA	Madagascar	F	*Striga* screening protocol, marker development	3 months

Mr Sadate AMADOU	Togo	F	Mutation induction; population development and screening; efficiency enhancing technologies	3 months
Mr Modeste PALANGA	Togo	F	Mutation induction; population development and screening; efficiency enhancing technologies	3 months
Mr Phillipe NIKIEMA	Burkina Faso	F	Mutant population development *Striga; Striga* screening protocol	6 months
Mr Solomon OTU	Ghana	F	Marker-assisted selection protocol in barley; *in vitro* haploid rice	3 months
Mr Bawoumodom BODJONA	Togo	F	Marker-assisted selection protocol in barley; radio-sensitivity testing cowpea	3 months
Mr Clement ANNOR	Ghana	F	Radio-sensitivity testing taro; marker-assisted selection protocol in barley	4 months
Mr N'pagyendou LARE	Togo	F	Radio-sensitivity testing taro; marker-assisted selection in barley	3 months
Jehad RADWAN	Palestine	F	Mutation induction; population development and screening; efficiency enhancing technologies	4 months
Mr Thadey TAIRO	Tanzania	F	Mutation induction; population development and screening; efficiency enhancing technologies	5 months
Mr James ALPHONACE	Tanzania	F	Mutation induction; population development and screening; efficiency enhancing technologies	3 months
Mr Semi CAKAUNITAVUKI	Fiji	F	Radio-sensitivity testing and bulk irradiation sweet potato and yam	4 months
Mr Winda PUSPITASARI	Indonesia	F	Mutation induction; population development and screening; efficiency enhancing technologies	3 months
Ms Eunice TEMU	Tanzania	F	Mutation induction; population development and screening; efficiency enhancing technologies	4 months
Ms Habibah AL-MENAI	Kuwait	F	Marker-assisted selection in barley	2 months
Mr Edwin THEKKINEN	Austria	I	Crosses and marker-assisted selection barley; sesame phenotyping	2 months
Ms Samira TAJEDINI	Iran	I	Haploid in rice and sorghum; mutant population development *Striga*	5 months
Ms Yuling YUE	China	I	Drought/*Striga* screening protocols and marker development in rice and sorghum	8 months
Ms Li ZHU	China	I	Drought/*Striga* screening protocols and marker development in rice and sorghum	11 months
Mr Marcos CONDE	Spain	I	Computational analysis workflow in snakemake	3 months
Mr Anza GHAFFAR	Pakistan	I	Allele visualization tools using R	9 months

F: Fellow; I: Intern; SV: Scientific Visitor

Publications

Books

GHANIM, A.M.A., BADO, S., ALI, A.B., SANGWAN, R.S., FORSTER, B.P., INGELBRECHT, I.L. X-Ray Irradiation for Mutation Induction in Crop Plants (*in press, FAO*).

Manual on Mutation Breeding, Third Edition

Edited by Madeleine Spencer-Lopes, Brian P. Forster and Ljupcho Jankuloski. Co-published by the International Atomic Energy Agency (IAEA) and the Food and Agriculture Organization (FAO) of the United Nations.

URL: http://www.fao.org/3/I9285EN/i9285en.pdf

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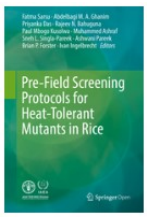
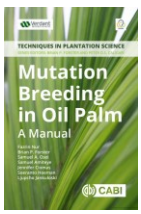


Pre-Field Screening Protocols for Heat-Tolerant Mutants in Rice

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. (2018) Springer. 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. (2018) CABI Publishing.

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Peer-reviewed Publications

2019

KENZHEBAYEVA, S., ABEKOVA, A., ATABAYEVA, S., YERNAZAROVA, G., OMIRBEKOVA, N., ZHANG, G., TURASHEVA, S., ASRANDINA, S., SARSU, F., WANG, Y. (2019) Mutant Lines of Spring Wheat with Increased Iron, Zinc, and Micronutrients in Grains and Enhanced Bioavailability for Human Health. Hindawi BioMed Research International Volume 2019, Article ID 9692053, 10 pages.
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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.

OBERHOFER, M., HESS, J., LEUTGEB, M., GÖSSNITZER, F., RATTEI, T., WAWROSCH, C. and ZOTCHEV, S.B. (2019). Exploring Actinobacteria Associated with Rhizosphere and Endosphere of the Native Alpine Medicinal Plant Leontopodium nivale Subspecies alpinum. Frontiers in Microbiology 10.
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TRAMONTANO, A., JARC, L., JANKOWICZ-CIESLAK, J. HOFINGER, B.J., GAJEK, K., SZURMAN-ZUBRZYCKA, M., SZAREJKO, I., INGELBRECHT, I. and TILL, B.J. (2019). Fragmentation of Pooled PCR Products for Highly Multiplexed TILLING. G3-Genes Genomes Genetics 9(8):g3.400301.2019.
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a Unique Single-Stranded DNA Virus Representing a New Taxon. Scientific Reports 8, Article number: 5698. DOI: 10.1038/s41598-018-23739-y

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KAMAL, N.M., MOHAMMED, Y., GHANIM, A.M.A. (2018) Performance of Sorghum Stay-green Introgression Lines Under Post-Flowering Drought. April 2018. International Journal of Plant Research 7(3). DOI: 10.5923/j.plant 20170703.02

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Conference Abstracts and Posters

2019

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.

2018

ENAYATI SHARIATPANAHI, M., TAJEDINI, S., GHANIM, A.M.A., FAKHERI, B., OROOJLOO, M., MAHDINEJAD, N. (2018) Haploidy in Rice (*Oryza sativa* L.) Mutation Breeding for *Striga* Resistance. Poster 79 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

ENAYATI SHARIATPANAHI, M., TAJEDINI, S., GHANIM, A.M.A., FAKHERI, B., OROOJLOO, M., MAHDINEJAD, N. (2018) Enhancing Efficiency of Mutation Breeding for *Striga* resistance in Sorghum by Haploid Technology. Poster 82 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

MUNASINGHA JAYASUNDARA MUDIYANSELAGE PRIYANTHI KUMARARATHNA, GHANIM, A.M.A. (2018) Mungbean Radiosensitivity Test to Gamma Irradiation for Mutation Breeding in Mungbean. Poster 100 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

SARAYE, B., JANKOWICZ-CIESLAK, J., PEERBOCCUS, S., TILL, B.J., NOWBUTH, R.D. (2018) Induced Genetic Variability for Yield and Heat Tolerance in Tomato (*Solanum lycopersicum*). Poster 111 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

MAGHULY, F., JANKOWICZ-CIESLAK, J., GUPTA, P., TILL, B.J., LAIMER, M. (2018) Creation and Characterization of an EMS Mutant Population of *Jatropha curcas*. Abstract 184 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

SARAYE, B., JANKOWICZ-CIESLAK, J., TILL, B.J. (2018) A Pre-Screening Methodology for Identification of Heat Tolerant Mutant in Tomato (*Solanum*

lycopersicum L.). Poster 254 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

DUSSORUTH, B., JANKOWICZ-CIESLAK, J. (2018) Irradiation as Means for Increasing Genetic Diversity in Banana: The Need to Carry Out Radiosensitivity Tests on *In Vitro* Cultures at Appropriate Stage of Growth. Poster 255 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

HASSAN, O., GHANIM, A.M.A., INGELBRECHT, I. (2018) Mutation Induction in Pearl Millet (*Pennisetum glaucum*) and Fingermillet (*Eleusine coracana*) for Drylands in Sudan. Poster 257 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

LAOUAR, M., TILIOUINE AMRI, W., DAHBIA, T., JANKOWICZ-CIESLAK, J., TILL, B.J. (2018) Early Assessment of Lentil and Chickpea Mutant and Evaluation of Low-Cost TILLING on M_2 Chickpea. Abstract 269 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

SARSU, F., GHANIM, A.M.A., PAREEK, A. FORSTER, B.P., INGELBRECHT, I., ASHRAF, M., KUSOLWA, P.M., DAS, P., BAHUGUNA, R., SINGLA-PAREEK, S.L. (2018) Screening Protocols for Heat Tolerant Mutants in Rice. Poster 273 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

TRAMONTANO, A., JARC, L., JANKOWICZ-CIESLAK, J., HOFINGER, B.J., GAJEK, K., SZURMAN-ZUBRZYCKA, M., SZAREJKO, I., INGLEBRECHT, I., TILL, B.J. (2018) Fragmentation of Pooled PCR Products for Deep Amplicon Sequencing. Poster 286 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

JANKOWICZ-CIESLAK, J., GOESSNITZER, F., CHAO, C.-P., HUANG, S.-H., DATTA, S., INGELBRECHT, I., TILL, B.J. (2018) Induced Mutagenesis for Generating Bananas Resistant to Fusarium Wilt TR4. Poster 287 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology 27–31 August 2018, Vienna, Austria.

JANKOWICZ-CIESLAK, J., HOFINGER, B.J., JARC, L., JUNTTILA, S., GYENESEI, A., INGELBRECHT, I., TILL, B.J. (2018) Mapping the Landscape of Gamma and X-ray-Induced Mutations in Rice. Poster 288 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

JANKOWICZ-CIESLAK, J., SARAYE, B., JUNTTILA, S., GYENESEI, A., INGELBRECHT, I., TILL, B.J. (2018) Whole Genome Sequencing of Advanced Mutant Lines of Heat Tolerant Tomato Induced by Gamma Irradiation. Poster 289 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

TILL, B.J., JANKOWICZ-CIESLAK, J., HUYNH, O., HOFINGER, B., ATTA, S., TRAMONTANO, A., JARC, L., NIELEN, S., FORSTER, BP., MBA, C., INGELBRECHT, I. (2018) Genomics Tools to Facilitate Plant Mutation Breeding. Abstract 290 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

GHANIM, A.M.A., SNIGDHA, R., JANKULOSKI, L., INGELBRECHT, I. (2018) Pre-Field Phenotyping of Lentil Mutants for Drought Tolerance Using Polyethylene Glycol. Poster 291 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

GHANIM, A.M.A., MUSTAFA, N.S., JANKULOSKI, L., INGELBRECHT, I. (2018) Optimization of doubled haploid production for enhancing efficiency of wheat mutation breeding. Poster 292 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

GHANIM, A.M.A., SEN, A., SHIRAZI, F.T., JANKULOSKI, L., INGELBRECHT, I. (2018) Rapid Cycling Techniques to Accelerate Plant Mutation Breeding in Cereals. Poster 293 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

GHANIM, A.M.A., ABDUL MALEK, M., JANKULOSKI, L., INGELBRECHT, I. (2018) Optimization of screening for salt tolerance in soybean for mutation breeding. Poster 294 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

GHANIM, A.M.A., DADA, K., INGELBRECHT, I. (2018) Irradiation-dose optimization for mutation induction in coffee. Poster 295 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

GHANIM, A.M.A., ALI, A., JANKULOSKI, L., INGELBRECHT, I. (2018) Mutation breeding for resistance to the parasitic weed *Striga* in major cereal crops for sustainable food security. Poster 296 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

INGELBRECHT, I., HOFINGER, B., AKGUN, E., MATIJEVIC, M., ALI, A., JANKOWICZ-CIESLAK, J.,

JARC, L., JANKULOSKI, L., GHANIM, A.M.A., GRAUSGRUBER, H. (2018) Development of a functional marker for marker-assisted selection of 'Orange Lemma' mutants to improve feed quality in barley. Poster 298 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

WARTHMANN, N., GHANIM, A.M.A., ALI, A., MATIJEVIC, M., JANKOWICZ-CIESLAK, J., INGELBRECHT, I. (2018) Creating desired traits for African sorghum, semi-dwarf and early maturing, and molecular characterisation of their genetic architecture. Poster 299 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

RABEFIRAISANA, H.J., GHANIM, A.M.A., ANDRIANJAKA, A., RASOAMAMPIONONA, B., JANKULOSKI, L., RAZAFINDRASOA, M.A., RAVELONJANAHARY, N.H., RAKOTOARISOA, N.V. (2018) 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. Poster 148 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

RAKOTOARISOA, N.V., GHANIM, A.M.A., ANDRIANJAKA, A., RASOAMAMPIONONA, B., RABEFIRAISANA, H.J., JANKULOSKI, L., RAKOTONJANAHARY, X.R.T. (2018) Induced Mutation for Developing Mutant Rice Lines Tolerant to the Parasitic *Striga asiatica* (L.) Kuntze. Poster 151 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

SULIMAN, S., GHANIM, A.M.A. (2018) Mutation-Induced Variability for Improved Yield in Spring Wheat Under Hot Irrigated Environments. Poster 248 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

AL-MAMARI, A.H.K., GHANIM, A.M.A. (2018) Mutation Induction for Sorghum And Rice Using Gamma and X ray Irradiations. Poster 251 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

HUSSAIN, M., JAWDAT, D., MYAT LWIN, K., JANKULOSKI, L., MALEK, M., ISLAM, M.K., RAHEMI, M.R., ZHANG, T. (2018) Improving Sustainable Cotton Production through Enhanced Resilience to Climate Change Using Mutation Breeding. Abstract 6 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

JANKULOVSKA, M., KUZMANOVSKA, B., BOSHEV, D., JANKULOSKI, L., MARKOSKI, M., IVANOVSKA, S. (2018) Evaluation of Advanced Wheat Mutant Lines for Food and Feed Quality. Abstract 266 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

JANKULOVSKA, M., IVANOVSKA, S., KUZMANOVSKA, B., BOSHEV, D., JANKULOSKI, L., MARKOSKI, M. (2018) Agronomic Performance of Wheat Mutant Lines for Food and Feed Quality on Farmer's Fields. Poster 267 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

FARID UDDIN, M., JAWDAT, D., MYAT LWIN, K., JANKULOSKI, L., MASSOUD, M., HUSSAIN, M., KAMRUL ISLAM, M., RAHEMI, M.R., ZHANG, T. (2018) Adaptation of Mutation Breeding for Enhancing Cotton Resilience to Climate Change in Bangladesh. Poster 12 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

JAWDAT, D., SALEH, A., MYAT LWIN, K., JANKULOSKI, L., HUSSAIN, M., MALEK, M., KAMRUL ISLAM, M. AL-ALI, M., TAHEIR, N., ZHANG, T. (2018) Evaluation of Two Advanced Cotton Mutant Lines in a Different Climatic Area from their Geographic Origin. Poster 83 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

ALAMEH, A., HROUB, I., JANKULOSKI, L., BASHEER-SALIMIA, R., HAMDAN, Y. (2018) Induced Mutations in Durum Wheat (*Triticum durum*) for Improve Productivity Components Traits. Poster 174 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

RAHEMI, M.R. ESKANDARI, A., MOGHISEH, E., MOZAFFARI, K., JANKULOSKI, L., HUSSAIN, M., RAHIMI, M., MALEK, M., AMIRIPARI, M., ALISHAH, O. (2018) Evaluation of New Cotton Mutant Cultivars for Adaptation to Climate Change in Iran. Poster 200 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

DANSO, K., GHANIAM, A.M.A., DWARKO, D., JANKULOSKI L., NUNEKPEKU, W. (2018) Dose Optimisation for Pollen and Embryos Irradiation Mutation Induction in Oil Palm. Poster 221 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

GRAUSGRUBER, H. EMSENHUBER, C., KLEVENHUSEN, F., HOCHHAUSER, F., JANKULOSKI, L., ZEBELI, Q. (2018) Evaluation of Hooded (Kap1), Awnless (Lks1) and Orange Lemma (*Rob1*) Mutants of Barley (*Hordeum vulgare* L.) for their Use as Forage Crop. Poster 276 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

DOKTYRBAY, G., KENZHEBAYEVA, S., ABEKOVA, A., TASHENEV, D., SARSU, F., OMIRBEKOVA, N. (2018) Improvement of Spring Wheat Grain Micronutrients Concentrations through Mutation Breeding. Poster 260 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

HORN, L.N., SARSU, F., MWADZINGENI, L., LAING, M.D., HUSSEIN, S. (2018) Genotype-By-Environment Interaction of Elite Varieties of Cowpea Derived through Mutagenesis. Abstract 16 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

TOMLEKOVA, N., SARSU, F., SOFKOVA-BOBCHEVA, S., MUHOVSKI, Y. (2018) Induced Mutagenesis for Bean (*Phaseolus vulgaris* L.) Production Improvement in Bulgaria. Abstract 209 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

KLAKHAENG, K., SARSU, F., PROMNART, U. (2018) Improving Submergence Tolerance in Thai Rice Using Electron Beam Induced Mutations. Poster 17 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

MATOVA, P.M., MUKUNGURITSE, C., KUTYWAYO, D., GASURA, E., SARSU, F., SHIMELIS, H., CHIPFUNDE, O. (2018) A Decade of Progress in Cowpea Genetic Improvement Using Mutation Breeding in Zimbabwe. Poster 113 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.113

MUNOZ FLOREZ, C., DEOBOUCK, D., RAO, I., SARSU, F. (2018) Developing Stress Tolerant Tepary Bean through Mutation Breeding. Poster 143 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

PROMNART, U., SARSU, F., KLAKHAENG, K., DOUNGSOONGNEM, P. (2018) Thai Rice Breeding for Flood Tolerance through Electron Beam-induced Mutation. Poster 252 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

SARSU, F., GHANIM, A.M.A., PAREEK, A., FORSTER, B.P. INGELBRECHT, I., ASHRAF, M., KUSOLWA, P.M., DAS, P., BAHUNGUNA, R.N., SINGLA-PAREEK, S.L. (2018) Screening Protocols for Heat Tolerant Mutants in Rice. Poster 273 presented at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018, Vienna, Austria.

Web-based Protocols

Library Preparation for Medium- to High-throughput DNA Sequencing on the Illumina Sequencing Platform.

A Low-Cost Protocol and Marker Kit for Marker-Assisted Selection of Orange Lemma (*rob1*) for Forage Barley Improvement.

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
  http://www-naweb.iaea.org/nafa/news/index.html
- Joint FAO/IAEA Division Publications
  http://www-naweb.iaea.org/nafa/resources-nafa/publications.html
- Food and Agriculture Organization of the United Nations (FAO):
  http://www.fao.org/about/en/
- FAO Agriculture and Consumer Protection Department:
  http://www.fao.org/ag/portal/index_en/en/

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