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To Our Readers

Dear Colleagues,

FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology, 27–31 August 2018.

I am honored, proud and excited to take on the responsibilities as Section Head for Plant Breeding and Genetics (PBG) within the Joint FAO/IAEA Division of Nuclear Applications in Food and Agriculture. Plant mutation breeding has long played a globally recognized role in the development of improved crop varieties. Not fully realized or utilized yet is the potential of the technology in present times to create sufficient and rapid genetic variation for accelerated genetic gain in food, feed, fodder and cash crops. This potential has critical significance in the face of

two most important challenges currently threatening the planet: pressures on food security from a growing population; rate of climate change and the need for rapid adaptation of crop plants to it.

Induced mutations create more rapid changes in the genome than that normally occurs spontaneously in nature. Nuclear technologies offer a tried-and-proven avenue to safely and easily induce mutations. Heritable positive genetic changes and their associated phenotypes are routinely selected for the development of improved crop varieties. In the present post-genomic era, the molecular bases of these changes are elucidated more easily than ever before with cost- and time-efficient sequencing technologies, combined with precise phenotyping. Such information constitutes the foundation for molecular breeding in its different connotations. Beyond routine crop improvement, the combination of induced mutations and current genomic technologies thus constitute a powerful and cost-efficient functional genomics platform to identify molecular markers for forward breeding, and candidate genes for biotechnology. In crop improvement per se, the ability of induced mutations to create rapid evolutionary change, and the combination with 'speed-breeding' technologies such as doubled haploids, shuttle breeding and marker-assisted selection can accelerate the pace of developing improved crop varieties.

Building on the shoulders of the giants who have been here before us, the current Plant Breeding and Genetics team is excited at the tremendous potential of the mutation breeding technology in present times to not just directly improve crop varieties, but to also serve as a foundational platform for molecular information that supports other crop improvement methodologies. While excited, we realize well the challenges involved: (1) precise phenotyping is as crucial for confident calls of gene-to-phenotype (marker-trait) associations as it is for confident selections; (2) establishment of a bioinformatic workflow to understand these associations requires concerted effort and time; (3) complex traits call for genomic selection methodologies rather than simple marker-trait associations; etc.

With this introduction, I am happy to present the contributions of the PBG subprogramme over these last six months. A key event for the subprogramme during this period was the hosting of the **International Symposium on Plant Mutation Breeding and Biotechnology** during 27–31 August 2018 in Vienna, Austria. The Symposium marked the 90th anniversary of the first successful use of induced mutations in crop breeding and genetics research by Lewis John Stadler. It was attended by 350 delegates (official number) from 84 Member states, two Non-Member States and four international organizations. The event was structured around selected plenary lectures, thematic sessions with keynote addresses, contributions by participants in the form of oral presentations and posters, and a panel discussion on *Current Challenges and Future Vision for Mutation Breeding*. Topics covered by the Symposium include: (1) Contribution and impact of mutant varieties to food security; (2) Mutation breeding for adaptation to climate change in seed propagated crops; (3) Mutation breeding for ornamental and vegetatively propagated crops; (4) Enhancing agro-biodiversity through new mutation induction techniques; and (5) New challenges and technologies in plant genomics and breeding. These sessions highlighted new developments, trends and challenges in the field of plant mutation breeding and biotechnology and fostered a broad exchange of information within the scientific community, and with the private sector. The Symposium discussed specific challenges faced by Member States, including emerging transboundary threats to crop production, and assessed the overall importance of mutation breeding to food security. More than 80 lectures and about 220 posters were presented at the symposium. The proceedings of the Symposium will be published in 2019 and will include 40–50 manuscripts covering the different sessions.

A **Scientific Forum on Nuclear Technology for Climate: Mitigation, Monitoring and Adaptation** was held during the 62nd General Conference on 18–19 September 2018, at the Vienna International Centre, and this included a session on **Adapting to a Changing Environment**. At this session, Mr Liu Luxiang, Professor at the Institute of Crop Science, Chinese Academy of Agricultural Sciences, gave a presentation on Mutation Breeding for Crop Adaptation to Climate Change which highlighted the importance of nuclear techniques in broadening genetic diversity to facilitate the development of improved crop varieties adapted to changing environments.

At another significant event during the second half of this year, the **IAEA Ministerial Conference on Nuclear Science and Technology** (27–30 November 2018, Vienna, Austria), Prof Luz Rayda Gomez Pando, Principal Professor in the Department of Crop Science at the National Agrarian University La Molina and our counterpart in Peru, discussed the implications of mutation breeding in crop adaptation to climate change. Climate change causes increasingly significant damage to agriculture, putting food production at risk in various parts of the world. Peru, located in South America, is a vulnerable country and it is estimated that production per hectare will be reduced by 17% by 2050 if temperatures rise by 2°C and rainfall varies by 20%. This would severely affect the availability of food in a country that imports many staple foods such as wheat and corn. Crop adaptation to climate change has therefore become a very critical need. Nuclear techniques in plant mutation breeding play a key role in crop adaptation to climate change. Plant mutation breeding helps to improve the tolerance of crop species to adverse climatic conditions such as high temperatures, drought, and incidence of pests and diseases. It also helps to improve agronomic characteristics of crop species that have a natural tolerance to adverse climatic conditions and are grown only in certain regions of the world such as the highlands of Peru.

The Plant Breeding and Genetics Section currently provides technical support to four Coordinated Research Projects (CRP), two of which held Research Coordination Meetings in the second half of 2018. The CRP on **Efficient Screening Techniques to Identify Mutants with Disease Resistance for Coffee and Banana (D22005)** held its third Research Coordination Meeting (RCM) during 26–30 November 2018 in Guangzhou, China. This was hosted by the Guangdong Academy of Agricultural Sciences. The CRP brings together research teams from Asia, Latin America, Europe and Africa to optimize mutation induction techniques for coffee and banana using *in vitro* tissue culture techniques and to develop technology packages for efficient screening for disease resistance in coffee (leaf rust) and banana (Fusarium wilt). Research progress was reviewed and recommendations for further implementation of the project was formulated during the RCM. The CRP on **Mutation Breeding for Resistance to the Parasitic Weed (*Striga spp.*) in Cereal Crops for Food Security, D25005,** held its second Research Coordination Meeting (RCM) in Vienna, Austria, during 15–19 October 2018. The parasitic weed *Striga* constitutes a major constraint 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 laboratory, screen-house and field protocols to screen mutant populations of sorghum and upland rice for resistance to *Striga asiatica* and to *S. hermonthica*. The CRP also focuses on rapid-cycling technologies, specifically, doubled haploidy and molecular markers for efficient selection and accelerated development of resistant varieties. The RCM discussed the successful optimization of screening protocols by Burkina Faso, Madagascar and Sudan (field and glass-house), and by Kenya, USA and Japan (laboratory protocols). The PBG Laboratory discussed its validation of the screening protocols, and verification of putative mutants developed by participating Member States. **A new CRP is currently in the process of development** through a Consultation Meeting in December 2018. This CRP will focus on selected grain legumes and attempt to tackle specific biotic and abiotic stress constraints imposed by climate change.

PBG, through partnership between IAEA and FAO, provides technical support at this time to 79 TC Projects, including 12 projects that are implemented in collaboration with Soil and Water Management and Crop Nutrition. We are also currently involved in the design process of 30 TC proposals submitted by Member States. These projects span a variety of food crops, and several have a central theme of adaptation to climate change. Significant success arising from past TC projects were reported in the Newsletter of June 2018. Most recently, a mutation breeding project was initiated for the first time in the Pacific Region, 'Improving crops resilience to climate change through mutation breeding in Pacific Islands', for the 2018–2022 timeframe. Participating countries include Fiji, Marshall Islands, Papua New Guinea and Vanuatu. In Africa, Sudan released the mutant groundnut variety, Tafra-1, with terminal drought tolerance and higher yield, performing better than all tested genotypes including the local check. Zambia released two mutant cowpea varieties, Lunkhwakwa and Lukusuzi, both with tolerance to aphids and with better yield than current local varieties. Further, through Technical Cooperation since 2009, Namibia has now established a plant breeding programme for the first time. Newly developed varieties of cowpea (7) and sorghum (4) with better tolerance to drought and with higher yields than local landraces selected by farmers are currently under seed multiplication. In South America, Brazil has developed two advanced mutant lines of rice resistant to the APP (aryloxyphenoxypropionates) group of herbicides, which will help overcome the significant constraint of weedy red rice in rice cultivation.

The PBG Laboratory (PBGL) successfully tested the marker for low lignin of barley, reported in June 2018, in the barley breeding program of Prof Grausgruber, BOKU, Austria. Prof Grausgruber's barley breeding program is aimed at improving the feed quality of the barley variety, Verdant, by stacking the 'hooded' trait of Verdant with the rob1 reduced-lignin trait of the variety, Bowman. The successful testing of the marker kit developed from Bowman in this population supports its use in marker applications in unrelated genetic backgrounds. The marker kit for the reduced-lignin trait of barley has now been transferred to the Member States, Austria and Kuwait. PBGL has also made progress in marker development for a semi-dwarf, early-maturing mutant trait in sorghum. Further, in continuation of the ongoing R&D activities related to the CRP on *Striga* (D25005), PBGL has conducted verification trials using the established protocol for screening of mutant population for resistance to *Striga spp.* A protocol of pot-screening was optimized using varieties of known reaction to *Striga* (resistant vs susceptible) both in sorghum and upland rice and validated on M_2 population of sorghum during January to May 2018. During July to November 2018 the established protocol was used to verify 19 putative mutants of maize (M4–M5) and 12 putative mutants of upland rice identified by the CRP contract holder in Madagascar. The mutants were tested against both *Striga asiatica* collected from Madagascar and *Striga hermonthica* collected from Sudan.

Once again, I am happy to be part of this research community, and look forward to productive interactions, discussions and collaborations with you. At the same time, I thank you all for the strong support, input and efforts over the current reporting period.

Sobhana Sivasankar
Head
Plant Breeding and Genetics Section

Staff

Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture

Name	Title	Email	Extension	Location
Qu LIANG	Director	Q.Liang@iaea.org	21610	Vienna

Plant Breeding and Genetics Subprogramme

Name	Title	Email	Extension	Location
Sobhana SIVASANKAR[1]	Section Head	S.Sivasankar@iaea.org	21626	Vienna
Ljupcho JANKULOSKI	Plant Breeder/Geneticist	L.Jankuloski@iaea.org	21623	Vienna
Stephan NIELEN[2]	Plant Breeder/Geneticist	S.Nielen@iaea.org	21617	Vienna
Fatma SARSU	Plant Breeder/Geneticist	F.Sarsu@iaea.org	21618	Vienna
Marie Madeleine SPENCER LOPES[3]	Consultant	M.Spencer@iaea.org	26844	Vienna
Thomas Henry Noel ELLIS[4]	Consultant			Home based
Katayoun ALLAF	Programme Assistant	K.Allaf@iaea.org	21621	Vienna
Luis Mauricio ALFONZO GODOY	Team Assistant	L.M.Alfonzo-Godoy@iaea.org	21620	Vienna
Ivan INGELBRECHT	Laboratory Head	I.Ingelbrecht@iaea.org	28285	Seibersdorf
Abdelbagi MUKHTAR ALI GHANIM	Plant Breeder/Geneticist	A.Mukhtar-Ali-Ghanim@iaea.org	28268	Seibersdorf
Norman WARTHMANN	Plant Molecular Geneticist	N.Warthmann@iaea.org		Seibersdorf
Mirta MATIJEVIC	Technician	M.Matijevic@iaea.org	28317	Seibersdorf
Joanna Beata JANKOWICZ-CIESLAK	Technician	J.Jankowicz@iaea.org	28275	Seibersdorf
Florian GOESSNITZER	Technician	F.Goessnitzer@iaea.org	28279	Seibersdorf
Adel ALI	Technician	A.Ali@iaea.org	28427	Seibersdorf
Tazirul ISLAM[5]	Field/Greenhouse Worker			Seibersdorf
Indra GIRI	Consultant	I.Giri@iaea.org		Seibersdorf
Joanna MLETZKO	Team Assistant	J.Mletzko@iaea.org	28362	Seibersdorf
Edwin THEKINNEN	Intern	E.Thekinnen@iaea.org		Seibersdorf
Samira TAJEDINI	Intern	S.Tajedini@iaea.org		Seibersdorf

Plant Breeding and Genetics Section
Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture
Wagramer Strasse 5, P.O. Box 100, 1400 Vienna, Austria
Phone: +431 2600 + extension; Fax: +431 26007

Plant Breeding and Genetics Laboratory
FAO/IAEA Agriculture & Biotechnology Laboratories, 2444 Seibersdorf, Austria
Phone: +431 2600 + extension; Fax: +431 26007

[1] Joined in September 2018
[2] Separated in September 2018
[3] Separated in September 2018
[4] Joined in December 2018
[5] Joined in September 2018

Staff News

Section Head

Sobhana Sivasankar

Sobhana (Shoba) Sivasankar is Section Head, Plant Breeding and Genetics, at the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. Shoba has over 20 years of experience leading/managing agricultural programmes and projects, with fourteen years in the seed/biotechnology industry, and about ten years in the public sector including academia. Prior to her current role, Shoba served in the CGIAR as Director for two CGIAR Research Programmes, namely, Dryland Cereals, and Grain Legumes, and led the successful merger of these two programmes into the current Grain Legumes and Dryland Cereals (GLDC) programme for the CGIAR Phase II. Before joining the CGIAR, she worked at Dupont Pioneer at its Headquarters in Johnston, Iowa, leading the development and global coordination of the biotechnology pipeline for agronomic traits from discovery research to early product development. During her career at DuPont Pioneer, her work covered abiotic stress tolerance, nutrient use efficiency, stover digestibility, and the establishment of DuPont's FASTcorn high-throughput phenotyping platform. Shoba has a Master's degree in agronomy from Kerala Agricultural University, India; a PhD from the University of Guelph, Canada, specializing in plant physiology; and an MBA from the University of Iowa, USA. She has over a hundred patent filings, and several peer-reviewed publications.

Farewell

We are sad to bid farewell to two excellent colleagues:

Stephan Nielen left the Agency after his most recent seven years' tenure that included the role of Acting Laboratory Head, and that of Technical Officer. Mr Nielen's engagement with the Plant Breeding and Genetics Section started very early in his career. He joined us first as a JPO in 1997, coming directly from the University, and then continued as Technical Officer until 2004. After a seven-year break during which he worked as research scientist at Embrapa, Brazil, he rejoined the Section in January 2012. Mr Nielen has been a key player in several national and regional TC projects, including AFRA and ARCAL. Several good results from the TC projects were presented at the recent International Symposium in August 2018, one being that of advanced mutants of the important fodder grass Brachiaria in Kenya. Mr Nielen also provided scientific leadership to the OFID grant on coffee mutation breeding and to the Coordinated Research Project on coffee and banana. He was a key player in the development and administration of the Mutant Variety Database. Mr Nielen holds a Masters' Degree in Biology and a PhD in Molecular Cytogenetics, Genetics and Plant Biotechnology, both from the Free University in Berlin.

Marie Madeleine Spencer Lopes recently led the successful coordination and editing of the Manual on Mutation Breeding, Third Edition, for publication; This work was published as a Joint FAO/IAEA effort in July 2018. Though her most recent role in the Plant Breeding and Genetics has been as Consultant, Ms Spencer is not a new face to the Section. In her more than 30 years of experience in plant sciences, she spent over eight years at the Section as Technical Officer providing leadership to Coordinated Research Projects, as well as technical and scientific support to several Technical Cooperation projects. Prior to this role, she led the Soybean Breeding Programme at the University of Tennessee, at Knoxville, USA. Ms Spencer's research focus has been on plant biotechnology, spanning topics on plant physiology using radioisotopes, plant tissue culture (morphogenesis, micropropagation), plant molecular biology on super-nodulating soybean mutants, introgression of RR® genes into elite Tennessean soybean lines, identification of RFLP and SSR markers for high stearic acid, low palmitic and low linolenic acid soybean lines, and most recently on mutation breeding for a variety of traits including abiotic stress tolerance in sorghum and rice. A Senegalese by heart, and a Cape Verdean by birth, Ms Spencer holds a PhD from the University Cheikh Anta Diop, Dakar, Senegal.

Consultant

Thomas Henry Noel Ellis has more than 30 years of experience in plant molecular genetics. He is currently an honorary academic in the Dept of Biological Sciences at the University of Auckland, New Zealand. Before this, he was Director of the CGIAR Research Programme on Grain Legumes based in Hyderabad, India; Professor of Crop Genetics at IBERS Aberystwyth, Scotland; and Associate Head of Crop Genetics at the John Innes Centre in Norwich, UK. He moved to the John Innes directly after completing his PhD at the University of Edinburgh. The focus of his

research in recent years has been on the evolution and diversification of legumes at genomic and phenotype levels.

Interns

Edwin Thekkinen joined the Plant Breeding and Genetics Laboratory (PBGL) in August 2018. He graduated from the University of Nottingham, UK with a BSc in Biotechnology, specializing in crop improvement. In his thesis he studied the susceptibility of tomato mutants to the necrotrophic fungus *Botrytis cinerea*. During his degree, Edwin worked as a research assistant in the analysis of lateral root formation in the model plant *Arabidopsis thaliana* using light sheet fluorescence microscopy at the Plant Science department of the University of Nottingham.

Currently, he is working on our project in the utilization of barley Orange Lemma (*rob1*) mutant in livestock production systems for climate-smart agriculture. The confirmed higher digestibility of the *rob1* mutant in livestock feed is a beneficial genetic trait. Subsequently, *rob1* is aimed to be back-crossed with numerous barley varieties using marker-assisted selection. Edwin's passion in plant sciences will make him a natural fit as an intern to the PBGL.

Samira Tajedini joined the PBGL in May 2018 as an intern. Samira is currently a PhD student at Zabol University, Iran, and conducts her thesis work at the Agricultural Biotechnology Research Institute of Iran (ABRII) in the lab of Mehran Enayati Shariatpanahi. Samira's PhD thesis is titled *Study of Haploidy system in rice and sorghum via androgenesis.*

The objective of Samira's work in the lab is to develop reproducible and workable androgenesis in rice and sorghum. Samira cultures isolated microspores and/or anthers with the goal of producing doubled haploid (DH) plants from M1 mutants, which will then be screened for *Striga* resistance. Being able to produce DH plants greatly accelerates breeding. Samira's work thus contributes to PBGL's project *Enhancing Efficiency of Mutation Breeding for Resistance to Striga in Rice and Sorghum by Optimization and Integration of Doubled Haploid Technology*.

Samira has experience in research and development in plant breeding and biotechnology as well as in extension work. Prior to embarking on her PhD studies, Samira evaluated the performance of Barley Genotypes in Multiple Locations in Iran for her Master's degree. She evaluated the yield stability of 15 farmer-preferred barley varieties in five locations in Iran.

Forthcoming Events

Regional Coordination Meeting on Improving Sustainable Cotton Production through Enhanced Resilience to Climate Change, RAS5075, Bangkok, Thailand, 1–5 April 2019

Project Officer: L. Jankuloski

The negative effects of climate variability and change such as flood, drought, heat, salinity and diseases. are constraints affecting sustainable agricultural productivity globally. With increasing climate change and variability, it is important to develop improved cotton varieties with enhanced adaptability to harsh conditions of high temperatures, drought, soil salinity, acidity or low nutrient availability, as well as resistance to diseases and pests.

Cotton has a special significance and plays an important role in the economies of Australia, Bangladesh, China, India, Islamic Republic of Iran, Myanmar, Pakistan and Viet Nam.

This leading fibre crop is grown on 20.5 million hectares in the three-main cotton producing countries of the Asia and Pacific region i.e. China, India and Pakistan, with an annual contribution of about 60–65% of the total world cotton production. Emerging demands from Viet Nam and Bangladesh for their cotton mill use signifies the increased role of cotton production in the economy of the countries in the region.

This regional coordination meeting will review and assess results obtained since the start of the RAS5075 project in 2016. Regional results and achievements will be compiled, any bottleneck and constraints encountered will be discussed, lessons learned, and proposed solutions will be explored.

The purpose of this reginal coordination meeting is to:

- Review progress, results and achievements;
- Prepare the final project review;
- Develop future guidelines for cotton mutation breeding; and
- Provide future directions and recommendations for cotton mutation breeding in the region.

The regional coordination meeting will be organized in collaboration with the Government of Thailand, Nakhonsawan Field Crop Center, Department of Agriculture.

The regional coordination meeting will be attended by the main counterparts participating in RAS5075 (Bangladesh, Cambodia, China, Indonesia, Islamic Republic of Iran, Malaysia, Myanmar, Pakistan, Syrian Arab Republic and Thailand).

Regional Training Course on Improving Crop Resilience to Drought and Heat Stress, D23031, Suva, Fiji, 22–26 April 2019

Project Officer: F. Sarsu
Course Director: S. Cuquma

This training course will be organized in collaboration with the Fiji Government through the Ministry of Agriculture's Research Division, Koronivia Research Station, Pacific Community (SPC). It is open to candidates from TC project RAS5079 on Improving Crops Resilience to Climate Change through Mutation Breeding in Pacific Islands.

The purpose of this course is to provide participants with theoretical as well as practical information on application of mutation induction on crops of the Pacific Region for better resilience to climate change, specifically drought and heat stress.

The course will include lectures and practical sessions on:

- Mutation breeding procedures/methodologies and handling of mutated populations of crops, specifically taro, sweet potato, banana, yam, bread fruit;
- Identification, evaluation and selection of breeding lines in laboratory and field conditions;
- Genetics of drought-stress tolerance;
- Physiology of drought and heat stress tolerance;
- Pre- field screening methodologies for heat and drought stress tolerance;
- Breeding for abiotic stress, specifically, drought and heat stress through mutation breeding, conventional breeding and utilization of appropriate biotechnologies; and
- Field demonstration and practical sessions.

The participants should be from all participating Member States involved in the project RAS5079, actively working in mutation breeding and have a basic knowledge in crop breeding and *in vitro* techniques. The course will enhance capacities of scientists with at least a M.Sc. degree in plant breeding and genetics. Participants should have a strong affinity and interest in modern plant breeding methods involving induced mutation and mutation screening (high-throughput phenotyping).

Workshop on Farmers Field Days to Support the End Users and Disseminate Technology Packages on Improved Varieties as well as Nutrient and Water Saving Technologies, RAS5073, Kuantan, Malaysia, 29 April–3 May 2019

Project Officer: L. Jankuloski

Rice is the most important food crop contributing to food security in Asia and worldwide. The negative effects of climate change such as flood, drought, heat and salinity are major constraints affecting sustainable agricultural productivity globally. Most cultivated areas depend on rainfall. Despite the advances in increasing yields, abiotic and biotic factors continue to limit productivity.

The contribution of plant breeding to improve rice is remarkable. The use of mutation induction for creating useful new germplasm and developing new cultivars is a profitable approach to improvement. If desired traits are to be enhanced and mutant varieties with high yield, short duration, shatter-resistance, and stress tolerance are to be developed, it is important that various valuable mutant germplasm are generated, identified, and utilized efficiently.

The project objectives are capacity building in Asian countries and developing new improved rice mutant varieties resistant to abiotic and biotic stresses as well as dissemination to farmers.

The purpose of the workshop is to discuss a regional approach and strategy and the role of plant mutation breeding and improved nutrient and water management on socio-economic impacts for national and regional development. The workshop will include:

- Technical/field visit to rice mutant varieties with best nutrient management;

- Case studies of successful dissemination of rice varieties and nutrient and water management practices to farmers;
- Discussion to promote and strengthen collaboration in plant mutation breeding among the regional Asia and Pacific countries, including capacity building;
- Site-specific nutrient management (SSNM) approach and its application;
- Dissemination and partnership in developing crop mutant varieties and best water, nutrient management practices to stakeholders including academia, company/industry and farmer cooperatives; and
- Sharing of information on national plant mutation breeding programme and mapping challenges in the region.

The one-week workshop will include lectures and practicals given by plant breeders and stakeholders/farmers on mutant varieties released, dissemination and collaboration with extension centres, dissemination to farmers and socio-economic impact.

This workshop is part of the regional TC project RAS5073 on Supporting Climate-Proofing Rice Production Systems (CRiPS) Based on Nuclear Applications and will be organized in cooperation with the Government of Malaysia through the Malaysian Nuclear Agency (Nuclear Malaysia). The course is organized for the counterparts from the participating Member States in RAS5073 (Bangladesh, Cambodia, China, Indonesia, Lao P.D.R., Malaysia, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Thailand and Viet Nam).

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

Project Officer: F. Sarsu

This Coordinated Research Project (CRP) is focused on improving rice and sorghum to drought tolerance for climate variability. These two crops are essential staples in the diets of millions of impoverished and vulnerable populations, and therefore any attempt to increase their yields under drought stress could have a major and positive impact in terms of food security and income generation. Eight research contracts, two technical contracts and two agreement holders were awarded under this CRP. The second RCM of the CRP D23031 will be organized in collaboration with the Chinese Government through the Institute of Crop Sciences, Chinese Academy of Agricultural Sciences, in Beijing China.

The meeting objectives are to present progress made in the activities of the project after the first meeting and to review and consolidate the work plan for the next cycle. The participants will 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. They will also report on the development of robust protocols for rapid advancement of generations and of screening packages of mutant populations for drought tolerance. During the RCM, individual project progress will be reviewed and evaluated especially in respect to improved drought tolerance (more information on page 20).

Regional AFRA Training Course on Field Experimental Design and Data Analysis in Mutation Breeding, RAF5076, Quatre-Bornes, Mauritius, 17–21 June 2019

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

This regional training course will be organized in cooperation with the Government of Mauritius through the Food and Agricultural Research and Extension Institute (FAREI). It is open to candidates and project partners in the project RAF5076 on Improving Crops Using Mutation Induction and Biotechnology through a Farmer Participation Approach.

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

The course will include lectures and practical sessions on:

- Application of mutation breeding for crop improvement;
- Establishment of the proper starting material for specific project objectives;
- Breeding procedures, methodologies and handling of mutated population;
- Experimental design for accurate data collection, analysis and interpretations;
- Analysis of experimental data;
- Randomization/replication/control of experimental error;
- Computer applications to agricultural experiments using statistical packages;

- Statistical analysis for breeding;
- Analysis of variance for plant breeding;
- Analysis of multi-locational, multi-year data;
- Interpretation of statistical data for crop improvement;
- Stability and its importance in plant breeding; and
- Using molecular analysis to detect mutations and use of molecular markers in breeding.

Participants should be from all participating Member States involved in the project RAF5076, actively working in mutation breeding and have basic knowledge of crop breeding. The course will enhance the capacities of scientists with at least a M.Sc. degree in plant breeding and genetics. Participants should have a strong affinity and interest in modern plant breeding methods involving induced mutation, mutation screening (high-throughput phenotyping and genotyping) and techniques that can facilitate the breeding process.

Regional Training Course on Farmer Participatory Variety Selection Approach in Plant Mutation Breeding for Important Crops in the Region, RAS5068, San Jose, Costa Rica, June 2019 (Exact date to be decided)

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

This training course will be organized in collaboration with the Government of Costa Rica through Universidad Nacional de Costa Rica. It is open to candidates and project partners involved in the project RAS5068 on Improving Yield and Commercial Potential of Crops of Economic Importance, actively working in mutation breeding, and having basic knowledge in crop mutation breeding and related biotechnologies.

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

The purpose of this course is to provide participants with theoretical as well as practical knowledge. It involves a farmer participatory approach in the selection of mutant lines in important crops for the ARCAL CL region.

The course will include lectures and practical sessions on:

- Handling of mutated populations;
- Evaluation and selection of mutant varieties together with farmers in farmers' fields;
- Participatory variety selection with farmers;
- Increasing the rate of dissemination and adoption of mutant/released varieties;
- Breeders rights and Intellectual Property issues;
- Strategies to fast and efficient variety release; and
- Dissemination of mutant lines/varieties using SMTA in the ARCAL region.

The course is organized for the countries that participate in RLA5068 (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru and Venezuela), and specifically for scientists directly involved in mutation breeding.

Past Events

Regional Training Course on Molecular Techniques Applied in Mutation Breeding, RAS5073, Seibersdorf, Austria, 19–29 June 2018

Technical Officer: L. Jankuloski
Course Director: I. Ingelbrecht

New sequencing and marker genotyping technologies provide opportunities to accelerate selection through molecular breeding. Availability of genomic tools and resources is leading to a new revolution of plant breeding, as they facilitate the study of the genotype and its relationship with the phenotype. Next Generation Sequencing (NGS) technologies are allowing the mass sequencing of genomes, which is producing a vast array of genomic information, which allows discovering new genes, their positions, makes available large collections of molecular markers and allow identification of markers linked to the genes and QTLs. These markers can be used for marker assisted selection, including marker assisted backcross selection or genomic selection.

The regional training course was organized by the International Atomic Energy Agency under the TC RAS5073 on Supporting Climate-Proofing Rice Production Systems (CRiPS) Based on Nuclear Applications. Fifteen RAS5073 participants from Bangladesh, Cambodia, China, Indonesia, Lao PDR, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Thailand and Viet Nam attended the training course. In addition, the training course was attended by six scientific visitors and fellows from three different countries.

The training course covered molecular breeding techniques with specific focus on applications of molecular markers and Next Generation Sequencing (NGS) for mutation breeding of self-pollinated crops. The course consisted of practical experiments and lectures in genetics and molecular techniques, including latest advances in DNA sequencing and bioinformatics tools for the characterization of mutant traits. Approaches for the development and use of molecular markers for plant mutation breeding were also covered.

In addition to the PBGL staff, Dr Tilak Raj Sharma, expert from National Agri-Food Biotechnology Institute, India, provided lectures and practicals during the training course. Dr Sharma gave lectures illustrating the development and application of molecular makers for blast resistance breeding in rice.

The training course provided lectures on theory and practicals covering the following areas:

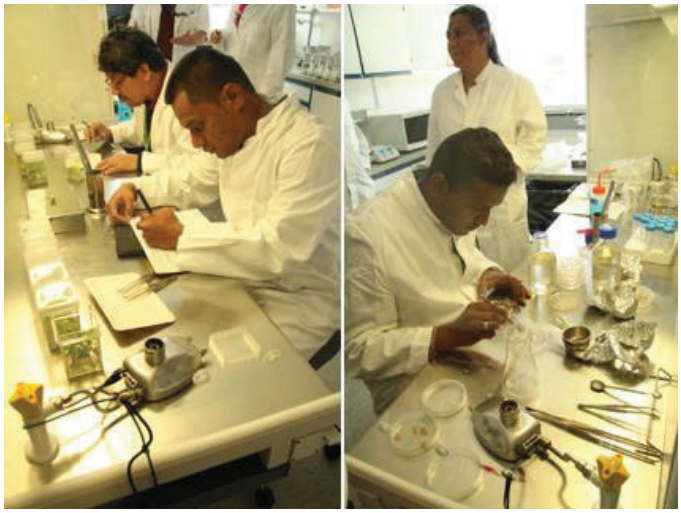
Lectures:

- Mutation induction, development of mutant populations and phenotypic screening;
- Primer in genetics, DNA sequencing and molecular markers;
- Blast disease in rice;
- Developing mapping populations and mapping of blast disease resistance gene;
- Cloning and functional validation of blast resistance genes;
- Application of DNA markers in marker-assisted selection (MAS) for rice varietal development;
- Allele mining for blast resistance;
- Development of allele-specific marker for rice blast MAS;
- Accelerated breeding techniques in cereals;
- Introduction to data analysis;
- Genetic mapping and the role of NGS.

Practicals:

- DNA extraction and quantification;
- Set up of PCR and gel preparation;
- Agarose gel electrophoresis, data interpretation and presentation of results;
- Sequencing library preparation for Illumina sequencing;
- Data analysis (integrative genomics viewer, computer practical);
- Genetic mapping.

In addition to the training course, participants presented their work plans and had a very useful discussion on the most relevant techniques for the targeted plant species in their respective projects. Participants expressed full satisfaction with the content and organization of the training course.



Practical lecture during the training course in PBGL.

Training of fellows and interns from Members States in the use of an allele-specific molecular marker assay for speeding up mutant trait introgression for barley fodder breeding.

Mid-Term Project Coordination Meeting on Improving Crops by Using Mutation Induction and Biotechnology through a Farmer Participatory Approach, RAF5076, Tangier, Morocco, 25–29 June 2018

Technical Officer: F. Sarsu

This meeting was hosted by the Institut National de la Recherche Agronomique (INRA). The meeting was officially opened with a welcome address by Mr Alami Mohamed, Regional Director of Institut National de la Recherche Agronomique (INRA), Morocco, Tangier and opening remarks by Dr Chentouf Mouad, Head of INRA Regional Centre, Tangier. After the opening, Mr Thuloane Tsehlo led participants through the agenda and explained the objectives of both the project and its expected results and those of the meeting. The Technical Officer, Ms Fatma Sarsu, then gave an overview of impact of mutation breeding to food security, recent developments in the field and their impact in Africa and implication to the project.

Project coordinators from eighteen Member States (Benin, Burkina Faso, Burundi, Cameroun, Central African Republic, Democratic Republic of the Congo, Egypt, Ghana, Libya, Madagascar, Mali, Mauritius, Namibia, Sierra Leone, Senegal, Tanzania, Zimbabwe and Morocco (host country)) attended the meeting. Nine Member States (Algeria, Botswana, Cote d'Ivoire, Ethiopia, Lesotho, Niger, Sudan, Tunisia and Zambia) were not represented at the meeting.

Meeting participants.

The overall objective of the meeting was to review progress made under the regional project, plan for the remaining tenure of the project, and identify sustainability mechanisms after completion of the project. The specific intended outputs from the meeting were:

- Status of attending Member States in Mutation Induction and Biotechnology by 1 June 2018;
- Regional work plan 2018–2019;
- Regional project design 2020–2023.

The meeting discussed progress that was being made by individual countries participating in the project, including work plans for 2018–2019. The meeting provided technical advice on how best to implement research activities in the various countries.

The meeting developed forward planning under the regional project. This segment finalized the 2018 and 2019 work plans, discussed work plans for the project for 2020 and 2021 and agreed on experts' requirements during 2018 for member countries. The meeting also discussed the concept note for the new plant mutation breeding project to start in 2020. A full concept document was developed, including Logical Framework Matrix for the new project. The meeting also assessed special support needed by Member States. The Technical Officer (TO) and Programme Management Officer (PMO) had one-on-one meetings with project counterparts and discussed challenges identified in their project implementation.

Although various countries are at various stages in the mutation breeding process, it was noted that advanced mutant lines had already been obtained and mutant varieties released during 2017 and 2018. Namibia released four mutant varieties of sorghum and three of cowpeas by December 2017. The country also had advanced mutant lines for cowpea and sorghum, which were earmarked for release in 2020. Zimbabwe released one drought-tolerant and disease-resistant mutant variety of cowpea in 2017. Zambia released two cowpea mutant varieties with better resistance to aphids and with drought tolerance.

Workshop on Improving Sustainable Cotton Production through Enhanced Resilience to Climate Change, RAS5075, Mandalay, Myanmar, 2–6 July 2018

Technical Officer: L. Jankuloski

Workshop participants.

This workshop was organized in collaboration with the Government of Myanmar, Biotechnology Research Department, Kyaukse, Ministry of Education, Mandalay, Myanmar.

It was attended by RAS5075 counterparts from Bangladesh, Cambodia, Indonesia, Islamic Republic of Iran, Myanmar, Pakistan, Syrian Arab Republic and Thailand.

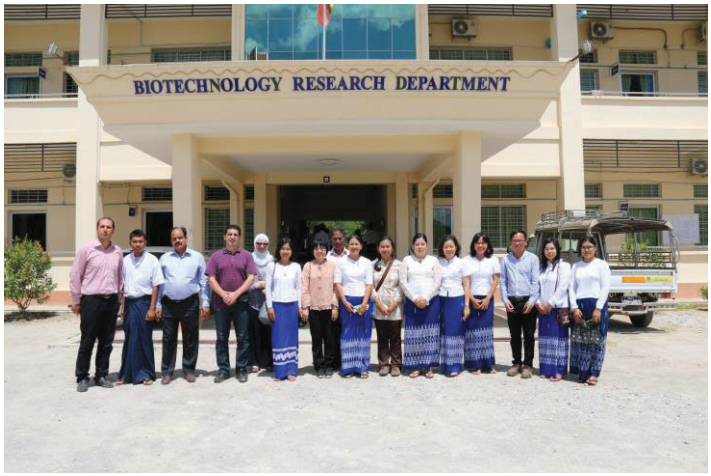
The purpose of the workshop was to provide counterparts with practical lectures for handling mutant populations and to review the current status of cotton mutation breeding in participating countries.

During the workshop, participants visited experimental fields with M_2 populations and M_4 cotton mutant lines. During the visit, Dr Manzoor, expert in cotton mutation breeding from Pakistan, provided theoretical and practical lectures. The practical session of screening and selection in M_2 and M_4 generations was especially valuable for participants. Dr Manzoor demonstrated in the experimental field with M_2 generation the most critical steps and morphological parameters important for screening and selection for drought and heat tolerance in cotton. Participants had an opportunity, under the supervision of Dr Manzoor, to identify mutant plants (based on phenotype) and to screen for putative plants tolerant to heat and drought.

Participants visiting experimental field with M_4 generation.

Participants also visited laboratories at Biotechnology Research Department in Kyaukse. Ms Khin Myat Lwin, host organizer, provided practical lectures on plant tissue culture in cotton, demonstrating the use of different types of material for *in vitro* propagation.

Practical lecture given by Dr Manzoor.



Workshop participants at the Biotechnology Research Department.

During the workshop, participants presented the status of cotton breeding and cotton mutation breeding in their respective countries, expected roles of nuclear techniques and related biotechnologies in the project, as well as gaps and needs for the application of mutation breeding techniques.

After reviewing national cotton breeding programmes and discussion with counterparts, it was concluded that the regional project is progressing as planned. The current achievements from the project are:

- Pakistan released one cotton mutant variety (NIAB 878) in 2017 and two cotton mutant varieties (NIAB 545 and NIAB 1048) in 2018. In addition, many advanced mutant lines with tolerance to drought and fine fiber quality have been developed.
- Myanmar developed 30 M_4 mutant lines with improved agronomic characteristics compared to parent and control line. In addition, Myanmar generated new M_2 population, which was used for practical lectures, and which will support the future development of mutant lines.
- Bangladesh, Islamic Republic of Iran, and Syrian Arab Republic made screening and selection in M_2 in 2017 and established M_3 generation in 2018.
- Cambodia, Indonesia and Thailand joined the regional project in 2017 and are in the initial phase of cotton mutation breeding, irradiation of seed material and generation of M_1 and M_2.

The next reginal coordination meeting will be held in Bangkok, Thailand, 1–5 April 2019.

Training Course on Methodologies and Mechanisms for Screening against Abiotic Stresses, RAS5077, Jakarta, Indonesia, 9–20 July 2018

Technical Officer: S. Nielen

This second training course under the regional TC project RAS5/077 on Promoting the Application of Mutation Techniques and Related Biotechnologies for the Development of Green Crop Varieties (RCA) was organized in cooperation with the Government of Indonesia through the National Nuclear Energy Agency of Indonesia (BATAN) and its Center for Isotopes and Radiation Application (CIRA).

The two-week training course provided thorough theoretical background and hands on training on screening techniques for crop tolerance to various abiotic stresses.

Nineteen scientists from institutes that are actively involved in the national work teams of project RAS5077 participated in the course. The participants came from Bangladesh, Cambodia, China, India, Indonesia, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand and Viet Nam. The Course Director was Dr Soeranto Human from CIRA. Researchers from CIRA and other national institutes, as well as two IAEA expert, Dr Hiroshi Kato (National Agriculture Research Organization, Japan – first week), and Dr Antonio Costa de Oliveira (Federal University of Pelotas, Brazil – second week) provided lectures and prepared and guided practical exercises and demonstrations on the following topics: Mutation breeding for higher yielding rice mutants; Screening for salt and drought tolerance in rice, including use of hydroponics; Transcriptomic analyses of stress related genes; Protocols for screening for iron stress and cold stress tolerance; Bioinformatic approaches to stress tolerance genes; Mutant screening using marker assisted selection.

One of the course days was held at the Ministry of Agriculture Research Center (BALITHI), Cipanas, West Java, and 'Kebun Bunga Nusantara', the Plant Biodiversity Collection in West Java. Here the participants had the chance to learn more about the application of mutation breeding and other nuclear techniques in horticulture.

The success of this course was based on the very good organization at CIRA, the high-quality lectures and practical exercises and the great contribution of the external lecturers, who also had individual discussion with the participants, where fruitful recommendations for the future work on their projects was provided.

Training course participants and lecturers after mutant selection in the field.

International Symposium on Plant Mutation Breeding and Biotechnology, Vienna, Austria, 27–31 August 2018

Scientific Secretaries: L. Jankuloski and I. Ingelbrecht

Over the last fifty years, the Food and Agriculture Organization of the United Nations (FAO) and the International Atomic Energy Agency (IAEA) have played a critical role in supporting their Member States in the use of induced mutation to develop improved crop varieties.

The successful application of gamma rays and other physical and chemical mutagens in plant breeding over the past 90 years has increased crop biodiversity and productivity across the world.

Induced mutation offers many benefits with regard to crop improvement, especially when there is no reliable source of traits (variation) in nature that could be introduced to varieties by conventional breeding techniques such as hybridization. The induced mutation technique is becoming increasingly important to bring about heritable changes in plants and offer new genetic varieties to plant breeders.

Plant biotechnologies are crucial to the effective application of mutation breeding techniques, and they are increasingly being considered for crop improvement to ensure that crops are better adapted to climate change. The application of mutation induction coupled with biotechnologies, genomics and molecular marker techniques can speed up all the main stages of breeding programmes, from the generation of variability, through selection to rapid multiplication of the desired genotypes.

This **International Symposium on Plant Mutation Breeding and Biotechnology** marked the 90th anniversary of the first successful use of induced mutations in crop breeding and genetics research by Lewis John Stadler. The widespread use of induced mutants in plant breeding programmes throughout the world has led to the official release of thousands of mutant crop varieties, resulting in economic impacts measured in billions of USD. Induced mutations have also become an important genetic resource for genomic research and gene discovery during the past decades, which in turn will greatly aid crop breeding activities.

The symposium was attended by 350 delegates (official number) from 84 Member States, two Non-Member States and four international organizations. The symposium provided opportunities to present and discuss current research and technology development in this field and establish linkages among scientists in order to develop knowledge-based breeding strategies. It enabled project managers from international and national organizations, as well as multinational and private companies engaged in plant breeding activities to bring themselves up to date on developments in the application of novel technologies in mutation breeding. Accordingly, the target audience for this symposium included: Plant breeders involved in mutation breeding, Geneticists engaged in applied research related to crop improvement, Molecular geneticists and scientists engaged in basic research, Plant pathologists etc.

The symposium highlighted new developments, trends and challenges in the field of plant mutation breeding and biotechnology and fostered a broad exchange of information within the scientific community as well as with the private sector. This event discussed specific challenges faced by Member States, including emerging transboundary threats to crop production, and assessed the overall importance of mutation breeding to food security. More than 80 lectures and about 220 posters were presented at the symposium.

The symposium was structured around selected plenary lectures, thematic sessions with keynote addresses, contributions by participants in the form of oral presentations and posters, and panel discussion on **Current Challenges and Future Vision for Mutation Breeding.**

This symposium and its deliberations and conclusions provided useful feedback to the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture which will help to address Member States' needs in future programming.

The proceeding of International Symposium on Plant Mutation Breeding and Biotechnology is expected to be published next year and will include about 40–50 manuscripts covering the thematic areas of the symposium.

Regional Training Course on Advanced Tissue Culture Techniques Combined with Mutagenesis for Crop Improvement, RAS5070, Hanoi, Viet Nam, 10–14 September 2018

Technical Officer: F. Sarsu
Course Director: L. Huy Ham

The training course was organized in collaboration with the Government of Vietnam through the Institute of Agricultural Genetics, Centre for Agricultural Biotechnology, Hanoi, Viet Nam. It was open to candidates and partners in the project RAS5070 on Developing Bioenergy Crops to Optimize Marginal Land Productivity through Mutation Breeding and Related Techniques (RCA). It was attended by 19 participants from 16 different countries (Bangladesh, Cambodia, China, India, Indonesia (2), Lao People's Democratic Republic (2), Malaysia (2), Mongolia, Myanmar, Pakistan, Sri Lanka, Thailand and Viet Nam (3)).

Participants, experts and officials of the Agricultural Genetics Institute.

The purpose of this training course was to provide participants with theoretical as well as practical knowledge using mutation induction, on advanced tissue culture techniques combined with mutagenesis for crop improvement, and an application of *in vitro* techniques and *in vitro* screening for biotic and abiotic stress tolerance in crop breeding.

The one-week training course consisted of lectures and practical sessions on:

- Plant tissue culture for mutation breeding;
- Handling mutant plant populations;
- *In vitro* mutation screening methods;
- Application of advanced tissue culture techniques in crop improvement;
- Using doubled haploidy techniques in plant breeding;
- Practical examples of *in vitro* mutagenesis; and
- Security and safety in the laboratory.

This training emphasized practical exercises with skills on applying the above techniques in present and future crop breeding programmes. It was very much appreciated by the participants.

Participants discussing how to select suitable explants for culture initiation using cassava shoots.

Second Research Coordination Meeting on Mutation Breeding for Resistance *Striga* Parasitic Weeds in Cereals for Food Security, D2.50.05, Vienna, Austria, 15–19 October 2018

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

The main tasks of the *Striga* CRP D2.50.02 were to optimize field, screen-house and laboratory screening protocols for resistant mutants to *Striga* in cereals (Sorghum and upland rice), validate protocols to identify mutants, analyse allelism and mechanisms of induced resistance, and develop and integrate efficiency enhancing technologies such as doubled haploidy and molecular markers to accelerate wide use of induced mutations in breeding for resistance to *Striga* by Member States. This second RCM was organized in Vienna at the Vienna International Center (VIC) from 15–19 October 2018. The meeting objectives were to review the progress made in the planned activities during 2016–2018 and agree on the work plans for 2018–2019.

RCM participants.

The meeting was attended by six research and two technical contract holders, two agreement holders and one observer, as well as the staff and concerned Fellows/Interns of the Plant Breeding and Genetics Section and Laboratory. In the first two days of the meeting, contract and agreement holders of the CRP made presentations highlighting their progress on the planned activities during 2016–2018 and their work plans for 2018–2019. These were followed by discussions to assess progress made and challenges faced, and review of work plans. On the fourth day of the meeting, participants visited the Plant Breeding and Genetics Laboratory in Seibersdorf, toured the facilities and has received presentations from the Laboratory Head (Ivan Ingelbrecht), Norman Warthmann and Abdelbagi M.A. Ghanim on the lab activities and prospective lab contributions to the CRP.

It was generally agreed that progress made by participants on planned activities during 2016–2017 was satisfactory and even excellent in certain projects, toward the goals set forth in the first RCM and according to their individual work plans.

Participants, having communicated their individual work plans for the 2018/19 period at the end of their presentations on days one and two, were given input from the group and modified these according to suggested revisions.

It was requested that those involved in field, pot and lab screening draft protocols and submit these to the CRP officer for compilation.

Tasks for all participants to advance mapping activities toward gene identification and marker development for promising mutants (with clear and consistent phenotypes) were identified and agreed upon. Research contract holders in Burkina Faso, Madagascar and Sudan were requested to choose the top three mutant genotypes from each crop they are targeting toward this goal.

Specific recommendations were made for those producing mutagenized germplasm improving screening in field (at least two sites) and pots for mutant verification.

Advanced generations of top 10 mutants from Burkina Faso, Madagascar and Sudan will be shared with the PBGL to be distributed to laboratories of Technical and Agreement holders for characterization and fine phenotyping to determine possible mechanisms of *Striga* resistance.

It was suggested to organize the third RCM in Nairobi, Kenya, at the Biosciences Eastern and Central Africa (BecA) Hub facility.

Regional Training Course on Mutation Induction and Molecular Marker Applications for Crop Improvement, RAF5076, Morogoro, United Republic of Tanzania, 22–26 October 2018

Technical Officer: F. Sarsu
Course Director: P.M. Kusolwa

The training course was organized in cooperation with the Government of the United Republic of Tanzania through Sokoine Agricultural University under the regional AFRA TC project RAF5076 on Improving Crops Using Mutation Induction and Biotechnology through a Farmer Participation Approach. The training course was facilitated by the staff of the university and Prof Kusolwa. Twenty-three participants from Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central Africa, Cote d'Ivoire, Democratic Republic of the Congo, Egypt, Ethiopia, Ghana, Lesotho, Madagascar, Mali, Mauritius, Morocco, Namibia, Niger, Senegal, Sierra Leone, and Tunisia, along with five local participants from the United Republic of Tanzania attended the training course. They were researchers actively working in mutation breeding, with knowledge of the principles and techniques of crop breeding.

Training course participants.

The purpose of the training course was to provide participants with opportunities to familiarize themselves with three important aspects of crop breeding: 1) molecular techniques to be applied; 2) data collection, data handling and analysis of field data; and 3) laboratory data generated by molecular marker technologies (SSRs, AFLP, SNPs etc.).

After the opening session, the training course started with scientific background of mutation induction and its application to crop breeding. It was then followed by i) DNA as the source of genetic information; ii) Introduction to Molecular Marker Systems; iii) Principles of the polymerase chain reaction (PCR); iv) Principles of mapping (recombination, linkage data and segregation analysis, Quantitative Trait Loci (QTL) analysis) and other molecular biology techniques used in crop improvement; v) Genotypic screening for desired mutations in genes of interest; and vi) Utilization of appropriate technologies for mutant phenotyping and genotyping.

Participants practicing the loading of PCR products on a gel for electrophoresis.

Hands-on practical sessions were also conducted on i) Isolation of genomic DNA from oil palm leaf tissues;

ii) PCR amplification of a specific gene in oil palm; iii) Cleaved Amplified Polymorphic Site (CAPS) marker analysis; iv) Isolation of genomic DNA from potato leaf tissues and verifying quantity and quality of isolated DNA on agarose gel, and dissolving/diluting DNA template; and v) Running electrophoresis and SINE marker analysis.

At the closing session, participants had the opportunity to exchange opinions, suggestions and ideas for future application of the training in crop improvement and cooperation between countries in the project. The participants were given certificates issued by the IAEA and signed by both IAEA and Sokoine University, for successful participation.

Final Regional Coordination Meeting of RAS5070 on Developing Bioenergy Crops to Optimize Marginal Land Productivity through Mutation Breeding and Related Techniques, Jakarta, Indonesia, 22–26 October 2018

Technical Officer: F. Sarsu

The final regional coordination meeting was organized in collaboration with BATAN, Indonesia, under TC project RAS5070. The objectives of the meeting were to: i) review the national projects' progress on soil, nutrient and water management, and plant mutation breeding practices in marginal land using nuclear and isotopic techniques according to work plans for 2015–2018; ii) report on the progress made over the last four years under the project RAS5070; iii) discuss and decide on exchange/preservation arrangements of mutant germplasm/lines/varieties, which are generated under the project; iv) discuss on using the techniques/protocols provided by regional training courses; and v) discuss and identify needs in the region for other crops and/or agricultural activities to be addressed by the IAEA.

National country coordinators from 12 countries in the region (Bangladesh, Cambodia, India, Indonesia, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Sri Lanka, and Vietnam) as well as the Project Management Officer (PMO) Mr Sinh Van Hoang and the Technical Officer (TO) Ms Fatma Sarsu participated in the meeting. The Chairman of BATAN, Mr Djarot Sulistio Wisnubroto joined the opening session. Each country representative presented their progress and achievements. The details of these achievements were discussed, and technical feedback was provided to support and enhance activities towards the overall objective.

It was noted that through mutation breeding programme, some Member States have developed mutant lines/varieties for food, feed and/or bioenergy with potential for marginal land. Through application of N-15 or C-13 isotopic techniques, some Member States have successfully studied soil, water and nutrient use efficiency for bioenergy crop cultivation on marginal land. More than 100 young scientists in the region have been trained on plant mutation breeding and related techniques, contributing significant impact on capacity building, exchange of information and technology, and enhanced research collaboration in the region.

Following are the major achievements of this project:

1. Enhanced capacities of RCA Member States on application of mutation and other nuclear and isotopic techniques to develop high yielding varieties of bioenergy crops to increase marginal land productivity;
2. Research capability upgraded in terms of human capacity building in the areas of mutagenesis approaches, and nuclear and isotopic techniques for evaluating nutrient and water use efficiency to improve crop plants tolerant to main biotic and abiotic stresses;
3. Strengthened cooperation among the RCA Member States and partners, including a functional Asia and Oceania Association of Plant Mutagenesis; and
4. New mutant lines and varieties in food, feed and energy crops identified and tested for productivity, resource use efficiencies and tolerance to abiotic stresses under large field demonstration and/or commercialization across the region.

Meeting participants.

National Training Course on Molecular Biology Laboratory and Application of Molecular Techniques in Plant Breeding, URT5030, Zanzibar, United Republic of Tanzania, 10–18 November 2018

Project Officer: L. Jankuloski
Training Coordinator: S.F. Hamad

Training on the use of lab equipment was held for six days from 12–18 November 2018 at Zanzibar Agricultural

Research Institute (ZARI). The total of eleven trainees from the Grain Crop Research, Horticultural, Root and Tuber Crops, and Food and Nutrition Units from ZARI had the opportunity to participate in the training. The training was organized by ZARI in collaboration with IAEA through the TC project URT5030. The experts for the training course were Professor Paul Kusolwa and his technician Mr Kassim R. Kabelwa - both from Sokoine University of Agriculture (SUA).

Practical lecture provided by Prof Kusolwa and his assistant, Mr Kabelwa.

The training included installation of the equipment for molecular biology provided by the IAEA, and theoretical and practical exercises on how to use the equipment and learning principles of safe use of a biotechnology lab.

The purpose of this training course was to provide participants with theoretical as well as practical knowledge on:

1. Preparation of solutions;
2. Extraction of DNA from cassava, sweet potatoes, banana and rice;
3. DNA quality and quantity analysis;
4. Running PCR;
5. Running gel electrophoresis;
6. Visualizing PCR product on gel imaging system (UV transluminator).

The presence of modern biotechnology laboratory and trained staff is a great opportunity for ZARI's breeding programmes, but also for research in different fields such us livestock breeding. The IAEA will continue to support the plant breeding programmes at ZARI through the ongoing TC project URT5030 and will upgrade molecular biology laboratory with necessary reagents for plant breeding and provide professional training for staff to improve the breeding and research efficiency at ZARI.

Participants extracting DNA.

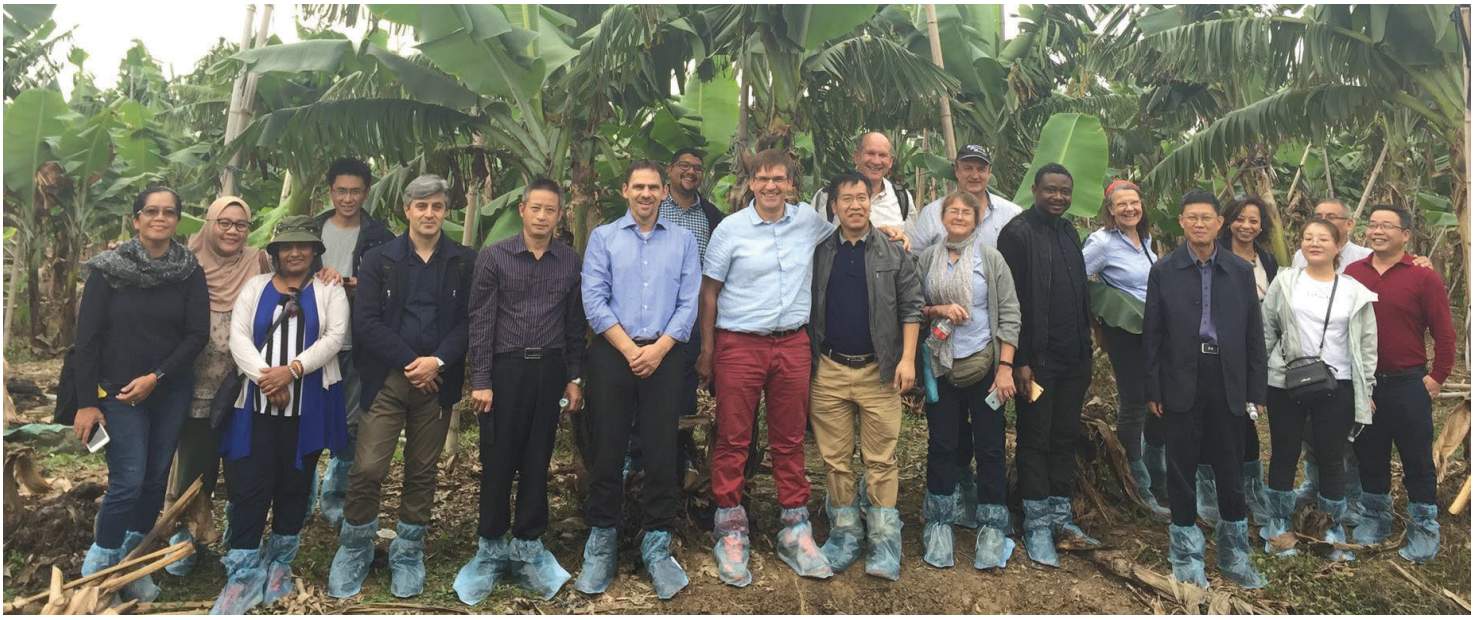
DNA quantification using NanoDrop.

Third Research Coordination Meeting on Efficient Screening Techniques to Identify Mutants with Disease Resistance for Coffee and Banana, D22005, Guangzhou, China, 26–30 November 2018

Project Officer: Ivan Ingelbrecht

The third Research Coordination Meeting of the CRP D22005 was organized in Guangzhou, China, and hosted by the Guangdong Academy of Agricultural Sciences. The CRP is focused on mutation breeding approaches for improving banana and coffee for resistance to Fusarium Wilt and Leaf Rust, respectively. Fusarium wilt in banana and coffee leaf rust are caused by fungal pathogens and have devastating effects on coffee and banana production in the affected countries. Coffee leaf rust has created recent epidemics in several countries in Central and Southern America while Fusarium wilt is affecting Asian countries, Australia and has recently spread to Mozambique. This CRP brings together research teams from Asia, Latin America, Europe and Africa. It aims to optimize mutation induction techniques for coffee and banana using *in vitro* tissue culture techniques and to develop technology packages for efficient screening

for disease resistance in coffee and banana. During this meeting, the R&D progress was reviewed and recommendations for further implementation of this CRP were formulated (detailed information on this CRP can be found on page 21).



Meeting participants visiting the Fusarium wilt banana field trials in Dongguan, China.

Coordinated Research Projects

Project Number	Ongoing CRPs	Project Officers
D22005	Efficient Screening Techniques to Identify Mutants with Disease Resistance for Coffee and Banana	I. Ingelbrecht
D25005	Mutation Breeding for Resistance to *Striga* Parasitic Weeds in Cereals for Food Security	A.M.A. Ghanim
D23031	Improving Resilience to Drought in Rice and Sorghum through Mutation Breeding	F. Sarsu
D23032	Disease Resistance in Rice and Wheat for Better Adaptation to Climate Change	L. Jankuloski
	CRP in Planning	
	Stress Tolerance in Crops for Intensification of Climate Change Agriculture	S. Sivasankar

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

Project Officer: L. Jankuloski

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

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

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

CRP Overall Objective

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

Specific Research Objectives

1. To generate genetic diversity and develop rice lines resistant to important diseases (blast, sheath blight, bacterial blight, and false smut).
2. To develop protocols for the screening of rice mutants resistant to diseases.
3. To develop molecular markers for disease resistance using available mutant germplasm.
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.
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.

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

Project Officer: F. Sarsu

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

The breeding of hardy, input-use efficient, 'climate-smart varieties' that are inter alia drought tolerant, which produce greater yields with fewer inputs, would constitute part of the solution to the predicted abiotic stresses arising from climate change.

The main objective of this CRP is to adapt and develop robust protocols for efficient screening of mutant populations for drought tolerance. The target crops are improved rice and sorghum tolerant to drought for current and future climate change scenarios. These two crops are essential staples in the diets of millions of impoverished and vulnerable populations and, therefore, any attempt in increasing their yields under drought stress could have a major and positive impact in terms of food security and improved health and income generation. The results from the first year of the CRP were reviewed and the second RCM is planned to be held Beijing, China, from 10–14 June 2019 (related information on page 8).

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

Project Officers: A.M.A. Ghanim and 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 mean objective of CRP (D25005) is to develop laboratory, screen-house and field screening protocols of mutant populations of sorghum and upland rice for resistance to *Striga asiatica* and *S. hermonthica*. In addition, the CRP focuses on technologies such as rapid cycling of generation of crop plants, doubled haploidy techniques, and molecular markers to enhance efficiency of mutant identification and accelerate delivery of resistant varieties.

The second RCM was organized from 15–19 October 2018 at the Vienna International Centre (VIC), Vienna, Austria. During the meeting it was shown that a significant progress is made on the planned activities by the participating research and technical contract holders. Field and glass-house screening protocols of mutant populations for resistance to *Striga* were optimized by Burkina Faso, Madagascar and Sudan; laboratory screening protocols using gel-assay, rhizotron and others were optimized by Kenya, United States of America (USA) and Japan. Contract holders planned to submit draft of these protocols during 2018/19 cycle. The Plant Breeding and Genetics Laboratory (PBGL) has optimized protocols for rapid crop cycling and screening for *Striga* resistance in glass-house. The PBGL validated the screening protocol on M_2 population of sorghum and used it to verify putative mutants identified by participating Member States. Encouraging progress is made on the optimization of doubled haploidy for upland rice in Iran and Turkey, while progress on sorghum was limited. During the second RCM, work plans were revised to timely deliver the targeted outputs of the CRP (see more under Past Events and Developments at the Plant Breeding and Genetics Laboratory in this Newsletter)

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

Project Officers: I. Ingelbrecht

The CRP officially started in November 2015 and had its first RCM from 7–11 December 2015 in Vienna, Austria. The second RCM was held from 29 May–2 June 2017 in Lisbon, Portugal and the third RCM was recently held in Guangzhou, China (26–30 November 2018). The project started with 12 participating institutes from ten countries (Austria, China, Islamic Republic of Iran, Malaysia, Nigeria, Peru, the Philippines, Portugal, South Africa and UK) and one International Organization (Bioversity International). Within the first year, two more research contract holders from Costa Rica and Mauritius joined the project and two research agreements (Austria and Portugal) were transferred to Technical Contracts.

The main objective of this CRP is to adapt and develop mutation induction and screening protocols that are suitable for mass screening of mutant lines to identify rare plants showing enhanced resistance to disease in banana and coffee. Cavendish bananas are clones and susceptible to diseases, including Fusarium wilt caused by *Fusarium oxysporum* f.sp. *cubense* (Foc) tropical race four (TR4). In recent years TR4 has caused epidemics in nine countries and is spreading from where it originated in Asia towards Africa (Mozambique) and Australia. Foc TR4 threatens especially the desert bananas which are important for small scale farmers and also agro-industries.

Coffee is the second most traded commodity behind crude oil and derivatives. Coffee leaf rust (CLR) caused by *Hemileia vastatrix* is devastating the affected plantations in countries in Central and Southern America. Global climate change has been directly implicated in the prevalence and spread of coffee leaf rust.

At the end of the third year of this project, considerable progress has been achieved in the development of screening techniques as well as in mutation induction techniques in both crops. In banana, a fast *in vitro* bioassay for TR4 resistance has been established and applied for screening of 6000 *in vitro* rooted plants derived from mutation induction experiments. Also, a technique has been optimized for greenhouse screening of small plants, as well as a hydroponic system for lab-based screening of Fusarium wilt.

In line with the defined expected project outputs, new methods for low cost tissue culture of banana have been developed. As for coffee, very little work on mutation breeding has been done before this CRP. Hence, the CRP is focused on developing and validating mutation induction techniques, specifically in *Coffea arabica*. Effective methods for seed irradiation were developed and the optimum dosages determined. As an alternative to seed irradiation, methods for callus induction, formation and regeneration of embryogenic callus, germination of embryo and development of seedlings were established, and different types of explants were irradiated with various dosages of gamma rays. Results from these experiments have emerged in the third year of the project.

Technical Cooperation Field Projects

Project Number	Country/Region	Title	Technical Officer(s)
ANG5015	Angola	Achieving Drought Tolerant Plants by Inducing Mutation with Gamma Rays	F.Sarsu
AZB5002	Azerbaijan	Developing Mutant Cotton Breeding Lines Tolerant to Diseases, Drought and Salinity through Mutation Breeding	F. Sarsu
BGD5029	Bangladesh	Evaluating Promising Abiotic Stress Tolerant Crop Mutants/Varieties and Measuring the Suitable Management Practices for the Promotion of Sustainable Production at Saline, Submergence and Drought Prone Areas	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section
BUL5014	Bulgaria	Screening of Cereal Germplasm Stress Response and Adaptation Potential by Advanced Nuclear, Omics and Physiological Approaches	L. Jankuloski
BUL5015	Bulgaria	Increasing Productivity and Quality of Basic Food Crops	F. Sarsu
BKF5016	Burkina Faso	Using Nuclear Techniques for Improving Rice Yield and Quality	L. Jankuloski/I. Ingelbrecht in collaboration with Soil and Water Management and Crop Nutrition Section
BKF5019	Burkina Faso	Improving Food Crop Genotypes for Enhancing Yield and Adaptation to Climate Change Using Mutation Breeding and Isotopic Techniques	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section
BDI5001	Burundi	Improving Cassava Productivity through Mutation Breeding and Better Water and Nutrient Management Practices Using Nuclear Techniques	I. Ingelbrecht in collaboration with Soil and Water Management and Crop Nutrition Section
CAF5008	Central African Republic	Improving Cassava Yield through Improved Crop Variety and Best Soil Management Practices Using Nuclear Techniques	F. Sarsu/I. Ingelbrecht in collaboration with Soil and Water Management and Crop Nutrition Section
CPR5024	China, People's Republic of	Enhancing the Accelerated Application of Mutant Germplasm and High-Efficiency Breeding in Crops	N. Warthmann

Project Number	Country/Region	Title	Technical Officer(s)
ZAI5019	Congo, Democratic Republic of the	Developing Mutations, *In vitro* and Molecular Techniques for Further Dissemination to Breeders and Pharmaceutical Plant Producers to Enhance the Livelihood of Target Populations	S. Sarsu/L. Jankuloski
ZAI5022	Congo, Democratic Republic of the	Improving Productivity and Quality of Crops (Soybean and Maize) Using Induced Mutation and Biotechnology	L. Jankuloski
ZAI5025	Congo, Democratic Republic of the	Increasing Genetic Variability in Cassava and Maize for Enhanced Tolerance to Biotic and Nitrogen Stresses	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section
ZAI5026	Congo, Democratic Republic of the	Improving Productivity and Quality of Crops (Soybean and Maize) Using Induced Mutation and Biotechnology	L. Jankuloski
PRC5002	Congo, Republic of the	Developing Disease Resistant Varieties of Cassava and Banana	S. Sivasankar
IVC5035	Cote d'Ivoire	Improving Maize Crops Subject to Severe Soil and Climate Degradation through Induced Mutants Adapted to these Areas	F. Sarsu/L. Jankuloski
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
GHA5036	Ghana	Screening Oil Palm M2 Population for Useful Mutants	L. Jankuloski
GHA5037	Ghana	Using Irradiated Pollen for the Development of Provitamin A Rich, Drought Tolerant and Cassava Mosaic Disease Resistant Cassava Mutants	I. Ingelbrecht
INS5043	Indonesia	Intensifying Quality Soybean Production to Achieve Self-Sufficiency	A.M.A. Ghanim/L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section
IRA5014	Iran, Islamic Republic of	Improving Wheat Yield and Stress Tolerance for Sustainable Production	L. Jankuloski
JAM5013	Jamaica	Improving Crops by Using Experimental Mutagenesis and Diagnostic Technologies	L. Jankuloski
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)
KEN5034	Kenya	Using Irradiated Improved *Brachiaria* Grass and *Dolichos Lablab* Species for Increasing Quantity and Quality of Milk Production and Reproduction for Smallholder Dairy Farms in Drought Prone Areas	F. Sarsu/L. Jankuloski
KEN5037	Kenya	Using Climate Smart *Brachiaria* Mutants to Develop Integrated Farm Model Technologies for Improved Livelihood Among Smallholder Farmers	F. Sarsu
KEN5038	Kenya	Using Nuclear Techniques to Evaluate and Improve the Impact of Mutated Forages on the Performance of Smallholder Dairy Cows	L. Jankuloski in collaboration with Animal Production and Health Section
KUW5002	Kuwait	Implementing Mutation Induction to Improve Barley Production under Harsh Environmental Conditions	L. Jankuloski
KUW5003	Kuwait	Implementing Mutation Induction to Improve Barley Production under Harsh Environmental Conditions – Phase II	L. Jankuloski
LAO5002	Lao, P.D.R.	Improving Soil Fertility and Water Use Efficiency in the Cassava-Rice-Soybean Production System under Smallholder Farming Systems	L. Jankuloski
LES5004	Lesotho	Using Nuclear Techniques for Improvement of Crop Yield, Quality and Stress Tolerance for Sustainable Crop Production (Continuation of the on-going project)	A.M.A. Ghanim
LES5005	Lesotho	Improving Crop Yield, Quality and Stress Tolerance for Sustainable Crop Production, Phase II	A.M.A. Ghanim
MAG5022	Madagascar	Strengthening Food Security	F. Sarsu/L. Jankuloski
MAG5023	Madagascar	Promoting Climate Smart Agriculture to Face Food Insecurity and Climate Change with Regard to Basic National Foods (Rice and Maize)	F. Sarsu/L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section
MAG5025	Madagascar	Enhancing Biocontrol of *Striga asiatica* (L.) Kuntze through the Development of Tolerant Rice and Maize Lines and its Links with Microbiological and Ecological Functioning of Soil	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section
MLW5003	Malawi	Developing Drought Tolerant, High Yielding and Nutritious Crops to Combat the Adverse Effects of Climate Change	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section

Project Number	Country/Region	Title	Technical Officer(s)
MAL5031	Malaysia	Establishing an Environmentally Sustainable Food and Fodder Crop Production System	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section and Animal Production and Health Section
MAU5006	Mauritania	Contributing to the Improvement of Rice Crop Yields through the Application of Nuclear Techniques to Water Management and Soil Fertility	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section
MAR5023	Mauritius	Improving Landraces of Crucifers (Cauliflower and Cabbage) and Carrot through the Use of Nuclear Techniques for Mutation Breeding and Biotechnology	F. Sarsu
MOZ5007	Mozambique	Enhancing Mutation Breeding of Sorghum and Pearl Millet to Develop High Yield, Disease Resistance and Drought Tolerance	A.M.A. Ghanim
NAM5014	Namibia	Evaluating Efficient Water and Nutrient Use, Molecular Characterization and Nutritional Composition of Mutant Germplasm Populations	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section
NAM5016	Namibia	Developing Drought Tolerant Mutant Crop Varieties with Enhanced Nutritional Content	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section
NEP5003	Nepal	Improving Crop Yield for Food Security and Economic Growth by Using Nuclear and Molecular Techniques	L. Jankuloski
NEP5006	Nepal	Enhancing Productivity of Corps and Fruit Employing Nuclear and Molecular Techniques	L. Jankuloski
NER5019	Niger	Improving Sesame Plant Productivity by Obtaining High-Yielding Induced Mutants Adapted to Semi-Arid Conditions	I. Ingelbrecht in collaboration with Soil and Water Management and Crop Nutrition Section
NER5021	Niger	Using Microbial Biotechnology to Improve Productivity and Adapt Cowpea to Climate Change	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section
NIC5011	Nicaragua	Broadening the Genetic Variation of Vegetative Propagated Crops Using Nuclear Techniques	S. Sivasankar

Project Number	Country/Region	Title	Technical Officer(s)
OMA5004	Oman	Building Capacity for the Improvement of Major Crops through Induced Mutation Using Nuclear and Related Techniques	A.M.A. Ghanim/I. Ingelbrecht
OMA5005	Oman	Enhancing the Application of Mutation Breeding and Supporting Biotechnology Techniques for the Improvement of Important Strategic Crops	A.M.A. Ghanim
PAL5009	Palestine	Enhancing the Performance of Durum Wheat Landraces by Induced Mutation (Phase II)	L. Jankuloski
QAT5006	Qatar	Enriching Genetic Diversity and Conserving Plant Genetic Resources Using Nuclear Techniques and Related Technologies	A.M.A. Ghanim
RAF5066	Regional Africa	Improving Crops Using Mutation Induction and Biotechnology through a Farmer Participation Approach (AFRA)	F. Sarsu
RAF5076	Regional Africa	Improving Crops by Using Mutation Induction and Biotechnology through a Farmer Participatory Approach	F. Sarsu
RAS5069	Regional Asia	Complementing Conventional Approaches with Nuclear Techniques towards Food Risk Mitigation and Post-Flood Rehabilitation Efforts in Asia	L. Jankuloski
RAS5070	Regional Asia	Developing Bioenergy Crops to Optimize Marginal Land Productivity through Mutation Breeding and Related Techniques (RCA)	F. Sarsu/L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section
RAS5073	Regional Asia	Supporting Climate-proofing Rice Production Systems (CRiPS) Based on Nuclear Applications-Phase II	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section
RAS5074	Regional Asia	Enhancing Wheat and Barley Productivity through Induced Mutation with Supportive Breeding and Related Biotechnology Techniques (Phase III)	F. Sarsu
RAS5075	Regional Asia	Improving Sustainable Cotton Production through Enhanced Resilience to Climate Change	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section
RAS5077	Regional Asia	Promoting the Application of Mutation Techniques and Related Biotechnologies for the Development of Green Crop Varieties (RCA)	L. Jankuloski

Project Number	Country/Region	Title	Technical Officer(s)
RAS5079	Regional Asia	Improving Crop Resilience to Climate Change through Mutation Breeding in Pacific Islands	F. Sarsu
RLA5068	Regional Latin America	Improving Yield and Commercial Potential of Crops of Economic Importance (ARCAL CL)	F. Sarsu
SEN5034	Senegal	Using an Integrated Approach to Develop Sustainable Agriculture in a Context of Degrading Soil Fertility, Climate Change and Crop Diversification	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section
SIL5017	Sierra Leone	Selecting and Analysing Bio-Enriched and Bio-Fortified Rice and Cassava Lines and their Efficient Postharvest Transformation to Popular Food Products	S. Sivasankar
SIL5020	Sierra Leone	Enhancing the Concurrent Selection and Evaluation of Biofortified and Bio-enriched Varieties Derived from Mutant Rice, Cassava and other Crops	S. Sivasankar
SRL5045	Sri Lanka	Establishing a National Centre for Nuclear Agriculture	F. Sarsu in collaboration with Animal Production and Health Section
SUD5033	Sudan	Enhancing Productivity of Major Food Crops (Sorghum, Wheat, Groundnut and Tomato) under Stress Environment Using Nuclear Techniques and Related Biotechnologies to Ensure Sustainable Food Security and Well-Being of Farmers	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section
SUD5037	Sudan	Applying Nuclear Techniques to Improve Crop Productivity and Livelihood of Small-scale Farmers in Drought Prone Areas	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section
TOG5002	Togo	Improving Crop Productivity and Agricultural Practices through Radiation Induced Mutation Techniques	L. Jankuloski in collaboration with Soil and Water Management and Crop Nutrition Section
URT5028	Tanzania, United Rep. of	Improving Crop Production and Productivity through the Use of Nuclear and Nuclear-Related Techniques	L. Jankuloski
URT5029	Tanzania, United Rep. of	Improving Rice and Barley Production through the Application of Mutation Breeding with Marker Assisted Selection	F. Sarsu/L. Jankuloski
URT5030	Tanzania, United Rep. of	Improving Rice and Barley Production through Application of Mutation Breeding with Marker Assisted Selection	F. Sarsu/L. Jankuloski

Project Number	Country/Region	Title	Technical Officer(s)
URT5032	Tanzania, United Rep. of	Developing Maize Cultivars for Improved Yield and Resistance to Viral Disease	F. Sarsu
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
NHE5001	Vanuatu	Enhancing the Productivity and Quality of Crops through the Application of Mutation Breeding Techniques	L. Jankuloski
VIE5020	Viet Nam	Enhancing the Capacity for Research and Applications of Nuclear Techniques in Plant Breeding	L. Jankuloski
YEM5008	Yemen	Introduction of Gamma Ray Irradiation Techniques for Agriculture Purposes	S. Sivasankar
ZAM5031	Zambia	Improving the Yield of Selected Crops to Combat Climate Change	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section
ZIM5021	Zimbabwe	Assessing and Promoting Sustainable Agricultural Production in Communal and Newly Resettled Farms	F. Sarsu in collaboration with Soil and Water Management and Crop Nutrition Section

Developments at the Plant Breeding and Genetics Laboratory

The Plant Breeding and Genetics Laboratory (PBGL) carries out applied R&D to enhance the scope and efficiency of crop mutation breeding. The PBGL also provides hands-on training in crop mutation breeding and efficiency enhancing (bio) technologies through individual and group training.

During this reporting period, the laboratory infrastructure has been further strengthened with the installation of light and fluorescence microscopes, and a biohazard fume hood for the handling and growth of plant pathogens.

Below is a brief review of progress in select R&D activities, as well as an overview of PBGL's training and irradiation services provided at the time of writing of this newsletter (26 November 2018).

A Marker Kit for Marker-Assisted Selection of a Feed Quality Trait – Reduced Lignin – in Barley

Improving feed quality is an important breeding goal for barley which is widely used as feed for animals. In the context of CRP D23030 on Integrated Utilization of Cereal Mutant Varieties in Crop/Livestock Production Systems, we previously reported the development of a molecular marker assay at the PBGL for the mutant allele '*rob1*' in the barley Bowman genetic background. During this reporting period, the marker has been tested in the barley breeding program of Prof Grausgruber, BOKU, Austria for its potential to predict the reduced lignin phenotype when introduced into Verdant, an elite winter barley variety. Verdant is a 'hooded' barley mutant where the awn is replaced by an inverted floret and is useful for animal feed applications. Prof Grausgruber's barley breeding program is aimed at further improving the feed quality of Verdant by stacking 'hooded' with the *rob1* reduced lignin trait. We are pleased to report that the marker correctly predicted the *rob1* phenotype in a segregating F2 population derived from a cross between Verdant and Bowman *rob1*. This result extends the use of the marker kit to predict the reduced lignin phenotype to unrelated genetic background such as Verdant, thus opening perspectives for wider applications in Member States with barley fodder breeding programs.

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

In continuation of the ongoing R&D activities related to the CRP on *Striga* (D2.50.05), the PBGL has conducted verification trials using the established protocol for screening of mutant populations for resistance to *Striga spp.* A protocol for pot-screening was optimized using varieties of known reaction to *Striga* (resistant vs susceptible) both in sorghum and upland rice, and validated on an M_2 population of sorghum. During this reporting period, the protocol was used to verify 19 putative mutants of maize (M_4–M_5) and 12 putative mutants of upland rice identified by the CRP contract holder in Madagascar. The mutants were tested against both *Striga asiatica* from Madagascar and *Striga hermonthica* from Sudan. *Striga* seeds (0.05g) were placed in medium-size pots filled with soil mixture as described previously. Four pots were assigned for each mutant per each of the two *Striga* treatments. Wildtype parents were included for each crop in four pots with and without *Striga* seeds. Plants were maintained in a glass-house under 25-degree Celsius temperature and natural light at the PBGL facility in Seibersdorf, Austria. Seedlings were irrigated two times a week until establishment of 4–6 leaf stage and then continued with one watering per week. No fertilizer was applied. *Striga* plants started to emerge above the soil in about 40 days in *S. hermonthica* and 60 days in *S. asiatica* treatments. After three months, the experiment was uniformly covered with *Striga* plants at different stages including many flowering plants (see photo), and the damage became clear on the host plants with many completely dead in the *S. hermonthica* treatments. Generally, all the evaluated mutants in maize and rice were infected by *S. hermonthica* while there was variation among mutants in their reactions (resistance/tolerance) to *S. asiatica* (see photos). Among the tested maize mutants, 9, 8 and 2 were resistant, tolerant and susceptible to *S. asiatica* respectively, while 6, 4 and 2 of the test rice mutants were resistant, tolerant and susceptible. Seeds were collected for further advanced analyses to identify their allelism and the underlining mechanism of resistance.

The presented results clearly prove the efficiency and accuracy of the established protocol in verifying putative mutants. Our work will continue to verify other putative mutants identified by the CRP contract holders from Burkina Faso and Sudan. Few (three from each crop/participating country) of the most consistent mutants will be chosen for development of molecular marker to facilitate introgression and pyramiding to produce superior resistant varieties in the respective crops by Member States.

Verification experiment showing maize infested with Striga asiatica at flowering (110 days after planting).

Verification experiment showing Maize infested with Striga hermonthica at flowering (100 days after planting).

Progress towards Marker Development for a Semi-Dwarf/Early-Maturing Mutant Trait in Sorghum

The PBGL has continued its work towards developing molecular markers for important mutant traits. In many cases, molecular markers linked to the traits will enable faster introgression and wider utilization of the trait by Member States.

We are using a pilot experiment on Sorghum to establish a comprehensive genomics approach to genetically map causal loci in a cost-effective manner. In case of our pilot study on sorghum, we are suspecting one causal locus, because the semi-dwarf/early-maturing trait segregates like a classical mendelian recessive locus with a ratio of one in four.

To quickly recapitulate: *Wad Ahmed* is a popular sorghum variety among farmers in Sudan, however, it matures slightly late and is tall, which makes it prone to yield losses by terminal drought and lodging. For mutation induction, seed bags of *Wad Ahmed* were subjected to different doses of gamma radiation. Six promising mutants that exhibited a smaller stature and/or matured earlier than the wild-type were identified from 500 rows of M_2 plants. These mutants, D1–D6, were progressed to the M_6-stage by single seed descent.

For genome wide identification of candidate mutations, we produced second-generation DNA sequencing data by Illumina DNA sequencing for all six mutagenized lines (D1–D6, M_6-generation) and for wild-type *Wad Ahmed* plants. In order to compare mutants with wild-type, the sequencing reads were aligned to the publicly available Sorghum reference genome (v3.10). We then searched for differences between the mutants and wild-type *Wad Ahmed* and detected hundreds of small variants such as SNPs and InDels (Figure 1) and some large structural variants; most pronounced is a large, six megabase-long deletion close to the Centromere on Chromosome nine (Figure 2).

Obviously, for marker development we will need to zoom in on those variants that are closely linked to the trait; ideally identifying the causal mutation. The variants that we have identified (Figures 1 and 2) are currently too many to take guesses. *Genetic mapping* is the best way forward. *Genetic mapping* describes a set of techniques that can identify links between variants (genotype) and phenotype by exploring co-segregation of the trait with the variant in so-called segregating populations. We hence created suitable segregating populations and we are currently using those for genetic mapping experiments: M_6-plants from each mutant population were backcrossed to *Wad Ahmed* (M_6BC_1). The resulting F1-generations ($M_6BC_1F_1$) were self-pollinated to develop F2-populations ($M_6BC_1F_2$), in which the phenotypes segregate. During the growing season of 2018 we phenotyped two of the F2-populations for flowering time and final plant height in the greenhouse and in the field. We are currently characterising their genotypes, again using Next Generation Sequencing (Illumina). We are exploring an approach whereby we sequence large numbers of individuals which we then, in-silico, pool by phenotype. Contrasting those phenotypic pools should result in a manageable mapping interval.

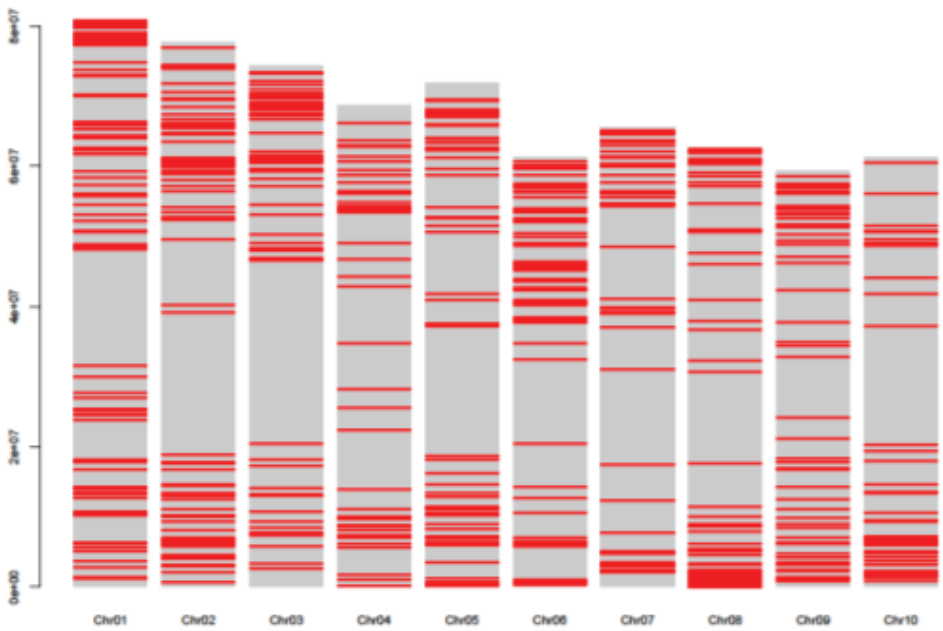


Figure 1. Distribution of small DNA variants (SNPs and small InDels) across the ten sorghum chromosomes as identified by whole-genome sequencing of six mutant lines.

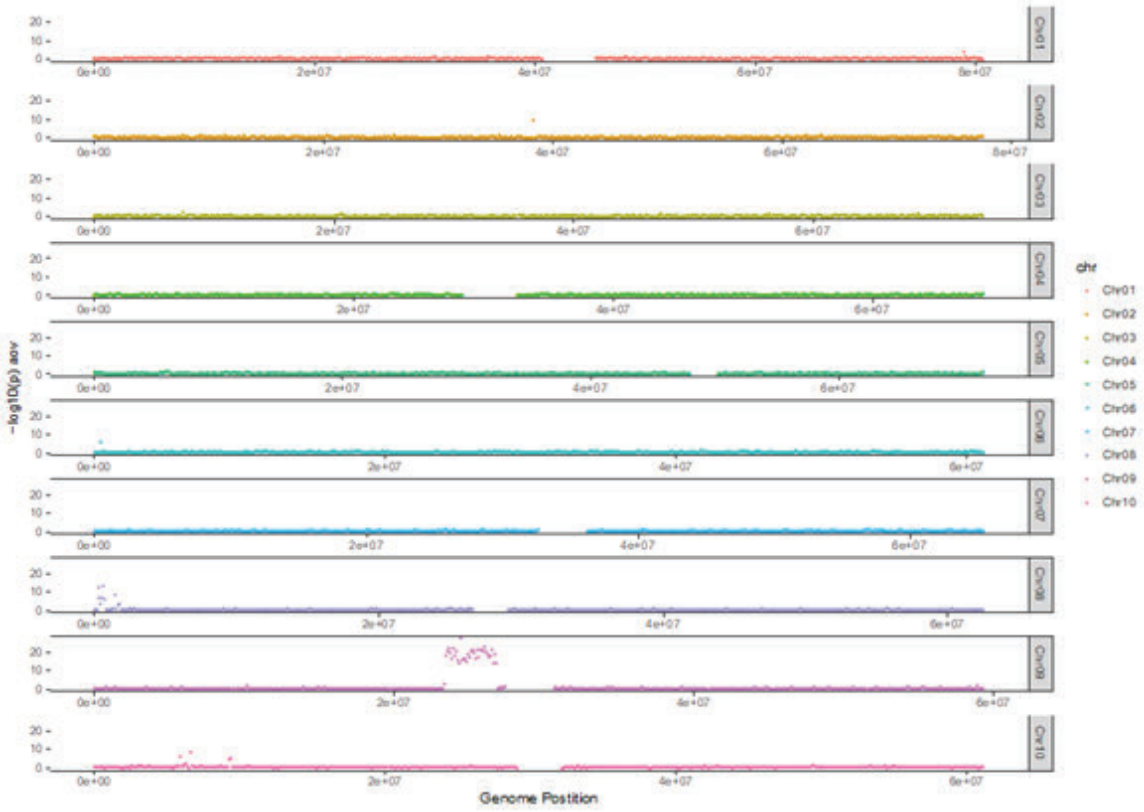


Figure 2. Large structural variants compared to wildtype and shared by the six mutants as identified. Comparative sliding window analysis of read coverage along the 10 chromosomes of the sorghum reference genome. Most pronounced is a six megabase-long region close to the centromere on Chromosome 9 (2nd from below).

Irradiation Services Provided to Member States

At the time of writing (3 December 2018), the PBGL has received a total of 39 irradiation service requests for the year. Under the new TC project cycle 2018–2019, we have received several requests for vegetatively propagated crops, including taro, cocoyam and sweet potato as well as trees/perennial crops such as eucalyptus, coffee, and breadfruit. This year, the PBGL has started to engage the requesting organization to carry out the radio-sensitivity testing in the country of origin, with guidance and technical backstopping provided by the PBGL. A comprehensive list of irradiation requests received so far is presented in the table below. Requests in the context of Coordinated Research Projects (CRP) or Technical Cooperation (TC) projects are indicated as such.

Request Number	Country	Request Type	Crop
1541	United Kingdom		Wheat
1542	Hungary		Ornamental
1543	Austria	CRP	Coffee
1544	France/ Vanuatu	TC	Sweet Potato
1545	Nepal	TC	Sweet Potato
1546	Ireland		Eucalyptus
1547	Mongolia	TC	Wheat, Barley, Rape
1548	Germany		Ornamental
1549	Kazakhstan	TC	Wheat
1550	Togo	TC	Rice
1551	Niger	TC	*Neocarya macrophylla*
1552	The Netherlands		Ornamental
1553	Austria, PBGL	CRP, Training	Coffee, Petunia
1554	Congo, Democratic Republic of	TC	Soybean
1555	The Netherlands		Ornamental
1556	Hungary		Ornamental
1557	Czech Republic		*Papaver sominiferum*
1558	Mongolia	TC	Rape
1559	Fiji	TC	Sweet Potato, Yam, Breadfruit
1560	Germany		Ornamental
1561	Vanuatu	TC	Sweet Potato
1562	Cambodia	TC	Rice
1563	PBGL	F	Rice
1564	PBGL		Sorghum
1565	Jamaica	TC	Ginger
1566	Nicaragua	F	*Xsanthosoma violaceum, Xsanthosoma sagittifolium*
1567	United Kingdom		*Alopecurus myosuroides*
1568	Senegal	TC	Cowpea
1569	Kenya	TC	Dolichos, Wheat, Rice, Maize
1570	Namibia	TC	Sorghum
1571	Palestine	TC	Barley
1572	Zimbabwe	TC	Common Bean
1573	Namibia	TC	*Vigna subteranea, Cleome gyandra*
1574	Kuwait	TC	Barley
1575	Ireland		*Eucalyptus sp.*
1576	Malawi	TC	Maize, Soya, Groundnut
1577	Zimbabwe	TC	*Vigna subteranea, Cicer arietinum*
1578	Chile	TC	*Camelina sativa, Linum usitatissiumum*
1578	Namibia	TC	Cowpea, Bambaragroundnut

Individual Training Activities at the PBGL

In 2018, the PBGL hosted eight Scientific Visitors (SV), 16 fellows (F) and two interns (I) for training and technology transfer in mutation breeding and related (bio)technologies as summarized in the table below.

Name	Country	Status	Topic	Period
Mr Guillermo REYES CASTRO	Nicaragua	SV	*In vitro* tissue culture	10 days
Mr Andrew PEARSON	Jamaica	SV		1 day
Ms Huijun GUO	China	SV	FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology	5 days
Mr Luxiang LIU	China	SV	FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology	5 days
Mr Ham Huy LE	Viet Nam	SV	FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology	5 days
Mr Thao Duc LE	Viet Nam	SV	FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology	5 days
Mr Hoi Xuan PHAM	Viet Nam	SV	FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology	5 days
Ms Aisha AL-KUWARI	Viet Nam	SV	FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology	5 days
Mr Seyni BOUREIMA	Niger	F	*Striga* screening protocol, marker development; EMS mutagenesis pearl millet	2 months
Mr Hamissou ZANGUI	Niger	F	Allelic diversity of key traits for sesame breeding, marker development	2 months
Mr. H. Jhonny RABEFIRAISANA	Madagascar	F	*Striga* screening protocol, marker development	7 months
Mr. Ryan FRANCIS	Jamaica	F	Mutation induction in vegetatively propagated plants	3 months

Name	Country	Status	Topic	Period
Ms. Heeidy COREA NARVAEZ	Nicaragua	F	Mutation induction in vegetatively propagated plants	3 months
Mr. Lameck NYALIGWA	Tanzania, United Republic of	F	Mutation induction and detection	2 weeks
Mr. Francis Nabieu LASSAYO	Sierra Leone	F	Mutation induction and detection	1 month
Ms. Habibah AL-MENAI	Kuwait	F	Mutation induction and detection	2.5 months
Ms. Ngoyi CHIBALANGE	Zambia	F	Mutation induction and detection	3 months
Mr. Faiz AHMAD	Malaysia	F	Mutation induction and detection using NGS techniques	3 months
Mr. Mustapha AKIL	Malaysia	F	Mutation induction and detection using NGS techniques	3 months
Mr. Saleh Ali Said AL HINAI	Oman	F	Mutation induction and detection	3 months
Mr. Ahmed Said Ali AL-MAWALI	Oman	F	Mutation induction in vegetatively propagated plants	3 months
Mrs. Donnette JACKSON-HOWELL	Jamaica	F	Mutation induction in vegetatively propagated plants	3 months
Mr Seyni BOUREIMA	Niger	F	*Striga* screening protocol, marker development; EMS mutagenesis pearl millet	2 months
Mr Hamissou ZANGUI	Niger	F	Allelic diversity of key traits for sesame breeding, marker development	2 months
Ms Samira TAJEDINI	Iran	I	Haploid in rice and sorghum; mutant population development *Striga*	7 months
Mr Edwin THEKKINEN	Austria	I	Molecular markers for trait discovery in barley	6 months

PBGL Visitors and Outreach

In 2018, the PBGL team produced a new flyer summarizing the laboratory activities and leaflets describing ongoing CRP-related R&D at the PBGL (see photo) which were disseminated at the FAO/IAEA International Symposium on Plant Mutation Breeding and Biotechnology (27–31 August 2018) and the Ministerial Conference (28–30 November 2018) both held in Vienna, Austria.

Outreach materials produced by PBGL.

Infographic on Marker Assisted Plant Breeding

Markers and marker-assisted selection are important for plant breeding; However, the concept of genetically mapping a causal locus and the use of markers is fairly abstract. To support a growing understanding of these techniques, PBG developed an Infographic, which is available online on the Joint FAO/IAEA Programme's Multimedia page:
http://www-naweb.iaea.org/nafa/resources-nafa/multimedia.html#

With the direct link to the infographic:
http://www-naweb.iaea.org/nafa/resources-nafa/Marker-Assisted-Plant-Breeding-ST-English-web.mp4

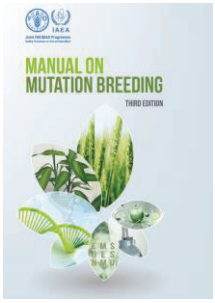
Further, during the Ministerial Conference (28–30 November 2018), a film showing five innovative techniques related to nuclear applications, including the use of molecular markers for plant mutation breeding, was shown. The film is available on the IAEA website https://www.iaea.org/events/ministerial-conference-on-nuclear-science-and-technology-2018.

Why are markers useful?

A *marker* is in principle anything that co-segregates with the trait of interest and is hence predictive of the trait. Markers can be phenotypes themselves or, so-called, genetic or molecular markers. These terms are used synonymously and mean an assay that can be used to interrogate for a particular DNA variant. Subjecting an individual to a *marker assay* yields the so-called *genotype* of this individual for this *marker*. Genotyping for a marker linked to a trait allows to predict whether this individual will exhibit the trait or not. And this is very powerful: It is of importance in cases where the trait itself can only be observed in late stages of development and/or if the trait is expensive or complicated to phenotype. Imagine a fruit trait in a coffee plant. Coffee plants can take up to three years to bear fruits that can be harvested. Being able to genotype them as seedlings saves a lot of space and work. In addition, modern marker assays are *co-dominant*, which allow for the identification of heterozygous individuals. In the case of *recessive* traits, and those are the majority of traits created using random mutagenesis, these plants would otherwise be overlooked and lost. In some crops, being able to identify heterozygotes allows to skip entire generations during the breeding cycle. In summary, molecular/genetic markers can be used to cost-effectively screen individuals for a trait of interest, thus greatly accelerating plant breeding.

Publications

Books



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.

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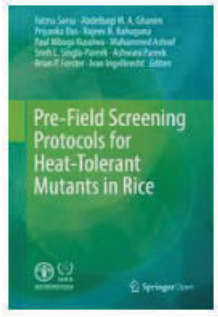
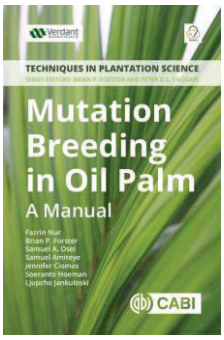


Pre-Field Screening Protocols for Heat-Tolerant Mutants in Rice

Sarsu, F., Ghanim, A.M.A., Das, P., Bahuguna, R.N., Kusolwa, P.M., Ashraf, M., Singla-Pareek, S.L., Pareek, A., Forster, B.P., Ingelbrecht, I. (2018) Springer.
ISBN 978-3-319-77338-4

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



Mutation Breeding in Oil Palm: A Manual

Nur, F., Forster, B.P., Osei, S.A., Amiteye, S., Coimas, J., Hoeman, S., Jankuloski, L. (2018) CABI Publishing.

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

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

Peer-reviewed Book Chapters

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

Peer-reviewed Journal Articles

2018

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.
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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).
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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

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Conference Abstracts and Posters

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.

Websites and Links

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

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