Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Plant Breeding & Genetics Newsletter

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To Our Readers

Part of the important germplasm maintained in the Plant Breeding and Genetics greenhouses during the lock-down period: Striga-resistant sorghum mutant lines; sorghum and coffee mutant populations for amplicon sequencing and exome capture, respectively.

Dear Colleagues,

These are clearly turbulent times for the world, and I hope that you are all doing well. I hope that the COVID-19 pandemic situation stabilizes globally as soon as possible.

Plant Breeding and Genetics (PBG) started 2020 with enthusiastic coordination with counterparts towards the implementation of Technical Cooperation (TC) Projects of the 2020–21 cycle, planning of a Consultation Meeting for a new Coordinated Research Project (CRP) on technologies for mutation breeding in vegetative crops, and continued implementation of ongoing CRP and TC projects. Early 2020 saw the final project coordination meeting of the regional Latin America project, '*Improving Yield and Commercial Potential of Crops of Economic Importance'* (RLA5068), held in Quito, Ecuador during 2–6 March 2019. Importantly, this meeting, while reporting advanced mutant lines from several countries, ended with the **Second Latin American Symposium on Nuclear Applications in Agriculture**. The latter was organized by the National

Institute for Agricultural Research (INIAP, the Ecuadorian counterpart), with support from the IAEA and other strategic partners such as the University of San Francisco de Quito, and the Korea Program on International Agriculture (KOPIA).

With the start of the pandemic-induced work-from-home period at the IAEA and many of our counterpart institutions, expert missions, fellowships, consultation and coordination meetings, scientific visits and training courses were postponed and rescheduled with tentative later dates. Emphasis was thereafter placed on early procurements for all TC projects, and on the preparation/completion of important technical documents, research articles and books for publication. Alongside, PBG is supporting the development of new Country Programme Notes and concept notes for the 2022–23 TC cycle.

In the PBG Laboratory (PBGL), a small number of staff continued essential activities on five crucial greenhouse projects across barley, coffee, maize, rice and sorghum, and on sub-culturing and maintenance of cell and tissue cultures in the lab, ensuring the continuity of highly valuable genetic material and avoiding loss of invested prior efforts. Sincere appreciation goes to the essential PBGL staff who were involved in this effort! PBGL has resumed irradiation services for seed and vegetative material during the third week of May after temporarily stopping it since 16 March.

In alignment with the PBG mid-term roadmap, **Functional Genomics for Trait Utilization (FGTU)** is becoming an important effort at PBGL to harness emerging genomic technologies such as amplicon sequencing and exome capture to identify and utilize the molecular basis of mutations for marker-assisted breeding.

Following the **First Workshop of the Mutation Breeding Network (MBN)** in Jingzhou, China, during 22–25 July 2019, an update letter was sent to MBN participants in April 2020, the full version of which can be accessed on Page 30. An important ongoing effort reported in this update letter is the assessment of **seed systems models** in Asia through a TC project. The goal is to identify and/or refine successful seed system model(s) that can eventually be tested in a few countries for the dissemination of seeds of mutant crop varieties. A home-based consultancy is in progress to develop a concept note for an initial Consultation Meeting this year. More information will be available once the concept note is ready. Discussions are ongoing for the next MBN meeting and plans for the Achievement Awards in mutation breeding are postponed to 2021.

I thank you for all your support and efforts during these difficult times and look forward to continuing strong collaborations as the year progresses, and beyond. Hoping for a stabilized global situation soon.

Shoba Sivasankar
Head
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[1] Joined in December 2019
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[5] Separated in June 2020

Staff News

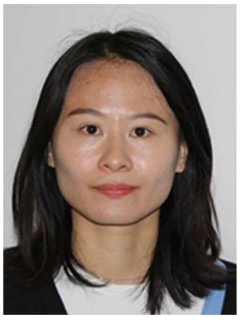
Welcome and Farewell

Starting 15 May 2020, Ms Joanna Mletzko handed over the Team Assistant functions that she provided to the PBGL to Ms Caroline Wafula in view of Joanna's planned relocation to the Yukiya Amano Laboratories later in the year. While we are sad to see Joanna move, we are very thankful for her dedication, friendship and professional support to the PBGL over the many years. As part of the new arrangement, Ms Caroline Wafula will take over from Joanna as PBGL Team Assistant on a part-time basis (50%). We wish Joanna all the best and warmly welcome Caroline as new PBGL team member!

Caroline Wafula

Joanna Mletzko

Farewell



Yuling Yue: On 31 March 2020, we bid farewell to Ms Yuling Yue who had joined the PBGL in May 2019 as an intern from China. Yuling quickly settled in at the PBGL and made important contributions to the CRP on *Striga* resistance to cereal crops, amongst other projects. For example, she successfully completed the work on *in vitro* doubled haploids in rice, which is highlighted in this Newsletter. We want to thank Yuling for her dedication and hard work during her stay at the PBGL and are very pleased that she will continue her professional development as a PhD student at the University of Zurich in Zurich, Switzerland.

Zhu Li: On 30 June 2020, we bid farewell to Ms Zhu Li who had joined the PBGL in June 2019 as an intern from China. Zhu also got quickly up to speed at the PBGL and contributed to the projects on mutation breeding for resistance to drought and the parasitic weed *Striga* in sorghum and rice, and in molecular marker analysis. Our sincere thanks to Zhu for her valuable contributions to the PBGL. Zhu, it was great having you on board and we wish you the very best in your future endeavours!

Forthcoming Events

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

Third Research Coordination Meeting (RCM) on Improving Resilience to Drought in Rice and Sorghum through Mutation Breeding, D23031, Jakarta, Indonesia, 12–16 October 2020. (More information on Page 10)

Second Research Coordination Meeting (RCM) on Disease Resistance in Rice and Wheat for Better Adaptation to Climate Change, D23032, Vienna, Austria, 27–30 October 2020. (More information on Page 10)

Consultants Meetings

Consultants Meeting on Integrated Breeding of Major Mutant Traits for Food Security and Climate-Smart Agriculture, Vienna, Austria, 12–16 October 2020. (More information on Page 10)

Other Meetings

Training Course on Advanced Plant Mutation Breeding and Molecular Markers for the Development of Green Crop Varieties, RAS5077, Seibersdorf, Vienna, Austria, 28 September–2 October 2020. (More information on Page 24)

First Project Coordination Meeting on Enhancing Productivity and Resilience to Climate Change of Major Food Crops in Europe and Central Asia, RER5024, Ankara, Turkey, 5–9 October 2020. (More information on Page 24)

First Coordination Meeting on Enhancing Crop Productivity through Climate Smart Crop Varieties with Improved Resource Use Efficiency (AFRA) RAF5083, Vienna, Austria, 19–23 October 2020. (More information on Page 24)

Training Course on Plant Mutation Breeding and Efficiency Enhancing Techniques for Climate Change Adaptation, RER5024, Seibersdorf, Vienna, Austria, 19– 30 October 2020. (More information on Page 25)

Past Events

Other Meetings

Final Project Coordination Meeting on Improving Yield and Commercial Potential of Crops of Economic Importance, RLA5068, Quito, Ecuador, 2–6 March 2019. (More information on Page 23)

Coordinated Research Projects (CRPs)

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

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

Project Officers: S. Sivasankar; N. Warthmann

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 Officers: L. Jankuloski; I.K. Bimpong

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 10–14 December 2018 in Vienna, Austria. The second RCM is also planned to take place in Vienna, Austria from 27–30 October 2020.

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

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

The CRP officially started in October 2017 and 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 M_3 stage based on phenotyping in the field at M_3 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 Officers: A.M.A. Ghanim; L. Jankuloski

The parasitic weeds *Striga* are major biological constraints to cereal production in most of sub-Saharan Africa and semi-arid tropical regions of Asia. The main objective of CRP D25005 is to develop efficient screening protocols of mutant population of sorghum and upland rice for resistance to *Striga asiatica* and *S. hermonthica*. In addition, the CRP focuses on the use of advanced scientific innovations and technologies for mutant identification and accelerated delivery of resistant varieties to Member States. So far, a total of seven protocols covering field, laboratory and screenhouse screening, and *in vitro* doubled haploid in rice are have been drafted and are at various stages of review. The CRP produced substantial achievements in terms of new protocols, and new sources of *Striga* resistance in farmer-preferred germplasm. Furthermore, preliminary results in sorghum mutants showed that the scope of *Striga* resistance mechanism has been widened through this CRP for the first time. Details of these achievements will be published in the CRP book. The development of doubled haploid technology in rice at PBGL is described on Page 27.

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

Project Officers: I. Ingelbrecht; S. Sivasankar

This CRP set out to develop innovative mutation induction and screening protocols to improve banana and coffee for resistance to Fusarium Wilt Tropical Race 4 (TR4) and Leaf Rust, respectively. Coffee Leaf Rust has created recent epidemics in several countries in Central and Southern America while Fusarium wilt TR4 is devastating Cavendish banana production in South and East Asia, including China and the Philippines, and is also present in Northern Australia, the Middle East and Mozambique. In 2019 TR4 was detected for the first time in South America (Colombia), a major banana exporting region. Under this CRP, efficient TR4 screening protocols have been developed and a new TR4-resistant banana variety was released in China. In case of coffee, new methodologies for mutation induction have been developed and large mutant populations are now available. As this CRP is entering its final months, two protocol books summarizing these achievements are being compiled, one for coffee and one for banana. A total of 12 and 11 protocols have been drafted for banana and coffee respectively, which are now under review. Detailed information regarding progress on the development of a TR4 bioassay at the PBGL on Page 26.

Impact Assessment of Mutant Crop Varieties Developed by BINA, D20003

Project Officer: S. Sivasankar

This is a single-contract CRP awarded to the Bangladesh Institute of Nuclear Agriculture (BINA) to study the economic impact of mutant varieties released by BINA.

BINA is a specialized agricultural research institute in Bangladesh with the mandate to use nuclear techniques in agricultural research to make breakthroughs in crop production to help attain self-sufficiency in food. Using nuclear techniques, the institute has developed 76 mutant crop varieties of different crops (rice, jute, pulse, oil seed and vegetables, etc.), of which 15 are rice mutant varieties. So far, there is no information on the economic performance, varietal acceptability by farmers and constraints to the adoption of the BINA-generated mutant crop varieties in Bangladesh. In fact, no hard data are available on this issue to the farmers, extension workers, donor agencies and policy makers. Considering these, impact assessment study of these mutant crop varieties at the farmers' level and adoptability of mutant varieties is of utmost importance.

Overall Objective

The overall objective is to estimate the economic impacts of promising mutant crop varieties and to find out the best variety among the BINA-developed mutant varieties that contribute significantly in Bangladesh.

Specific Objectives

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

Output

The study will provide the following information: (1) Present economic returns from BINA-developed mutant crop varieties; (2) Best mutant variety with highest farmers' preferences among the mutant varieties developed by BINA; (3) Adoption level of BINA-developed mutant variety; (4) Farmers' constraints in growing mutant variety as the preferred variety; and (5) Socio-economic development of the farmer and country as a whole.

The study is expected to improve understanding of the socioeconomic performances of mutant varieties produced by farmers in the real-world situation faced by them. The results of this project may be useful at both the micro and macro levels. The study will further be helpful for the scientists of the newly developed Agricultural Economics Division of BINA through learning knowledge on techniques of impact assessment for conducting future research activities in Bangladesh.

Forthcoming Events

Consultants Meeting

Integrated Breeding of Major Mutant Traits for Food Security and Climate-Smart Agriculture

Vienna, Austria. 12–16 October 2020

Project Officer: I.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. The improvement of vegetatively propagated crops is 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 to obtain significant genetic diversity. 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.

Third Research Coordination Meeting (RCM)

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

Jakarta, Indonesia. 12–16 October 2020

Project Officer: F. Sarsu

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.

Second Research Coordination Meeting (RCM)

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

Vienna, Austria. 27–30 October 2020

Project Officer: L. Jankuloski

Cereals are the main staple crops of food security for the world’s population, supplying around 42.5% of the global food calorie supply. Rice is grown all over the world and is the main staple food of about 50% of the world’s 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 climates. Wheat provides around one-fifth of all calories and protein for people globally and in developing countries and feeds around 1.2 billion people.

Diseases are among the major obstacles hindering yield improvements, both in rice and wheat. Changing climatic conditions have increased the spread of diseases to new destinations and exacerbated 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, and 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 a 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 the development of the mapping population in order to map and develop molecular marker/s for rice blast and BLB.

The second RCM will be held in Vienna, Austria from 27–30 October 2020. All participants will present progress and achievements since the initiation of the project, and future work plans and activities will be fine-tuned in the following years.

Technical Cooperation Field Projects

Project Number	Country/Region	Title	Technical Officer(s)
ANG5015	Angola	Achieving Drought Tolerant Plants by Inducing Mutation with Gamma Rays	I.K. Bimpong
AZB5002	Azerbaijan	Developing Mutant Cotton Breeding Lines Tolerant to Diseases, Drought and Salinity through Mutation Breeding	F. Sarsu
BDI5001	Burundi	Improving Cassava Productivity through Mutation Breeding and Better Water and Nutrient Management Practices Using Nuclear Techniques	I.K. Bimpong *(Participating)* in collaboration with SWMCN *(Leading)*
BKF5019	Burkina Faso	Improving Food Crop Genotypes for Enhancing Yield and Adaptation to Climate Change Using Mutation Breeding and Isotopic Techniques	L. Jankuloski *(Leading)* in collaboration with SWMCN *(Participating)*
BOT5019	Botswana	Improving Selected Legumes and Cereals against Biotic and Abiotic Stresses to Improve Food Production and Security	I.K. Bimpong
BUL5015	Bulgaria	Increasing Productivity and Quality of Basic Food Crops	F. Sarsu
BUL5016	Bulgaria	Improving the Productivity and Quality of Economically Important Crops through Mutation Breeding and Biotechnology	F. Sarsu
CAF5011	Central African Republic	Building National Capacities for Improving the Efficiency of Biological Nitrogen Fixation for Food Security, Fertility Restoration and Rehabilitation of Degraded Soils	I. Ingelbrecht *(Participating)* in collaboration with SWMCN *(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
COL5026	Colombia	Enhancing Crop Productivity of Creole Potato Using Nuclear and Related Techniques	I.K. Bimpong *(Leading)* in collaboration with SWMCN *(Participating)*
CPR5024	China, People's Republic of	Enhancing the Accelerated Application of Mutant Germplasm and High-Efficiency Breeding in Crops	N. Warthmann
CUB5023	Cuba	Strengthening National Capacities for the Development of New Varieties of Crops through Induced Mutation to Improve Food Security While Minimizing the Environmental Footprint	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*

Project Number	Country/Region	Title	Technical Officer(s)
ERI5011	Eritrea	Developing Improved Banana and Maize Varieties through Mutagenic Nuclear Techniques	A.M.A. Ghanim
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
INS5043	Indonesia	Intensifying Quality Soybean Production to Achieve Self-Sufficiency	A.M.A. Ghanim/L. Jankuloski *(Leading)* in collaboration with SWMCN *(Participating)*
INS5044	Indonesia	Using Nuclear Technology to Support the National Food Security Programme	S. Sivasankar
IRA5014	Iran, Islamic Republic of	Improving Wheat Yield and Stress Tolerance for Sustainable Production	L. Jankuloski
IRA5015	Iran, Islamic Republic of	Enhancing Capacity of National Producers to Achieve Higher Levels of Self-Sufficiency in Key Staple Crops	I.K. Bimpong *(Participating)* in collaboration with FEP *(Leading)* and SWMCN *(Participating)*
IRQ5023	Iraq	Utilizing Nuclear Technology to Improve Key Legume Crops for Climate Change Adaptation	I.K. Bimpong
IVC5039	Cote d'Ivoire	Improving Maize Production in Savannah Areas with Severe Pedoclimatic Degradation in the North of Cote d'Ivoire through the Cultivation of Induced Mutants Adapted to these Areas	F. Sarsu/L. Jankuloski/I. Ingelbrecht/K. Bimpong *(Leading)* in collaboration with APH *(Participating)*
IVC5040	Cote d'Ivoire	Improving Agricultural Production of Maize, Rice and Cassava through Cultivation of Induced Mutant Adaptable to Climatic Changes	I.K. Bimpong
JAM5013	Jamaica	Improving Crops by Using Experimental Mutagenesis and Diagnostic Technologies	S. Sivasankar
JAM5014	Jamaica	Establishing a Self-Contained Gamma Irradiation Facility for the Introduction of Sterile Insect Technique and Experimental Mutagenesis and Diagnostic Technologies	S. Sivasankar *(Participating)* in collaboration with IPC *(Leading)*
KAZ5004	Kazakhstan	Developing Drought Tolerant and Disease Resistant Wheat Varieties with Enhanced Nutritional Content Using Mutation Breeding	F. Sarsu

Project Number	Country/Region	Title	Technical Officer(s)
KEN5038	Kenya	Using Nuclear Techniques to Evaluate and Improve the Impact of Mutated Forages on the Performance of Smallholder Dairy Cows	I.K. Bimpong *(Leading)* in collaboration with APH *(Participating)*
KUW5003	Kuwait	Implementing Mutation Induction to Improve Barley Production under Harsh Environmental Conditions – Phase II	L. Jankuloski
KUW5005	Kuwait	Implementing Mutation Induction to Improve Barley Production under Harsh Environmental Conditions – Phase III	L. Jankuloski
MAG5025	Madagascar	Enhancing Biocontrol of *Striga asiatica* (L.) Kuntze through the Development of Tolerant Rice and Maize Lines and its Links with Microbiological and Ecological Functioning of Soil	L. Jankuloski *(Leading)* in collaboration with SWMCN *(Participating)*
MAG5026	Madagascar	Enhancing Rice and Maize Productivity through the Use of Improved Lines and Agricultural Practices to Ensure Food Security and Increase Rural Livelihoods	L. Jankuloski/S. Sivasankar *(Participating)* in collaboration with SWMCN *(Leading)*
MAL5031	Malaysia	Establishing an Environmentally Sustainable Food and Fodder Crop Production System	L. Jankuloski *(Participating)* in collaboration with SWMCN *(Leading)*
MAL5032	Malaysia	Strengthening National Capacity in Improving the Production of Rice and Fodder Crops and Authenticity of Local Honey Using Nuclear and Related Technologies	F. Sarsu *(Leading)* in collaboration with FEP *(Participating)* and SWMCN *(Participating)*
MAR5023	Mauritius	Improving Landraces of Crucifers (Cauliflower and Cabbage) and Carrot through the Use of Nuclear Techniques for Mutation Breeding and Biotechnology	F. Sarsu
MLW5003	Malawi	Developing Drought Tolerant, High Yielding and Nutritious Crops to Combat the Adverse Effects of Climate Change	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*
NAM5016	Namibia	Developing Drought Tolerant Mutant Crop Varieties with Enhanced Nutritional Content	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*
NAM5017	Namibia	Improving Crops for Drought Resilience and Nutritional Quality	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*
NEP5006	Nepal	Enhancing Productivity of Corps and Fruit Employing Nuclear and Molecular Techniques	I.K. Bimpong
NER5024	Niger	Improving Key Staple Crops towards Food Security	S. Sivasankar

Project Number	Country/Region	Title	Technical Officer(s)
NHE5001	Vanuatu	Enhancing the Productivity and Quality of Crops through the Application of Mutation Breeding Techniques	L. Jankuloski
NIC5011	Nicaragua	Broadening the Genetic Variation of Vegetative Propagated Crops Using Nuclear Techniques	F. Sarsu/I.K. Bimpong
OMA5005	Oman	Enhancing the Application of Mutation Breeding and Supporting Biotechnology Techniques for the Improvement of Important Strategic Crops	A.M.A. Ghanim
PAL5009	Palestine	Enhancing the Performance of Durum Wheat Landraces by Induced Mutation (Phase II)	L. Jankuloski
PAR1005	Paraguay	Establishing National Capabilities in Irradiation Technologies for the Treatment of Patients with Burns and the Introduction of Mutation Breeding for Enhanced Quality and Productivity of Crops	S. Sivasankar *(Participating)* in collaboration with RPRT *(Leading)* and ARBR *(Participating)*
PER5034	Peru	Improving Yellow Potato and Coffee Crops through Mutation Breeding Techniques	L. Jankuloski
PRC5002	Congo, Republic of the	Developing Disease-Resistant Varieties of Cassava and Banana	I.K. Bimpong
QAT5008	Qatar	Developing Best Soil, Nutrient, Water and Plant Practices for Increased Production of Forages under Saline Conditions and Vegetables under Glasshouse Using Nuclear and Related Techniques	A.M.A. Ghanim *(Participating)* in collaboration with SWMCN *(Leading)*
RAF5076	Regional Africa	Improving Crops by Using Mutation Induction and Biotechnology through a Farmer Participatory Approach (AFRA)	F. Sarsu
RAF5083	Regional Africa	Enhancing Crop Productivity through Climate Smart Crop Varieties with Improved Resource Use Efficiency (AFRA)	S. Sivasankar
RAS0080	Regional Asia	Promoting Self-Reliance and Sustainability of National Nuclear Institutions	S. Sivasankar *(Participating)* in collaboration with PCG *(Leading)*, RPRT *(Participating)* and PHY *(Participating)*
RAS5073	Regional Asia	Supporting Climate-proofing Rice Production Systems (CriPS) Based on Nuclear Applications-Phase II	L. Jankuloski *(Leading)* in collaboration with SWMCN *(Participating)*
RAS5075	Regional Asia	Improving Sustainable Cotton Production through Enhanced Resilience to Climate Change	L. Jankuloski *(Leading)* in collaboration with SWMCN *(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)	I.K. Bimpong
RAS5079	Regional Asia	Improving Crop Resilience to Climate Change through Mutation Breeding in Pacific Islands	F. Sarsu
RAS5088	Regional Asia	Enhancing Crop Productivity and Quality through Mutation by Speed Breeding (RCA)	S. Sivasankar
RER5024	Regional Europe	Enhancing Productivity and Resilience to Climate Change of Major Food Crops in Europe and Central Asia	F. Sarsu
RLA5068	Regional Latin America	Improving Yield and Commercial Potential of Crops of Economic Importance (ARCAL CL)	F. Sarsu
RLA5084	Regional Latin America	Developing Human Resources and Building Capacity of Member States in the Application of Nuclear Technology to Agriculture	S. Sivasankar *(Leading)* in collaboration with SWMCN *(Participating)* and APH *(Participating)*
RWA5001	Rwanda	Improving Cassava Resilience to Drought and Waterlogging Stress through Mutation Breeding and Nutrient, Soil and Water Management Techniques	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*
SAF5016	South Africa	Promoting Mutation Breeding of Vegetables to Improve Rural Livelihoods — Phase I	N. Warthmann
SEY5011	Seychelles	Supporting Better Sustainable Soil Management as Climate Change Adaptation Measures to Enhance National Food and Nutrition Security	L. Jankuloski *(Leading)* in collaboration with SWMCN *(Participating)*
SIL5020	Sierra Leone	Enhancing the Concurrent Selection and Evaluation of Biofortified and Bio-enriched Varieties Derived from Mutant Rice, Cassava and other Crops	I.K. Bimpong
SIL5021	Sierra Leone	Improving Productivity of Rice and Cassava to Contribute to Food Security	I.K. Bimpong *(Leading)* in collaboration with SWMCN *(Participating)*
SRL5050	Sri Lanka	Supporting Genetic Improvement of Tea	S. Sivasankar
SUD5037	Sudan	Applying Nuclear Techniques to Improve Crop Productivity and Livelihood of Small-scale Farmers in Drought Prone Areas	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*
SWA5002	Eswatini, Kingdom of	Improving Adaptability of Cowpea to Climate Change through Mutation Breeding	L. Jankuloski
THA5056	Thailand	Strengthening Food Safety Laboratory Capacities	F. Sarsu *(Participating)* in collaboration for FEP *(Leading)*

Project Number	Country/Region	Title	Technical Officer(s)
TOG5002	Togo	Improving Crop Productivity and Agricultural Practices through Radiation Induced Mutation Techniques	I.K. Bimpong *(Participating)* in collaboration with SWMCN *(Leading)*
TUN5029	Tunisia	Developing Barley and durum Wheat Resilience to Drought and Heat Tolerance through Mutation Breeding	F. Sarsu
UGA5041	Uganda	Developing Disease Resistant High Yielding Farmer Preferred Cassava Varieties in Uganda through Induced Mutation Breeding	L. Jankuloski/I.K. Bimpong
URT5030	Tanzania, United Rep. of	Improving Rice and Barley Production through Application of Mutation Breeding with Marker Assisted Selection	F. Sarsu/L. Jankuloski
URT5032	Tanzania, United Rep. of	Developing Maize Cultivars for Improved Yield and Resistance to Viral Disease	F. Sarsu
URT5037	Tanzania, United Rep. of	Developing Rice Varieties with Resistance to Rice Blast and Salinity Tolerant Using Mutation Breeding and Biotechnology Techniques	L. Jankuloski
YEM5015	Yemen	Enhancing Sorghum and Legume Crop Productivity through Induced Mutations with Supportive Breeding and Bio-Technologies	A.M.A. Ghanim
ZAI5026	Congo, Democratic Republic of the	Improving Productivity and Quality of Crops (Soybean and Maize) Using Induced Mutation and Biotechnology	L. Jankuloski/I.K. Bimpong
ZAI5029	Congo, Democratic Republic of the	Enhancing Crop Productivity of Soybean and Maize through Improved Mutant Varieties and Lines	I.K. Bimpong
ZAM5031	Zambia	Improving the Yield of Selected Crops to Combat Climate Change	F. Sarsu *(Leading)* in collaboration with SWMCN *(Participating)*

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

Highlights of Technical Cooperation Projects

Namibia is Increasing the Production of Drought-Tolerant Mutant Cowpea Seeds for Dissemination to Farmers

Agriculture is a major contributor to the Namibian economy and is highly correlated to growth and development. The country has semi-arid and arid regions and is one of the driest countries of Sub-Saharan Africa; consequently, crop yields are severely limited by drought. Most of the crops are grown under rainfed conditions and the land is prone to severe soil degradation. Rainfall is low and erratic with an annual average between 300–700 mm.

As a collaboration between the Government of the Republic of Namibia through the Ministry of Agriculture, Water and Land Reform (MAWLR) and the International Atomic Energy Agency (IAEA), with the support of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, a mutation breeding programme was initiated with the objective of developing new mutant lines/varieties with high yield potential and enhanced tolerance to drought conditions. The focus has been on cowpea and sorghum.

The IAEA and the FAO supported Namibia through the transfer of technology and helped to build capabilities in plant mutation breeding. Seeds of local varieties of the two crops were treated with gamma rays at the FAO/IAEA's Laboratories, Seibersdorf, Austria. Training involved targeted techniques in the generation of new genetic diversity through mutation induction and in the field evaluation of mutant populations for selection of improved lines with drought tolerance.

MAWLR, with the assistance of the Joint FAO/IAEA Division, has enhanced existing seed varieties of cowpea and sorghum through this project and developed and pre-released seven cowpea and four sorghum mutant varieties in 2017. The high-yielding cowpea varieties serve as a supplement to the already existing varieties of cowpea, which have been in the farming community since 1999. Mr Percy W. Misika, the Executive Director of MAWLR, said that "Primarily, five mutant varieties have been selected for multiplication to ensure that there is adequate foundation seed to the cooperatives for their members to produce certified seed which will subsequently be sold to the farmers for grain production. However, insufficient foundation seed of the mutant varieties has significantly delayed the distributions and access of improved seed varieties by all potential farmers."

During the 2019–20 cropping season, MAWLR has produced 2 000 kg of foundation seed to be distributed to at least 50 farmers in six regions of Northern Namibia for the 2020–21 cropping season. This amount is expected to produce 33 tons next season which will be sufficient to target 750 farmers the following season (2022) to produce certified seeds (500 tons). This amount is sufficient to target all potential cowpea growers in the country during the 2023 cropping season.

Multiplication of foundation seed for the pre-released cowpea mutant variety BrR4P11.

Mannheim Crop Research Station's Acting Chief Agricultural Technician, Loide N. Aron, carrying out field inspection at the multiplication of foundation seed.

Multiplication of foundation seed for the pre-released cowpea mutant variety NkR8P9 growing at Mannheim Crop Research Station, Namibia.

Cotton Mutation Breeding in the Asian Region

Cotton has a special significance and plays an important role in the economies of Australia and Asian countries, China, India, Iran, Myanmar, Pakistan, Viet Nam and Bangladesh. This leading fibre crop is grown on 20.5 million hectares in the three main cotton producing countries of Asia i.e. China, India and Pakistan, with an annual contribution of about 60–65% in total world production of cotton.

Existing cotton varieties grown in the region are highly sensitive to extreme periods of heat stress resulting in decreasing yield and poor fibre quality. Development of high yielding, drought/heat tolerant and good fibre-quality cotton varieties is necessary for sustainable cotton production in the region. Use of induced mutations is an important approach to plant breeding for improvement of crops. The Joint FAO/IAEA Division through the technical cooperation project RAS5073, supported Bangladesh, Cambodia, China, Indonesia, Iran, Myanmar, Pakistan, Syrian Arab Republic and Thailand in human capacity building and technical advice to develop cotton varieties with improved yield and fibre quality.

Agriculture plays a central role in Pakistan's economy, and cotton has a significant role in driving the country's economy, contributing to 5.2% of the agricultural value added and 1% of the country's GDP. Increasing temperatures and frequency of climate extremes such as heat waves show an observed trend in Pakistan, and future projections based on climate modelling suggests a continuation of this trend. Year-to-year variation in yields of the cotton crop due to climate change is not only impacting the farming industry negatively, but also straining the positive development of cotton-based industry in Pakistan and in the region. The Joint Division's Plant Breeding and Genetics Section (PBGS) has supported the Nuclear Institute for Agriculture and Biology (NIAB) scientists for more than 30 years, providing equipment and technology packages for mutation breeding, as well as staff training through fellowships and national and regional training courses. Intensive collaboration through technical support and early technology transfer for mutation breeding has led to the release of four improved cotton mutant varieties since 2016 (NIAB 2008, NIAB 878, NIAB 545 and NIAB 1048). These varieties are adaptable to climate change, with improved tolerance to heat, higher yield, early maturity and with improved fiber quality.

These four mutant cotton varieties have gained popularity among the cotton farming community of Pakistan due to their wider adaptation potentials, their ability to sustain yield under changing climatic scenario, and good fiber quality - an important criterion in textile industry. In 2018, about 20% of a total of 1.88 million hectares planted to cotton in Pakistan (Panjab province) was covered with improved mutant cotton varieties. Due to the excellent performance of the improved cotton varieties, they are highly preferred by farmers and currently cover about 40% (774490 *ha*) of the total area.

Besides Pakistan, the following countries have successfully initiated their first cotton mutation breeding programme and developed mutant populations and advanced mutant lines with the support received from PBGS:

Thailand has developed one advanced mutant line with improved fibre quality and resistance to the leaf roll disease.

Bangladesh has developed nine M_4 cotton mutant lines with improved yield and fibre quality.

Iran has developed twenty-five M_4 cotton mutant lines with improved yield, earliness and fibre quality.

Myanmar has developed eight M_5 cotton mutant lines with improved agronomic characters.

Syria has developed fifteen M_3 cotton mutant lines with improved drought tolerance.

Cambodia has developed M_2 population.

IAEA through the Joint FAO/IAEA Division will continue to provide technical advice and knowledge to the countries in the region towards variety release and dissemination to farmers.

https://www.iaea.org/newscenter/news/mutant-varieties-satisfy-market-and-add-usd-6-billion-to-pakistans-economy

Seed multiplication of cotton mutant varieties and advanced mutant lines

Practical lectures in Pakistan with RAS5075 participants.

Practical lecture in cotton field in Myanmar.

Rice Mutant Variety Helps Farmers in Malaysia to Increase Yields and Income

Rice is the most important food crop contributing to food security in Malaysia and worldwide. The negative effects of climate change such as flood, drought, heat and salinity are major constraints affecting sustainable agricultural productivity in Malaysia. Most cultivated areas depend on rainfall. Despite the advances in increasing yields, abiotic and biotic factors continue to limit productivity. The use of mutation induction for creating useful new germplasm and developing new improved varieties is a highly feasible approach to crop improvement.

The Joint FAO/IAEA Division has helped Nuclear Malaysia to develop many improved crop varieties that are more tolerant to climate change. Support from the PBGS has included expertise, technical support and policy advice through several fellowships, training courses and workshops. It has also included field days, where farmers, seed companies and other stakeholders have been able to visit demonstration fields and see the results for themselves.

Most recently, through the project RAS5073, the Joint FAO/IAEA Division supported scientists from Nuclear Malaysia to strengthen human capacities to developed improved rice varieties and to promote and disseminate rice mutant variety to farmers.

The new rice mutant variety, NMR152, was developed by Nuclear Malaysia through mutation breeding techniques. NMR152 is a high yielding variety that was tested in farmers' fields before being released.

According to the testimony of farmers who have grown NMR152, yields of 7,5 *t/ha* is the average. In the Northern part of Malaysia, the farmer, Mohd Khairul Anuar B Abdul Raman grew this variety and harvested a yield of 9 *t/ha*.

At a Regional workshop on "Farmers filed days to support the end users and disseminate technologies packages on improved mutant varieties" the mutant line NMR152 was presented to farmers and seed companies.

The NMR152 rice mutant variety is preferred by farmers for its high yield and nutrient use efficiency. Farmers who have tested the variety have reported a 10% lower fertilizer use. Nuclear Malaysia has teamed up with two companies for seed production and multiplied 300 tons of seeds of NMR152. These seeds are expected to be sufficient for farmers to plant over 2,000 hectares of rice in Malaysia. Currently, the seeds are in the process of being disseminated to farmers for the upcoming planting season. It is expected that this mutant variety will cover up to 10,000 hectares in the country in the coming years.

Web links:

https://www.iaea.org/newscenter/news/malaysias-nuclear-agency-and-partners-bring-improved-rice-variety-to-countrys-farmers

https://www.iaea.org/newscenter/news/nuclear-package-helps-farmers-increase-rice-yields-and-income-in-northern-malaysia

https://www.iaea.org/newscenter/news/nuclear-technology-helps-southeast-asia-boost-climate-proof-rice-experts-demonstrate

Nuclear Malaysia signed agreement with seed companies for seed multiplication.

Harvest of NMR152 rice mutant variety during demonstration filed days with farmers and seed companies.

Seed multiplication of NMR152 rice mutant variety.

Jamaica Turns to Mutation Breeding as a Way Forward to Combat Deadly Ginger Disease

Ginger (*Zingiber officinale* Rosc., Zingiberaceae) is a valuable medicinal plant and has commonly been used as a spice and herbal medicine for more than 2000 years. Recent popularity of ginger has been attributed to its broad spectrum of biological and pharmacological applications including its antitumor, antioxidant, anti-inflammatory and antiapototic, cytotoxic, antidiabetic properties. Available data from the International Trade Center (2019), indicates that the total untapped export potential of ginger is estimated to be about 660 million United States Dollars (US$660). Jamaica was once documented as the leading producer of ginger in the world. However, ginger production over the past 20 years has significantly declined due to a disease commonly known as rhizome rot.

Ginger rhizome rot is a complex problem caused by both fungi (*Phythium aphanidermatum* and *Fusarium oxyporium*), bacteria (*Ralstonia solanacearum*) and nematodes (*Meloidogyne sp*.). The disease is prevalent in all major ginger production areas in Jamaica and it severely affects seed rhizomes resulting in a complete crop failure. The affected rhizomes become soft and pulpy, and on pressing, it collapses very easily due to the rotting of internal tissues. Leaves of affected plants turn yellow and have water- soaked areas that rot at the basal portion which leads to the shoots to finally wilt and collapse. Yield losses of ginger in Jamaica is estimated to be about 50–90 percent in the major production areas. The adverse effects of chemical control methods emphasize the need for the production of resistant cultivars. Mutation breeding has the potential to develop new genetic diversity in ginger lines with built-in resistance to the pathogen during plant growth. An ongoing IAEA project in Jamaica aims to improve local ginger varieties using mutation breeding and related biotechnology tools, thereby producing plants that are resistant to the disease. This is expected to lead to the production of high-quality ginger with appreciable yields to prevent the high economic losses currently being experienced by Jamaica local farmers.

The Joint FAO/IAEA Division provides technical support to the Biotechnology Department of the Scientific Research Council (SRC) and the Ministry of Industry Commerce, Agriculture and Fishery (MICAF-Bodles Research Station) through the project JAM5013, Improving Crops by Using Experimental Mutagenesis and Diagnostic Technologies.

Mutation induction of some popular Jamaica ginger varieties has been carried out at the IAEA/PBG laboratories in Seibersdorf, Austria and sent to Jamaica with the aim of developing resistant ginger mutants to combat the Rhizome rot disease. At SRC in Jamaica, the mutant lines are being advanced through multiplication, acclimatization, screening and selection of tolerant mutant plantlets.

To date, over 120 irradiated ginger mutants (M_1V_4) have been transferred from an upgraded *in vitro* growth rooms (Figure 1), to a shaded house for acclimatization prior to screening and identification of putative mutants (Figure 2). A new screenhouse facility has also been constructed with the inclusion of illumination system to initiate the screening and selection of putative mutants with resistance to the disease (Figure 3). Facilities at the tissue culture laboratory have also been upgraded through procurements of modern equipment to enhance the disease screening capacity of the diagnostic laboratories at the SRC.

The project has led to the enhancement of plant diagnostic competencies in the country where scientists/Lecturers from different institutes such as SRC, University of the West Indies (UWI), Northern Caribbean University (NCU) and MICAF have been trained through national training workshop (Figure 4), international fellowships and expert missions, with emphasis on phytopathological techniques for selecting disease resistance. This has enabled the Counterpart team to develop screening protocols to identify resistant traits in ginger mutant lines. It is expected that the project will lead to crop improvement of ginger in Jamaica for the international market.

Figure 1. Mutant lines in tissue culture growth room upgraded to LED illumination at the SRC.

Figure 2. Hardened mutant lines the shade house at the SRC.

Figure 3. Screen house constructed (A) and greenhouse upgraded (B) for the screening of mutant lines.

Figure 4. Fifteen (15) participants trained in phytopathological techniques at the SRC/IAEA workshop 13–16 May 2019.

Past Events

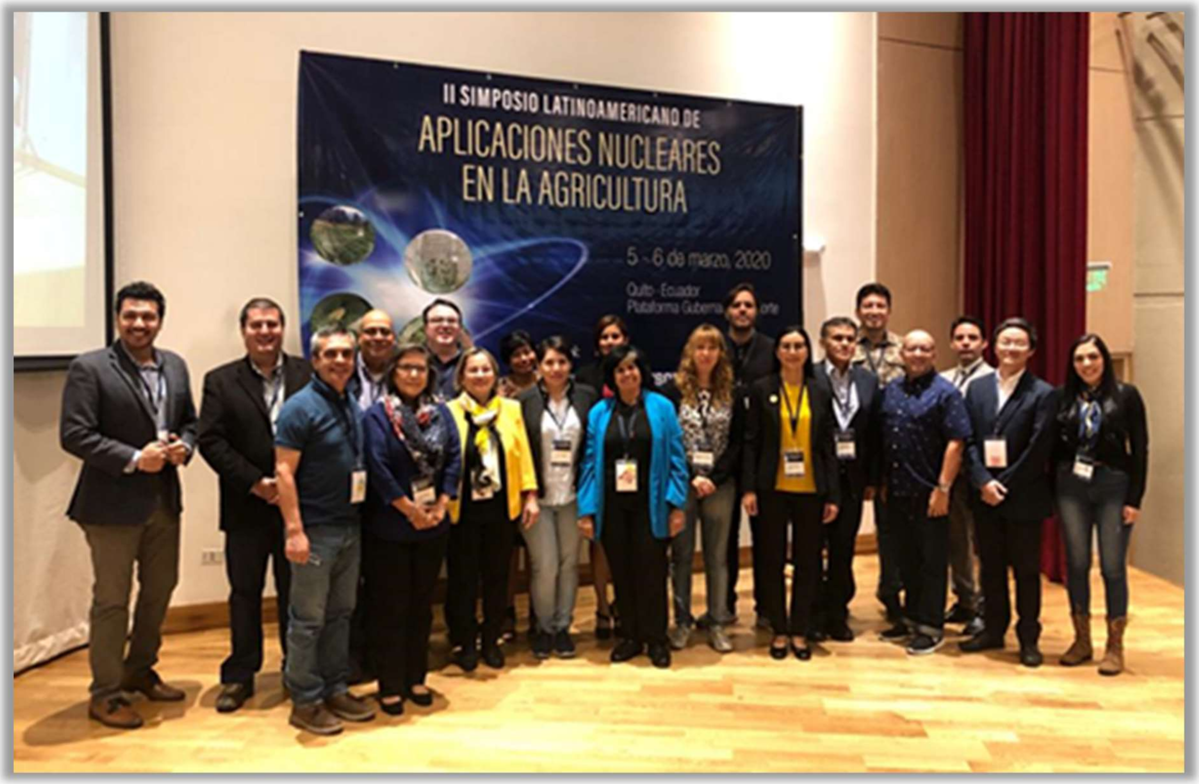
Final Project Coordination Meeting
Improving Yield and Commercial Potential of Crops of Economic Importance, RLA5068

Quito, Ecuador. 2–6 March 2020

Project Officer: F. Sarsu

The final project coordination meeting was conducted successfully and met its objectives and expected outputs. The project participants of RLA5068 have managed to develop many mutant lines including an herbicide-resistant rice mutant line in Brazil and Quinoa advanced mutant lines in Peru. Tomato and soybean advanced mutant lines are in the process of being released. The participating countries have all developed mutant lines which are expected to be released in the coming years. The project contributed to capacity building through regional training courses. Additionally, several undergraduate, master's and doctoral theses have been supported within the framework of the project. After four years, the 2016–2019 cycle was successfully closed with 18 participating countries in the region. The group demonstrated an outstanding performance and strong teamwork skill.

In a joint effort, the project ended with the Second Latin American Symposium on Nuclear Applications in Agriculture, which was organized by the National Institute for Agricultural Research (INIAP – the Ecuadorian counterpart), with support from the IAEA and other strategic partners, such as the University of San Francisco de Quito and the Korea Program on International Agriculture (KOPIA). It provided opportunities for participants of the regional project to demonstrate their new mutant lines and to disseminate the fruitful results of their work. The Technical Officer, Programme Management Officer and counterparts were among the 39 speakers who presented 45 research papers at the Symposium, including oral and poster presentations, highlighting their respective results.



Meeting participants of the Second Latin American Symposium on Nuclear Applications in Agriculture.

Forthcoming Events

Training Course

Advanced Plant Mutation Breeding and Molecular Markers for the Development of Green Crop Varieties, RAS5077

Seibersdorf, Vienna, Austria. 28 September–2 October 2020

Project Officer: I.K. Bimpong

Course Director: I. Ingelbrecht

The objective of the training course is to strengthen Member States' understanding and research laboratory capacities in advanced plant mutation breeding and molecular genetics techniques. These capabilities are necessary for mainstreaming applications in plant mutation breeding techniques, molecular genetics and bioinformatics tools for development of green crop varieties.

The training course will consist of lectures, demonstrations, and practical exercises on (i) Introduction to mutation breeding and its application in development of new crops, radiosensitivity study and estimation of optimal irradiation doses for breeding purposes, population development and data analysis of mutant, ii) Genotyping techniques, platforms, breeding informatics and decision support tools in mutation breeding, iii) Next Generation Sequencing (NGS) and applications for mutation breeding.

The course is for participating Member States involved in the project RAS5077. The Member States eligible to participate in this regional training course are Bangladesh, China, Fiji, India, Indonesia, Republic of Korea, Lao P.D.R., Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Palau, Philippines, Sri Lanka, Thailand, Viet Nam, and qualified scientists actively involved in the national working groups of the project.

First Project Coordination Meeting

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

Ankara, Turkey. 5–9 October 2020

Project Officer: F. Sarsu

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 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 available traits.

The overall objective of the project is to support the production of major food crops with higher yields, improved quality, and better resilience to climate change through mutation breeding and combined biotechnologies in order to contribute to food security in Europe and Central Asia. The expected outcome is the enhanced productivity and resilience to climate change of major food crops in the region.

The purpose of this first coordination meeting are to review the workplan of the new TC project RER5024 on Enhancing Productivity and Resilience to Climate Change of Major Food Crops in Europe and Central Asia and agree on regional activities to be implemented during 2020–2024; to establish a national workplan of the participating 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.

First Coordination Meeting

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

Vienna, Austria. 19–23 October 2020

Project Officer: S. Sivasankar

The project RAF5083 (AFRA) follows the most recent regional project, RAF5076, and builds upon previous initiatives and redirects regional attention towards neglected and underutilized food crops that are indigenous to Africa, while progressing the current efforts in all crops towards upscaling. The project is intended to enhance human capacities in both seed and vegetative crops. It will contribute to the improvement of process efficiencies and statistical rigor in field-testing for the selection of improved varieties; advance modalities for informal and formal seed systems for the multiplication and dissemination of quality seed; and develop capacities for the use of newly developed varieties for molecular characterization towards process efficiencies in future selection.

Nuclear techniques, such as the use of gamma irradiation for inducing mutations, in combination with related biotechnologies are efficient in breeding programmer for crop improvement and support efforts in enhancing crop productivity and yield stability. Induced mutations facilitate the creation of rapid genetic variability and broaden the traditional germplasm base, thus enabling more effective crop improvement. In addition, innovative new technologies, such as doubled haploidy, rapid cycling and marker-assisted selection, allow the reduction of normally long breeding times to almost half. The current project on mutation breeding for improved yield, quality and/or tolerance to abiotic and biotic stresses allows the low-input agriculture in sub-Saharan Africa and in most of the continent contribute to crop production with minimal environmental costs.

The First Coordination Meeting of the project will bring together representatives from participating Member States to discuss the project work plan and training needs for this four-year project. The meeting will also discuss current status of ongoing projects, existing infrastructure facilities, and existing technical capabilities for plant mutation breeding in both seed and vegetative crops.

The meeting will be open to designated counterparts of the project RAF5083.

Training Course

Plant Mutation Breeding and Efficiency Enhancing Techniques for Climate Change Adaptation, RER5024

Seibersdorf, Vienna, Austria. 19–30 October 2020

Project Officer: F. Sarsu

The training course will be organized under the Regional TC project RER5024 on Enhancing Productivity and Resilience to Climate Change of Major Food Crops in Europe and Central Asia. The objective of the training course is to strengthen Member States' understanding and research laboratory capacities in basic and advanced *in vitro* and molecular genetic techniques for improved mutation detection and selection. These capabilities are necessary for mainstreaming applications of *in vitro* plant cell and tissue culture techniques, molecular genetics and bioinformatics tools for improved resilience to climate change. The course will be compromised of practical and theoretical sessions on if) Scientific background of mutation induction and its application to crop breeding (Induced mutation, radio sensitivity test, handling mutated populations *in vivo* and *in vitro*); ii) Utilization of appropriate *in vitro* technologies for accelerated breeding (Double Haploids, embryo culture); iii) Marker-assisted Breeding and molecular marker application in mutation breeding; iv) Principles of genetic mapping (Recombination, Linkage data and segregation analysis); v) Next Generation Sequencing (NGS) and applications for mutation breeding.

Developments at the Plant Breeding and Genetics Laboratory (PBGL)

Transboundary Plant Diseases: A Protocol for Verification and Screening in Mutation Breeding for Resistance to Fusarium Wilt TR4 in Cavendish Banana

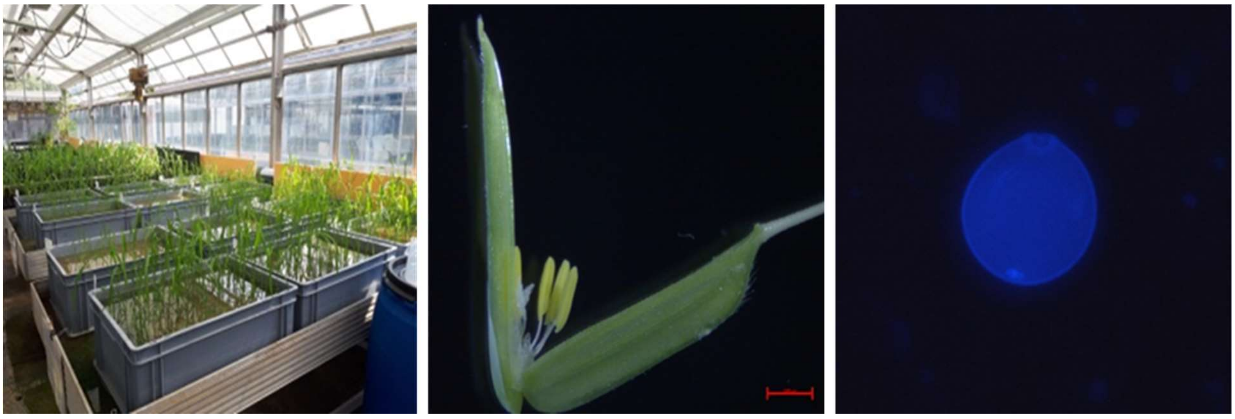
Fusarium exospores TR4 (Fox TR4) is a soil born pathogen that infects the banana roots causing obstruction of xylem vessels. This results in leaf wilting and, ultimately, necrosis and plant death. Fusarium Wilt TR4 is devastating Cavendish banana production globally. In the context of the CRP D22005 on 'Efficient Screening Techniques to Identify Mutants with Disease Resistance for Coffee and Banana' a protocol is being optimized at the PBGL to enable screening of mutant populations and verification of putative mutants of banana with resistance to Foch TR4 identified by Member States.

The *in vivo* bioassay was adapted to PBGL conditions using a TR4 susceptible Cavendish banana under contained, environmentally controlled conditions. The bioassay is carried out in trays containing 24 plants each for increased throughput. Two methods are used to measure TR4 symptom development: (1) a non-destructive Leaf Symptom Index (LSI) based on visual screening of leaf wilting; (2) a destructive Rhizome Discoloration Index (RDI) which assays discoloration of the inner rhizome. For these experiments a TR4 susceptible banana control variety is first multiplied *in vitro* and hardened using previously established procedures. TR4 symptom establishment requires successful infection of banana by the fungal pathogen and phenotypic expression of TR4 symptoms in the banana plants. Experiments were conducted to optimize the production of the TR4 inoculum, to compare two inoculation methods (liquid culture versus a millet seeds inoculum) and to determine the optimal TR4 concentration for symptom development. The millet seed inoculation method proved more robust compared to inoculation using liquid cultures. The entire process from *in vitro* multiplication to scoring of the symptoms takes approximately five months. Results for millet seed inoculation method followed by LSI and RDI scoring are illustrated in below Figure. As shown below, leaf wilting typical for TR4 infection can be visually scored and differentiated from natural leaf senescence in three-month-old banana plants using a 12 g millet seed inoculum. RDI scoring can be performed to confirm visual screening of leaf wilting as shown also in the following figure. This optimized protocol will be validated on known TR4 resistant cultivars and for verification of candidate TR4 resistant banana putative mutants generated under CRP D22005.

Leaf symptom development of a control TR4 susceptible non-inoculated banana plant (left) as compared to plants inoculated with 6 g (middle) and 12 g millet seed inoculum (right). Both leaf symptoms and root discoloration scoring methods for the evaluation of TR4 induced symptoms are shown.

Optimization of Doubled Haploid Technology to Accelerate Rice Mutation Breeding

Doubled haploid (DH) technology allows to rapidly produce homozygous plants which increases the efficiency of selection in mutation breeding. Most mutations induced through physical and chemical mutagenesis techniques are recessive and thus can only be expressed and observed in the homozygous condition. That is why selections for putative mutants normally starts at the M_2 generation as M_1 is usually heterozygous. By integrating doubled haploidy technology in mutation breeding the efficiency of mutant selection can be drastically increased through fixation of mutant traits in homozygous lines. In the context of CRP D25005 on mutation breeding for resistance to *Striga* in cereals, the PBGL optimized and integrated DH technology in rice mutation breeding. Using a few rice varieties selected by Member States together with a known responsive rice genotype called Taipei 309, procedures for haploid production by anther and pollen-shed methods were optimized. The material was grown in the PBGL glasshouse during May to November. The donor plants were kept in proper condition, fertilized with Yoshida solution once a week and well-watered. Spikes were collected at the appropriate stage after checking the right stage of the uninucleate microspore under microscope. Collected spikes were wrapped in wet tissue papers and kept at 4°C for about seven days. Sterilized anthers were cultured *in vitro*, either on liquid medium as conventional method or on a layer of liquid medium on top of a solid medium to liberate the pollen and induce haploid tissues. Once haploid tissues are obtained, they can be regenerated into haploid plants. Varieties responded differently to haploid induction and regeneration of green haploid plants. Haploids plants were produced equally from M_1 and parent plants of the respective varieties. The frequency of spontaneous doubling of haploid plants ranged between 30–40%. Flow-cytometer was used to verify haploid plants before chromosome doubling by colchicine treatment. Doubled haploid seeds were harvested from all varieties in about one year from planting of donor plants to harvest. These results are encouraging to expand large scale application of the methods in rice mutation breeding. Detailed protocols will appear in the book of protocols which will be published as an output of the CRP together with protocols of screening and characterization of mutants for resistance to *Striga* in cereals.



Photos from left to right showing; (i) donor rice plants propagated in the glasshouse (left); (ii) anther at the right stage for collection and in vitro culture (middle); and, (iii) microspore view under fluorescent microscope, stained with DAPI, showing the correct, late uninucleate stage for in vitro culture for haploid induction (right).

Photo left showing opened anther and mass of propagating microspores ready to be shed in the culture medium; right photo showing regenerated haploid plants ready for transfer to soil in the glasshouse.

Software Development: Computational Workflows for Mutation Detection

PBGL has sequenced more than 500 genomes over the past two years! With samples ranging from sorghum, rice, cowpea, tomato, and coffee. We use whole-genome re-sequencing to discover new mutations in mutant populations and for genetic mapping, where we establish causal links between a phenotype and the underlying genetic locus. PBGL strives to enable Member States to fully participate in the genomics revolution and thus enhance their Mutation Breeding projects. Whole genome re-sequencing with short read technology is cost-effective. DNA sequencing capacity is readily accessible around the world through competing sequencing service providers. PBGL identified the challenges of genome data analysis as one major obstacle for adoption by Member States.

Turning the raw sequencing data that comes off the sequencing machine into meaningful information for the plant breeder requires a series of computational steps: Quality control and trimming followed by alignment of each of the millions of sequencing reads to a closely related reference genome assembly, removal of PCR duplicates, consolidation of the alignments by realigning small Insertions and Deletions, and, finally, reading through the alignments and finding differences between the sequenced samples. This process yields a long list of genetic variants that then need to be further filtered and, ideally, visualised.

Many software tools for all steps in the process are publicly available, however, conducting such analysis with the off-the-shelf software requires substantial bioinformatics skills and experience. It is currently still more complicated than it needs to be. For our own analyses, we at PBGL have chained together existing publicly available software into computational workflows using *snakemake*, a workflow language build in Python. With such workflows, all analysis is fully reproducible and transferring the workflows to different datasets and crops is straightforward. The workflows are available from PBGL upon request and we are currently working towards making them publicly available.

Genome-wide Screening of Coffee Genes for New Mutations through Exome Capture

PBGL is actively involved in CRP D22005 where one objective is to develop innovative mutation induction techniques in arabica coffee to allow producing and screening large mutant populations for discovering rare valuable mutant alleles. In cooperation with CRP counterparts, especially Costa Rica, the PBGL has successfully induced mutations in coffee and currently over 500 mutant coffee plants (M_1 generation) are growing in the shade greenhouse in Seibersdorf, Austria.

Coffea arabica mutant populations growing in the PBGL shaded greenhouse, Seibersdorf, Austria. The populations are developed in cooperation with ICafe, Costa Rica and have been produced using chemical (EMS) and physical (gamma rays) mutagenesis. The plants are about two years old and some are about to make their first flowers.

Given the low probability of a beneficial mutation and the high-cost and long waiting times for assessing the coffee plants and beans, it is desirable to somehow pre-screen the mutant plantlets before planting them in the field. This would allow for focusing the trials on plants with promising mutations in candidate genes and pathways.

PBGL has chosen to pioneer the so-called exome capture sequencing technique in *Coffea arabica.* We will sequence all genes in our 500+ mutant coffee plants and identify novel, induced mutations by comparing the gene sequences of the mutants to those of wildtype plants. If successful, this technology will provide a cost-effective means for PBGL as well as for Member States to characterize mutant coffee plants and make this new diversity more readily available to the coffee breeding community.

Target capture techniques exploit the property that complementary DNA strands hybridize with each other to form a double strand. Using a set of synthesized oligonucleotides, a complementary (target) DNA molecule can be captured and in turn extracted from a mixture; hence the general name: target capture. In our case, the targets will be all exons of all genes, hence it is called 'exome capture'. Sequencing only the exome reduces the sequencing cost per sample significantly compared to sequencing the whole genome. Together with a commercial provider, PBGL has developed an Exome capture kit for *Coffea arabica*. The kit is now available from Arbor BioScience (Ann Arbor Michigan, USA) as a regular product for broad community use.

Crop Irradiation Services Provided to Member States

Due to the COVID-19 situation with related travel and shipment restrictions imposed by governments worldwide, a reduced number of requests were received by the PBGL during this reporting period. Furthermore, PBGL's crop irradiation service has been on hold between 13 March and 15 May 2020. At this time of writing (18 May 2020), the PBGL has received requests from seven Member States across 9 plant species covering a total of 38 varieties for crop irradiation as summarized in Table 1.

Table 1. Crop Irradiation Services

Request Number	Country	Request Type	Crop
1623	Ireland	Other	Eucalyptus
1624	Germany	Other	Ornamental
1625	Hungary	Other	Ornamental
1626	The Netherlands	Other	Ornamental
1627	Zambia	CRP	Cowpea, Groundnut
1628	Tanzania	TC	Rice
1629	Eswatini (Swaziland)	TC	Cowpea

Individual Training

Table 2 summarizes PBGL's training activities during this reporting period. Due to the COVID-19 situation, all individual fellow trainings planned for this reporting period have been postponed until further notice.

Table 2. Individual Training Activities at the PBGL

Name	Country	Status	Topic	Period
Ms Yuling YUE	China	Intern	Drought/*Striga* screening protocols and doubled haploids in rice and sorghum	8 months
Ms Zhu LI	China	Intern	Drought/*Striga* screening protocols in rice and sorghum	11 months
Mr Anza GHAFFAR	Pakistan	Intern	Computational Workflows for Mutation Detection	9 months

Reports

Mutation Breeding Network (MBN) Updates

1 May 2020

Mutation breeding activities and collaborations in the Asia Pacific Region continue through IAEA Technical Cooperation Projects (TCPs) and Coordinated Research Projects (CRPs), although Fellowships, Internships and Scientific Visits have been postponed from the originally planned dates. The list of IAEA TCPs and CRPs are routinely reported through the bi-annual Newsletter of the NAFA-PBG Section of IAEA.

- The Regional Asia RCA project, RAS5077, will have two regional training courses in July 2020 (Malaysia) and September 2020 (Vienna), and its final review meeting in November 2020 (Malaysia), subject to the evolving COVID-19 situation.
- A single-contract new CRP has been initiated with the Bangladesh Institute of Nuclear Agriculture (BINA) for a socioeconomic study on the impact of mutant rice varieties from BINA.
- A new IAEA Collaborating Centre, Gamma Greenhouse, has been established at the Malaysia Nuclear Agency in September 2019.
- A new IAEA Collaborating Centre for Nuclear Techniques in Plant Mutation Breeding has been established at the Institute of Crop Sciences, Chinese Academy of Agricultural Sciences in November 2019.
- The IAEA Collaborating Centre for Plant Mutation Breeding for Climate Smart Agriculture established at the National Nuclear Energy Agency of Indonesia (BATAN) continues to operate for the duration of 2017-2021. Many IAEA activities related to plant mutation breeding including joint research, meetings, scientific visits and trainings for the Asia-Pacific and Africa regions are being conducted.

A new effort through an IAEA TCP is currently in development to study **seed system modalities** in the Asia Pacific Region with the goal of identifying or refining successful seed system models that can be tested in a few countries for the dissemination of seeds of mutant crop varieties. A home-based consultancy is in progress to develop a concept note for an initial Consultancy Meeting this year in Vienna. More information will be available once the concept note is ready.

A **special issue on Plant Mutation Breeding** is currently in development by the open access journal, Plants (ISSN 2223-7747, https://www.mdpi.com/journal/plants). Contributions of articles can be submitted until 31 July 2020 at https://www.mdpi.com/journal/plants/special_issues/plant_mutation_breeding.

Discussions are ongoing for the next MBN meeting and plans for the Achievement Awards in mutation breeding are postponed to 2021.

It is hoped to provide similar brief updates on a bi-annual basis. If any of the participating countries have announcements related to mutation breeding R&D, they can also be communicated through these updates.

MBN Steering Committee:

Luxiang Liu (Chair)

Soeranto Human

Vikash Kumar

Shoba Sivasankar

Announcements

An online portal for Crop Irradiation Service to be open soon

A portal for the FAO/IAEA Joint Division's Crop Irradiation Service is currently in development, to be open for Member States by the end of the year to place irradiation requests for mutagenesis of seed or vegetative plant material as the first step in plant mutation breeding. This portal is also planned to allow the documenting, distributing and sharing of information on FAO/IAEA's Crop Irradiation Services, thus promoting its use.

The Joint FAO/IAEA Division's Plant Breeding and Genetics Laboratory (PBGL) has been working on the establishment of an online portal that would facilitate the online submission of requests for irradiation services of both seed and vegetative material. The portal is also planned to be linked to a database that would document information related to the PBGL's Crop Irradiation Service. It is intended to provide functionality for documentation, records access with the ability to download statistics, and generally encourage use by third parties. The portal would promote the use of nuclear techniques for generating novel genetic diversity for plant mutation breeding and crop improvement.

Since the 1950's, the application of mutation techniques in plants has generated a vast amount of genetic variability and is playing a significant role in plant breeding and genetics and advanced genomics studies. The use of mutation techniques in plant breeding programmes throughout the world has generated thousands of novel crop varieties in hundreds of crop species, and billions of dollars in additional revenue.

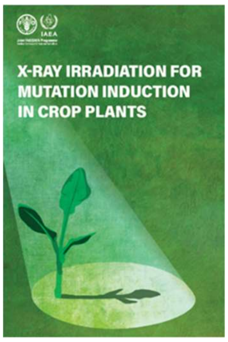
Since the 1960's the FAO/IAEA Plant Breeding and Genetics Laboratory has provided crop mutagenesis services to the FAO and IAEA Member States. Both X- and gamma-ray irradiation services are provided. By January 2019, the PBGL provided a total of 1578 irradiation service requests from Member States. Since each request invariably involves multiple crop species and/or crop varieties, the actual number of irradiated samples is manifold higher than 1578. Ongoing continuous demand for mutagenesis treatments illustrates the value of nuclear technologies for plant breeding and genetics. Thus far about 80% of all FAO and IAEA Member States have submitted requests for mutagenesis service to the FAO/IAEA PBG Laboratory.

The portal or database, that would be functional soon, is the result of a collaborative effort of PBGL with the IAEA IT group as part of an IT innovations competition, "IT Innovations Challenge", offered by the IT group and to which the PBGL had submitted a proposal for digitizing the laboratory's crop irradiation services.

A snapshot of the Joint FAO/IAEA Division's Crop Irradiation Service.

Publications

Books



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

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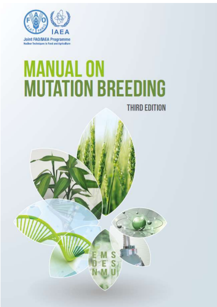

Manual on Mutation Breeding, Third Edition

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
ISBN 978-92-5-130526-3

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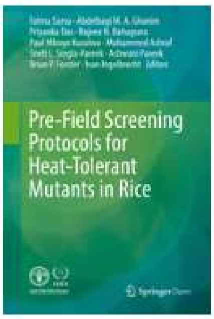


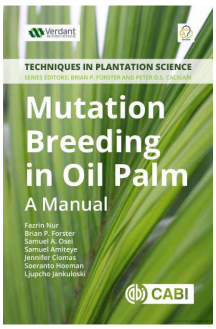
Pre-Field Screening Protocols for Heat-Tolerant Mutants in Rice

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.

Springer (2018)

ISBN 978-3-319-77338-4

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



Mutation Breeding in Oil Palm: A Manual

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

CABI Publishing (2018)

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

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

Peer-reviewed Publications

2020

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

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

HAWLICZEK, A., BOLIBOK, L., TOFIL, K., BORZĘCKA, E., JANKOWICZ-CIEŚLAK, J., GAWROŃSKI, P., KRAL, A., TILL, B.J. and BOLIBOK-BRĄGOSZEWSKA, H. Deep Sampling and Pooled Amplicon Sequencing Reveals Hidden Genic Variation in Heterogeneous Rye Accessions. (*submitted)*

JANKOWICZ-CIESLAK, J., GOESSNITZER, F., DATTA, S., VILJOEN, A., INGELBRECHT, I., and TILL, B.J. Induced Mutations for Generating Bananas Resistant to Fusarium Wilt Tropical Race 4. Chapter 9, Section 4. Mutation Breeding in the Post-Genomic Era. Proceedings of the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology. (*in press*)

MBA, C., ABANG, M., DIULGHEROFF, S., HRUSHKA, A., HUGO, W., INGELBRECHT, I., JANKULOSKI, L., LESKIEN, D., LOPEZ, V., MUMINJANOV, H., MULILA MITTI, J., NERSISYAN, A., NOORANI, A., PIAO, Y. and SAGNIA, S. (2020). FAO Supports Countries in the Implementation of the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture. Acta Hortic. 1267, 197-208.
DOI: 10.17660/ActaHortic.2020.1267.30.
https://doi.org/10.17660/ActaHortic.2020.1267.30

RABEFIRAISANA, H.J., GHANIM, A.M.A., ANDRIANJAKA, A., RASOAMAMPIONONA, B., JANKULOSKI, L., RAZAFINDRASOA, M.A., RAVELONJANAHARY, N.H., RAKOTOARISOA, N.V. Impact of Mulch-Based Cropping Systems Using Green Mulch and Residues on the Performance of Advanced Mutants Lines of Maize (*Zea mays* (L.)) Under Infested Field with the Parasitic Weed *Striga asiatica* (L.) Kuntze in Madagascar. Chapter 18. Section 2. Mutation Breeding in Crop Improvement and Climate-Change Adaptation. Proceedings of the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology. (*in press*)

ROY, S., GHANIM, A.M.A., NUNEKPEKU, W., RASHIDUL ISLAM, MD. RASEL AND MD. MAHMUD AL NOOR (2020). Phenotyping of Lentil Genotypes for Drought Tolerance Using Polyethylene Glycol. Indian Journal of Natural Sciences ISSN: 0976–0997; Vol.10, Issue 58, February 2020.

2019

PANTCHEV, I., AZIZ, S., SARSU, F., TOMLEKOVA, N. (2019) Applicability of ISAP, ISSR and SSR Markers in Tomato Breeding Programs. Vegetable Crops of Russia (6):24-26.
https://doi.org/10.18619/2072-9146-2019-6-24-26

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.
https://doi.org/10.1155/2019/9692053

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.
DOI: 10.3389/fmicb.2019.02531

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.
DOI: 10.1534/g3.119.400301

2018

TILL, B.J., DATTA, S., JANKOWICZ-CIESLAK. J. (2018) TILLING: The Next Generation. In: Advances in Biochemical Engineering/Biotechnology. Rajeev K. Varshney et al. (eds.), Springer.
DOI: 10.1007/10_2017_54

AMRI, W.T., LAOUAR, M., ABDELGUERFI, A., JANKOWICZ-CIESLAK, J., TILL, B.J. (2018) Genetic Variability Induced by Gamma Rays and Preliminary Results of Low-Cost TILLING on M_2 Generation of Chickpea (*Cicer arietinum* L.). Frontiers in Plant Science-Plant Breeding 9:1568. DOI: 10.3389/fpls.2018.01568

DATTA, S., JANKOWICZ-CIESLAK. J., NIELEN, S., INGELBRECHT, I., TILL, B.J. (2018) Induction and Recovery of Copy Number Variation in Banana through Gamma Irradiation and Low Coverage Whole Genome Sequencing. Plant Biotechnology Journal.
DOI: 10.1111/pbi.12901

GRONENBORN, B., RANDLES, J.W., DENNIS KNIERIM, BARRIÈRE, Q., VETTEN, H.J., WARTHMANN, N., CORNU, D., SILEYE, T., WINTER, S., TIMCHENKO, T. (2018) Analysis of DNAs Associated with Coconut Foliar Decay Disease Implicates a Unique Single-Stranded DNA Virus Representing a New Taxon. Scientific Reports 8, Article number: 5698.
DOI: 10.1038/s41598-018-23739-y

ZHANG, C, SIMPSON, R.J., KIM, C.M., WARTHMANN, N., DELHAIZE, E., DOLAN, L., BYRNE, M.E., WU, Y., RYAN, P.R. (2018) Do Longer Root Hairs Improve Phosphorus Uptake? Testing the Hypothesis with Transgenic *Brachypodium distachyon* Lines Overexpressing Endogenous RSL Genes. New Phytol. 2018 Jan 17; 157:97.

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. bioRxiv preprint first posted online 24 October 2018.
http://dx.doi.org/10.1101/451567

BACHIRI, H., DJEBBAR, R., MEKLICHE, A., DJENADI, C., GHANIM, A.M.A. (2018). Carbon Isotope Discrimination as a Physiological Marker to Select Tolerant Wheat Genotypes (*Triticum aestivum* L.) Under Water Limited Conditions. American Journal of Plant Physiology SSN 1557-4539, DOI: 10.3923/ajpp.2018.1-7

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

KAMAL, N.M., ALNOR GORAFI, Y.S., TSUJIMOTO, H., GHANIM, A.M.A. (2018) Stay-Green QTLs Response in Adaptation to Post-Flowering Drought Depends on the Drought Severity. BioMed Research International Volume 2018, Article ID 7082095.
https://doi.org/10.1155/2018/7082095

BAHUGUNA, R.N., GUPTA, P., BAGRI, J., SINGH, D., DEWI, A.K., TAO, L., ISLAM, M., SARSU, F., SINGLA-

PAREEK, S.L., PAREEK, A. (2018) Forward and Reverse Genetics Approaches for Combined Stress Tolerance in Rice. Indian Journal of Plant Physiology. https://doi.org/10.1007/s40502-018-0418-0

BADIGANNAVAR, A., TEME, N., OLIVEIRA, A.C., LI, G., VAKSMANN, M., VIANA, V.E., GANAPATHI, T.R., SARSU, F. (2018) Physiological, Genetic and Molecular Basis of Drought Resilience In Sorghum [*Sorghum bicolor* (L.) Moench]. Indian Journal of Plant Physiology. https://doi.org/10.1007/s40502-018-0418-0

ŞEN, A., SARSU, F. (2018) Genetic Diversity in Sodium Azide Induced Wheat Mutants Studied by SSR Markers. Trakya University Journal of Natural Sciences 19(2):129-135. DOI: 10.23902/trkjnat.424305

ŞEN, A., SARSU,F. (2018) Evaluating of Salt Stress Tolerance in Selected Wheat Mutant Progenies with Contributing Expression Analysis of TaWRKY Genes and Antioxidant Defence Parameters, Celal Bayar University Journal of Science 14 (3): 315-320.
DOI: 10.18466/cbayarfbe.430620

Conference Abstracts and Posters

2020

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

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

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

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.

Success Stories

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Websites and Links

- Plant Breeding and Genetics Section:
  http://www-naweb.iaea.org/nafa/pbg/index.html

- InfoGraphic on Mutation Breeding:
  http://www-naweb.iaea.org/nafa/resources-nafa/Plant-Mutation-breeding.mp4

- Mutant Variety Database:
  http://mvd.iaea.org

- Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture:
  http://www-naweb.iaea.org/nafa/index.html
  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/

Impressum

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