Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Plant Breeding & Genetics Newsletter

https://www.iaea.org/topics/plant-breeding
https://www.fao.org/agriculture/fao-iaea-nuclear-techniques/en/
ISSN 1564-2569
No. 51, July 2023

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To Our Readers

An eventful first half of 2023 involving Plant Breeding and Genetics. Collage of the "Seeds in Space" event, visit of the NASA Chief Scientist, the "Greenhouse Day" event, and joint visit of the US Ambassadors to the FAO and IAEA to our greenhouse. Design: M Godoy

Dear Colleagues,

The first half of 2023 was busy at Plant Breeding and Genetics (PBG) with important events, research results from Coordinated Research Projects (CRPs) and continuing strong support to Technical Cooperation Projects (TCPs) in crop improvement for several crops and traits of significance to Member States.

Mid-April 2023 saw the return of the Arabidopsis and sorghum seeds from our "**Feasibility Study on Seed Irradiation in Space for Induced Genetic Diversity and Plant Mutation Breeding**" to earth, splashing down off the coast of Florida, USA, as part of SpaceX's 27th commercial resupply mission, after being hosted at the International Space Station (ISS) for a period of approximately five months. The seeds arrived at our laboratories in Seibersdorf on 23 May for research investigations in plant biology and DNA structural variations as affected by cosmic radiation and microgravity in space. We had the opportunity to discuss our project with the Chief Scientist and Senior Climate Advisor, Dr Katherine Calvin, of the National Aeronautics and Space Administration (NASA), USA, during her visit to the IAEA on 14 February. The IAEA and FAO hosted a **"Seeds in Space"** event together with the University of Natural Resources and Life Sciences (BOKU) at the university campus on 27 March. The event aimed to inform and inspire students, scientists, decision makers, journalists and the general public about our starting research in space mutagenesis and astrobiology. The Directors General of both the IAEA and the FAO provided opening comments. NASA astronaut, Ms Kayla Barron, of the SpaceX Crew-3 mission spoke about experimentation at the ISS, with specific focus on plants. And yours truly represented PBG and spoke about our mission and research activities in crop improvement using radiation-induced novel genetic diversity and advanced biotechnologies.

I would like to highlight two other important events for PBG in early 2023. In January, PBG hosted the inaugural "**Plant Mutation Breeding" workshop** at the International Plant and Animal Genome (PAG) Conference in San Diego, USA (**PAG 30**, January 13-18, 2023), with the intention of establishing this workshop at PAG as a yearly networking hub for the plant mutation breeding research community, in support of our capacity building efforts in Member States. Further, on 23 February, PBG contributed to the **Greenhouse Reception** (or the ReNuAL2 reception) hosted by the Permanent Mission of the USA for the final round of fundraising for the new greenhouses that recently broke ground adjacent to the laboratories in Seibersdorf.

In trend with the featuring in our recent newsletters specific research topics of contemporary relevance to crop improvement and food security through radiation-induced novel genetic diversity, the current newsletter presents three feature articles on the theme of **vertical farming**. This is an important future research area for the application of mutation breeding in the development of plant phenotypes of critical importance in vertical farming under space-limited agriculture, including urban agriculture. While dwarf stature and the genes contributing to it have been well studied based on spontaneous or induced mutants, improvement of this or other relevant traits such as nutritional content, biomass productivity, plant response to light etc., with limited information of genetic associations is feasible with induced mutagenesis. Three feature articles discuss in brief, given space limitations, the science and practical applications of vertical farming in this issue.

In discovery research towards eventual technology transfer for the management of banana Fusarium Wilt *Foc* TR4, the **new CRP D23033, "An Integrative Approach to Enhance Disease Resistance Against Fusarium Wilt (*Foc* TR4) in Banana – Phase II"** was launched in May 2023 with its first coordination meeting in virtual mode. As part of the ongoing support to the **inter-regional TCP, INT5158**, a virtual regional meeting was held in March with 35 participants across 12 Member States in Latin America and the Caribbean to share experiences and discuss progress from the first year of work on disease detection and diagnosis for *Foc* TR4, and mutation breeding activities in banana for genetic resistance. Further, a workshop was held in virtual mode in April focusing on the topic of detection and diagnostics for the banana Fusarium Wilt, attended by 80 participants from the same 12 Member States in Latin America and the Caribbean.

Research and development in the CRP on biotic-stress tolerance of legumes (D22006) saw success from researchers at the International Crop Research Institute for Semi-Arid Tropics in the application of screening methodologies for pod-borer resistance in chickpea and the recovery of several promising M4 mutant lines with low larval survival in lab bioassays. Mutant M5 lines with resistance to the cowpea pod borer have been reported by researchers at the Bhabha Atomic Research Centre, India, while cowpea mutant populations at the University of Namibia showed mutant lines with pod borer resistance as well as lines with photoperiod insensitivity. Further, a standardised protocol for generating large-scale in vitro shoots, as a source of in vitro explants in olive crops, has been established for large-scale mutagenesis programs through CRP D24014, "Development of Integrated Techniques for Induced Genetic Diversity and Improvement of Vegetatively Propagated and Horticultural Tree Crops". This has resolved the issue of low success rates usually achieved during various in vitro stages. Research in the CRP is ongoing to test different slow-release nanoparticles of plant growth regulators and different types of auxin beads for regulating the induction of adventitious shoot or root meristems in vitro and for root regeneration.

Given the rapid advances in technology relevant to plant biology and breeding research, the PBG team held a two-day retreat during 31 May and 01 June between the Seibersdorf and Vienna labs/offices. The objective was to brainstorm on a **mid-term roadmap** over the next five years centered on our research focus on plant mutation breeding and associated biotechnologies. This built on the previous brainstorming session held during Nov 2018 and Jan 2019, and current discussions addressed processes and ideas around research and technology transfer in the various parts of the plant breeding pipeline identified in the diagram below.

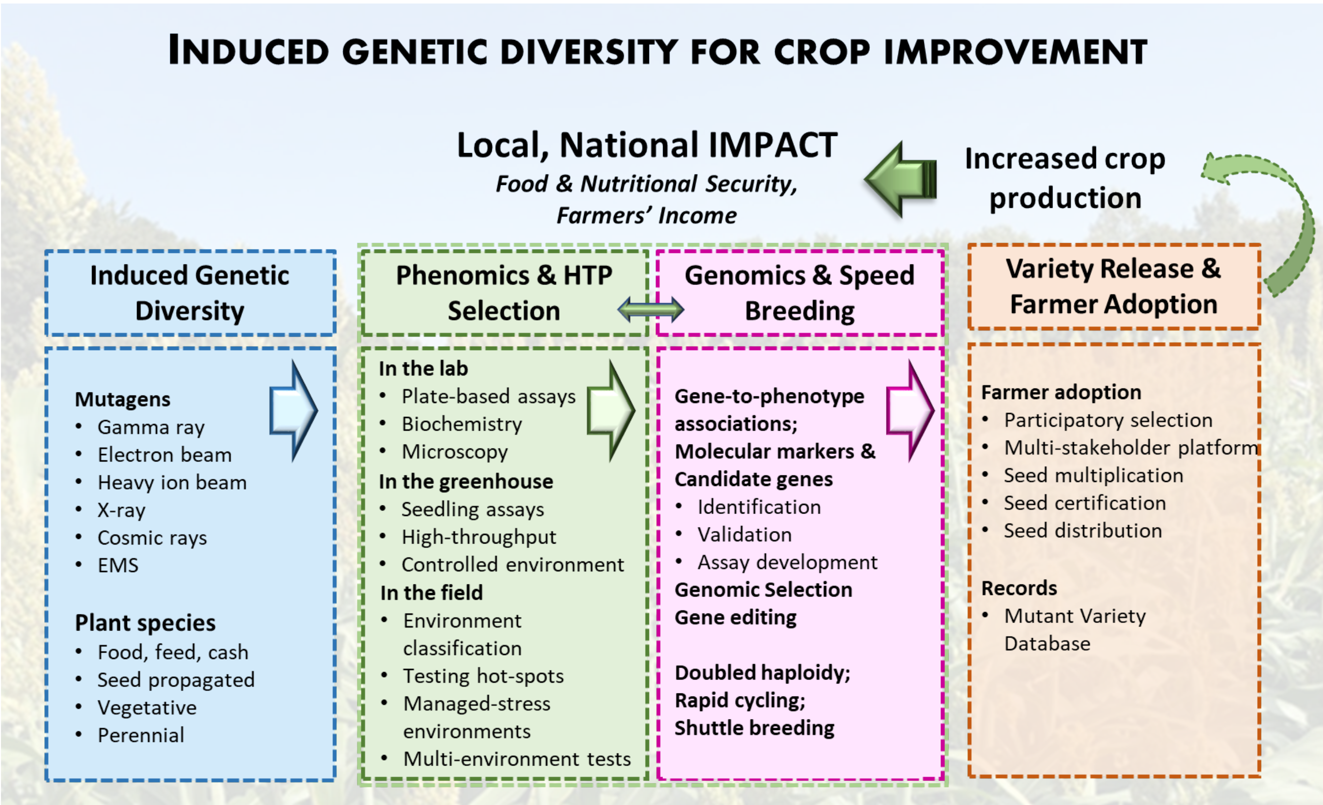
The PBG subprogramme continues to provide technical support to **72 active TCPs** across more than a hundred Member States, including ongoing projects from earlier years of start. Of the 72 active TCPs, 36 commenced in January 2022. Further, PBG is also supporting the design of 26 new TCPs for planned start in the 2024-25 biennium. The second half of 2022 was extremely productive in the organization and delivery of nine training courses at the national and regional levels that provided in-person or virtual training to a total of 65 women and 123 men.

In this issue, I am also the unfortunate bearer of the news of the passing of Prof. Dr. Alexander Micke at the wonderful age of 94 years. Dr Micke led Plant Breeding and Genetics as its second Section Head for 22 years during the period from 1969 to 1991. With him we have lost a person who had put a lot of energy into the success of our mandate and the work of the Joint Centre. We will remember Alexander as a courageous and optimistic personality and a committed and valued colleague (*In Memoriam*, page 35).

I also want to offer my warm welcome to Ms Pooja Bhatnagar-Mathur as new head of the PBG laboratory and Ms Fatma Sarsu as Technical Officer at the Section and to wish them the very best during their tenure.

I conclude with my sincere appreciation for your tremendous support and our joint efforts in induced genetic variation and mutation breeding for crop improvement. The strength of our continuing collaborations can deliver important outcomes towards global food and nutrition security under climate change.

Shoba Sivasankar
Head, Plant Breeding and Genetics Section



The Plant Breeding and Genetics R&D and technology transfer map that centred our mid-term roadmap discussions during 31 May – 01 June 2023

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Staff News

Welcome

Ms Pooja Bhatnagar Mathur (India) joined Plant Breeding and Genetics as Laboratory Head in March 2023. Pooja has a Ph D in Biotechnology from the Jawaharlal Nehru Technological University, Hyderabad, India. She brings over 20 years of experience from CGIAR in the field of cell & tissue technologies, associated biotechnologies for genome designs, precision genetics, and speed breeding methods for improving the precision and efficiency of breeding programs. She has been involved in a wide range of initiatives for the development of new technologies and techniques to deploy improved genetics of legumes and cereal crops that offer food and nutritional security for a large part of the world's population, especially in Asia and Sub-Saharan Africa.

Pooja comes to us from her most recent role as Precision Genetics Lead at the International Maize and Wheat Improvement Center (CIMMYT). Prior to this she worked at the International Crop Research Institute for Semi-Arid Tropics (ICRISAT) at its headquarters in Hyderabad, India, for about 20 years where her most recent role was as Cluster of Activities Lead for Enabling Technologies, under Flagship 5 of the CGIAR Research Programme on Grain Legumes and Dryland Cereals. Pooja is a thought leader for innovative ideas for long-term impacts on crop product profiles, and she has developed close partnerships across regions and organizations to ensure broad utility and impact of results. She has a strong track record of solving challenging and complex problems and has successfully developed breakthrough innovations resulting in a range of tools and methods, enabling technologies, one issued patent, one pending patent application, and over 100 peer-reviewed research publications.

Ms Fatma Sarsu (Türkiye) joined as Plant Breeder/Geneticist in January 2023. She has a Ph.D in Plant Mutation Breeding and Biotechnologies from the University of Ankara, Türkiye. Fatma was employed for more than 20 years by the General Directorate of Agricultural Research, Ministry of Agriculture, Türkiye, in various positions with increasing responsibilities in the field of plant breeding and genetics, with focus on oil crops such as sunflower, safflower, rapeseed, and soybean. She led Türkiye's industrial crops' breeding program for seven years from 2005 to 2012, providing oversight annually to about 90-100 national and international projects geared towards food security. Several of these projects utilized induced mutagenesis, mutation breeding and advanced biotechnologies for crop improvement. Her tenure at the Ministry of Agriculture was interrupted when she moved to the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture at its Plant Breeding and Genetics Section in Vienna Austria in 2012.

Fatma worked previously at the Joint FAO/IAEA Centre for nine years during the period from 2012 to 2021. She successfully implemented more than 60 national and 8 regional Technical Cooperation (TC) projects, and 2 Coordinated Research Projects (CRPs) using nuclear applications for crop improvement through plant breeding, genetics and associated biotechnologies towards the ultimate goal of food security in respective Member States. Results of these projects have been published in the form of several peer-reviewed research articles and book chapters, one book, one special issue of a crop journal in addition to several success stories on the web pages of the International Atomic Energy Agency. The projects she led had proven impact on enhanced technical capacities, improved infrastructure and knowledge transfer in the respective Member States, specifically in the application of nuclear technologies in plant breeding and crop improvement towards improved food security and sustainable agriculture.

After completion of her previous tenure at the Agency, she returned to her home country and the Ministry of Agriculture, General Directorate of Agricultural Research, as the Head of Projects Management Department (2021-2023), where she led a team that managed multidisciplinary projects in agriculture with funding from national/ international organizations. Fatma is an experienced R&D professional in agriculture with a proven track record in crop improvement and related sciences, project management, and national leadership. She has published extensively on themes relating to plant breeding and genetics, induced mutations and management of plant genetic resources for food and agriculture. Fatma re-joined us in January 2023.

Mr Sajid Shokat (Pakistan) joined the PBG Laboratory in May 2023 to work as a consultant in mutation assisted breeding. He completed his bachelor and master's degrees from University of Agriculture, Faisalabad Pakistan in Agriculture with specializations in plant breeding and genetics. He obtained his PhD degree in Crop Science from University of Copenhagen, Denmark and his thesis title was "Impact of post flowering drought and heat stress on physiology and yield performance of contrasting wheat genotypes under elevated CO_2". This PhD project contributed to bridging the gap between plant breeders and physiologists and for sustainable wheat production by maintaining ideal genetic diversity. While working on his PhD, Sajid also worked with CIMMYT seeds of discovery program and identified the novel (*Isoflavone reductase* like) gene playing a role in heat tolerance of bread wheat. This gene was further evaluated in green house studies by linking with agronomy, eco-physiology, antioxidant and phytohormones system and they proposed it as a candidate gene for marker-assisted breeding. Moreover, this PhD work was declared as one of the best theses and awarded diploma of excellence during 2021 from University of Copenhagen, Denmark.

Sajid is a plant breeder and physiologist by profession with 13 years of experience on rice and wheat, and he acted as principal and co-principal investigator for two projects related to drought and wheat rusts funded by Asian Development Bank and Pakistan Higher Education Commission respectively.

Farewell

Mr Ivan Ingelbrecht's term at the Plant Breeding and Genetics Laboratory ended in Jan 2023 after serving as Laboratory Head since 2016. We thank him for his leadership of the Research & Development directions at the lab during his time and wish him the very best in his future endeavours. Ivan came to us with over 20 years of experience, the majority of it as Head of the Central Biotechnology Laboratory at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria where he lived and worked for over 10 years. At IITA, Mr Ingelbrecht also served as Coordinator of the Program on Agricultural Biotechnology, Plant Breeding and Plant Genetic Resources and was an active member of IITA's Research-for-Development Council mandated to support R&D strategic development for the Institute.

As a Postdoctoral Researcher and later Senior Biotechnologist at IITA, he has worked on a range of tropical crops including cassava, banana/plantain, maize, and cowpea. As a Research Associate at Texas A&M (USA) he was involved in the genetic improvement of sugarcane and grapefruit using in vitro tissue culture and transgenesis approaches and molecular diagnostics. At IITA and Texas A&M, Mr Ingelbrecht has supervised many degree and non-degree students at the graduate and post-graduate level in *in vitro* tissue culture, molecular biology and molecular genetics tools for crop genetic diversity assessment, molecular marker development and also diagnostics.

Mr Ljupcho Jankuloski's term as Technical Officer at Plant Breeding and Genetics ended in Jan 2022, where he served for nine years since 2014. We thank him for his contributions during his time at the Agency and wish him the very best in his future endeavours. Ljupcho came to us from the University of Agricultural Sciences and Food, Skopje, Macedonia, where he was faculty at the Plant Breeding and Genetics Department. Ljupcho has good experience in mutation breeding on wheat and barley and is familiar with the optimal use of nuclear and biotechnology methods for the induction and detection of genetic alterations in plants leading to the improvement of important characteristics such as yield, product quality and resistance to diseases.

Feature Articles

Plant Ideotypes for Vertical Farming in Small or Commercial Scale Urban/Peri-Urban Agriculture

Shoba Sivasankar

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Recent newsletters of Plant Breeding and Genetics (PBG) have featured concise overviews, within our page limitations, of topics on crop improvement and food security with contemporary relevance for Member States of the IAEA and the FAO. Thus, the most recent newsletters of June 2022 and January 2023, respectively, focused on (1) management of the banana Fusarium Wilt disease caused by *Fusarium oxysporum f. sp. cubense* (*foc*) Tropical Race 4, in response to its most recent emergence in the Latin American region, and (2) astrobiology and space breeding, in exploratory mode to understand and apply mutation induction by cosmic radiation in plant seeds towards potential adaptation of crop plants to climate change. Both topics have ongoing efforts within the PBG team and/or in Member States. The current newsletter features a topic of important relevance to food and nutritional security, namely, vertical farming in urban agriculture, from the perspective of plant breeding. The concept of vertical farming is futuristic yet at PBG, although the crop traits and plant ideotypes of relevance are not entirely new in mutation breeding.

Global crop production is increasingly challenged by climate change phenomena such as droughts, rising temperatures and submergence, scarcity of fresh water, degradation of soils, loss of biodiversity and depletion of mineral resources. This has a profound impact on food security and the availability of nutritious food for a steadily rising population that is projected to reach 9 billion by 2050. Major recent catastrophes, namely, the covid-19 pandemic and the war in Ukraine have adversely impacted crop production and consequent rises in food prices, further threatening food security for populations across all continents. In 2021, the prevalence of undernourishment rose to 9.8 percent, from 8.0 percent in 2019, and between 708 to 828 million people were affected by hunger (FAO et al., 2022). Nearly 670 million people, eight percent of the world population, are projected to be still facing hunger in 2030.

There is an urgent need to increase the production and accessibility of nutritious food globally. Rapid urbanization of current times calls for the availability of fresh and nutritious food close to consumers in urban areas as well. One solution is to significantly enhance the production of nutritional or nutrition-enhanced crops per unit land area and vertical farming, a type of urban agriculture, is attractive especially in space-limited crop production. While there remain caveats including high energy costs and the limitation yet for types of crops grown in vertical farming systems, literature on the topic indicates that both low- and high-tech vertical farming are prevalent and feasible. An excellent review by O'Sullivan et al (2019) discusses strategies to improve productivity, product diversity and profitability of urban agriculture, including vertical farming. The feature article in this issue by O'Sullivan et al. (page 9) addresses low-cost, affordable vertical farming in small-holder agriculture. Higher-tech vertical farming for urban crop production is summarized by Chen (page 12) in the context of Singapore.

Plant breeding has to date focused on developing varieties to perform optimally in the field with stability of performance under different environmental conditions, and with tolerance or resistance to abiotic and biotic stresses. Under the controlled environment conditions of vertical farming, yield stability is less of an issue as both abiotic and biotic stresses can be better managed. Thus, crop traits of importance for breeding in vertical farming systems are those that facilitate increased year-round production and better consumer value. These include plant stature and architecture, biomass production (leafy vegetables), earliness, light response and photosynthetic efficiency, and nutritional value. Induced mutagenesis and selection for traits of interest, screening existing mutant populations developed for field environments, and editing specific genes with established genetic associations with traits of interest are avenues towards generating plant phenotypes suitable for vertical farming. Mutant alleles for several phenotypes important to vertical farming have been described and these can be targets for gene editing, provided that there is freedom to operate based on existing intellectual property rights. Ideally screening new or existing mutant populations for such plant ideotypes, without any associated pleiotropy, is a good approach to generate new cultivars. Establishment of genetic associations in these mutants could lead to the discovery of new alleles contributing to the trait and consequent novel intellectual property as well.

Dwarf stature is an important ideotype in vertical farming systems to accommodate growth within specific limits of planting heights. It is of critical significance especially for horticultural plants including fruits and vegetables. Of note here is that mutant alleles of the dwarfing genes of rice and wheat (*semidwarf1* or *sd1* and *Reduced height* or *Rht*, respectively) played a significant role in driving the Green Revolution during the second half of the twentieth century (Hedden 2002). The dwarf phenotype resulted from natural mutations in these genes. Both genes are associated with the gibberellin (GA) pathway, with *sd1* being a mutant in the GA biosynthetic pathway and *Rht* a mutant in the GA signal transduction pathway. This ideotype was important in the past century to prevent lodging of tall plants with heavy panicles and the consequent yield losses. Gibberellins are plant hormones, and mutations in genes contributing to their perception or biosynthesis can affect plant stature, flowering time, leaf development, axillary meristem growth and parthenocarpy. Several genes involved in GA biosynthesis and perception are known currently (see Zhang et al 2022 for a recent review).

Plant architecture such as compact growth habit and smaller root volumes are also beneficial, the latter due to the availability of sufficient moisture and nutrients in hydroponics or aeroponics or even pot-based soil culture in vertical farming systems. Mutant alleles for branching such as *teosinte branched1* or *tb1*, *branched1* or *brc1* and associated regulatory genes are known. While an insertion in the *TB1* gene reduces tillering in maize, the *BRC1* gene has a negative effect on branching with the mutant phenotype exhibiting high branching. Traits conferring ease of harvest are also of relevance, such as the formation of a flower abscission zone development mediated by the transcription factor gene, *JOINTLESS*, in tomato.

Due to the ability to manage light duration and intensities in the controlled environment conditions of vertical farming systems, photoperiod response per se is not an important breeding target for controlled environment systems as it is for field farming. However, early flowering and short duration are critical to enable multiple generations in controlled environments thereby contributing to increased production per unit area. It is noteworthy that, similar to short stature or dwarfism, this is a trait that is usually encountered in mutant populations. There are mutant varieties exhibiting the trait in several crop species represented in the FAO/IAEA Mutant Variety Database. Several genes including *FRIGIDA* or *FRI* and *FLOWERING LOCUS C* or *FLC* and their mutant alleles with effects in early flowering have been characterized.

Improving photosynthetic efficiency under the different lighting conditions of controlled environments is critical, and screening directly for higher productivity (either grain/fruit yield or biomass) under low light conditions is probably the most straightforward as an initial venture. Interaction of temperature and light quality/intensity on plant productivity is also an important area of study to manage the current high-energy costs of vertical farming systems.

While vertical farming systems are currently in operation for a limited number of crops/products, mainly leafy vegetables and microgreens, it is interesting to see that two crop simulation models based on a detailed indoor wheat experiment found that wheat grown under vertical farming conditions can generate measured yields 220 times the current world average (Asseng et al. 2020). As per the models, a 10-layer one-hectare indoor vertical facility can produce 700 ± 40 t/ha of measured yield in a year compared to the world average annual yield of 3.2 t/ha.

The energy costs of artificial lighting and temperature control remain high in vertical farming as do labour costs, and many vertical farming enterprises are facing challenging times presently. However, existing systems and knowledge can continuously evolve so that vertical farming can be one avenue to maximise crop productivity per unit area, given the possibility to breed for desirable plant ideotypes.

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Low-cost, vertical farming to increase productivity for smallholder farmers

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When most people think of vertical farming the image that they call to mind is a high-tech, controlled environment, indoor vertical farm. While systems like this are currently expanding and will likely continue to as the vertical farming industry scales globally, there is a role for lower-tech, more affordable options to help smallholder farms to increase the productivity of their limited growing space without facing insurmountable capital investments.

Smallholder farms (<2ha) produce 30-34% of food supply on 24% of gross agricultural area (Ricciardi, Ramankutty et al. 2018). Smaller farms produce a greater share of the world's fruits, pulses, and roots and tubers, while medium sized farms produce more vegetables and nuts, and large farms (>100 ha) produce more grain and oil crops. Herrero et al., (2017) note that the importance of small-holder farmers varies between countries. Farms smaller than 50 ha produce 51–77% of nearly all commodities and nutrients globally but very small farms (≤2 ha) are particularly important in sub-Saharan Africa, southeast Asia, and south Asia, where they contribute to about 30% of most food commodities.

Vertical farming provides a range of opportunities for farmers to increase their productivity and efficiency (Benke and Tomkins 2017). Vertically stacking crops allows farmers to greatly increase the yield per unit area from their farms. This is an important consideration in urban and/or smallholder farms where growers may be limited by the size of their farms. Many vertical farming installations are hydroponic or fertigated systems which creates opportunities to improve water and nutrient use efficiency by recycling nutrient solutions. Vertical farms are often incorporated into protected cropping systems ranging in complexity from plastic tunnel houses, glasshouses, up to fully indoor plant factories (Goldstein, Hauschild et al. 2016). These systems enable increasing levels of environmental control of the temperature, humidity, and lighting that the crops experience. This means that farmers can optimise the growing conditions to increase yield, change plant life cycles and alter harvest times. This can enable farmers to extend the harvest window of crops so that they are selling produce at premium prices at times of year when it is not available from field producers. In some cases, vertical farmers can produce crops completely out of season (e.g., leafy greens produced in high latitudes during winter).

Despite these advantages, high-tech, controlled environment, vertical farms are likely to remain out of reach for smallholders because of the high capital and operational costs required to set up and run the complex facilities (Musakwa, Louw et al. 2021). However, there are many examples of lower tech options. Esther Ndumi Ngumbi, in an article for The Conversation (Ngumbi 2017), presented the argument that Africa needs its own version of vertical farming to help feed growing urban populations. She gave several examples of low-tech, affordable vertical farming systems that growers are using to increase their productivity. It is likely that similar, grass-roots innovation is happening around the world as farmers develop solutions that fit their budgets and needs and are tailored to their individual environments.

Low-tech options for smallholders can range in complexity from simple racking systems mounted on walls or support structures, using vine crops trained to vertical systems, and integrating simple hydroponics or fertigation systems through to more expensive systems that make use of plastic tunnel houses and supplemental lighting to alter the growing environment (Adegun, Olusoga et al. 2022).

The emerging innovation in low-tech vertical farming is encouraging as it has the potential to enable a much greater number of farmers to increase their farm productivity. However, innovation in plant adaptation, selection and breeding is also needed to make the most of these systems. There are two key needs that plant sciences can address; increasing the diversity of crops that can be grown in vertical and hydroponic systems, and breeding/selecting for traits that are advantageous in those systems. Vertical farms are currently dominated by leafy greens, herbs and a handful of small fruiting crops (tomatoes, strawberries). If vertical farms are to have a significant impact on food security, they need to be able to produce a much wider variety of foods. In addition, the vast majority of vertical farms are using crop cultivars that have been selected for maximizing yield and resilience under field conditions. While it may be possible to grow these field varieties in vertical systems, there is an opportunity to adapt crops to vertical systems based on the unique traits that will increase their performance in these systems.

Vertical farmers need to be provided with cultivars that have traits that are specific to vertical systems. Desirable traits for plants grown in vertical farms may include short stature, tolerance of high planting density, short/no juvenile phase (i.e. precocious flowering), short life cycles and/or continuous flowering, high yields and high harvest index, shade tolerance (particularly in low-tech systems without supplemental lighting), disease resistance and differentiated consumer traits (appearance, flavour, health benefits) (O'Sullivan, McIntyre et al. 2020). While there is some research, prebreeding and breeding activity beginning to focus on developing fruiting crops adapted to indoor vertical farms (Kwon, Heo et al. 2020, Kwon 2023), much more is needed.

One example of a novel crop that is adapted to vertical growing systems is the table grape microvine (Figure 1a, b). Grape (*Vitis vinifera* L.) microvines are dwarf mutants of grapevines resulting from a somatic mutation in the gene *VvGai1*, which is involved in gibberellin signalling (Boss and Thomas 2002, Torregrosa, Rienth et al. 2019). Traditional grapevines are long-lived perennials, which take several years to reach full commercial productivity and produce high-value fruit over a period of decades once established (Deng, Wang et al. 2016). While it is possible to grow conventional field grapevine cultivars in hydroponics, they are not adapted to commercial production under controlled environments due to their large size, long establishment times and long juvenile phase.

***Figure 1**. Wild type Pinot Meunier grapevine (left), and grape microvines resulting from single nucleotide mutation of GA insensitive gene (VvGAI1). The trait is semi dominant the grape microvine (VvGAI1/Vvgai1) is shown in the centre and grape picovine (Vvgai1/Vvgai1) is shown on the right.*

The absence of gibberellin signalling creates a mutant grapevine (microvine) with desirable traits for vertical farming including dwarf stature due to shorter internodes, tendrils converted into inflorescences, meaning that fruit bunches form at every bud, a short juvenile phase, leading to a short cycle of 5 to 6 months from planting to first fruit maturation (Figure 2). This indeterminate growth and continuous flowering and fruiting after the onset of flowering is ideal for a vertical farming system (Boss and Thomas 2002, Torregrosa, Rienth et al. 2019).

***Figure 2.** Microvine grown in hydroponic system (cocopeat bags) after removal from the guidewire system for experimental measurements, showing fruit produced from all tendrils and ripening sequentially with the ripest fruit at the base. Image credit: CSIRO*

To date, the microvine has been used predominately as a model plant for research into grapevine physiology and genetics (Dry and Thomas 2015, Dias, Torregrosa et al. 2019, Torregrosa, Rienth et al. 2019, Dry, Davies et al. 2022) . More recently, the potential for microvines to be grown as a commercial indoor crop for table grape production has also been investigated (Anon 2020, CSIRO 2022) (Figure 3). Microvines can be planted at much higher densities than conventional grapevines and trained to follow vertical guidewires, similar to vine tomato production systems, creating vertical arrangements. It may also be possible to espalier the vine to fit different growing configurations.

***Figure 3**. Table grape microvines growing in fertigated pots in a glasshouse. Image credit: CSIRO*

While the microvine is just one example, it shows the genetic potential to adapt plants to vertical growing system that goes well beyond simply making smaller statured varieties. It is unknown if the particular mutation that resulted in the microvine phenotype in grapes can be reproduced in other crop species, but this example demonstrates the value of targeted research into plant adaption and breeding for vertical farming systems.

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Urban Solutions for Enhanced Food Security: A Case Study of Vertical Farming

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Urban Solutions for Global Food Security

With the world's population projected to increase from the current 7.7 billion to 9.2 billion in 2050, food security is becoming an increasingly important global issue.

It was estimated that food demand increases by 59 to 98% from 2005 to 2050 (Mok, 2020), with the demand for animal protein showing greater margin of increase from 61% to 144 for the same period of time.

Global food production and supply chains are facing unsustainable pressure from the rapidly growing world population, climate change, environmental deterioration (land and ocean), the COVID-19 pandemic, and more recently the war in Ukraine. Millions of people worldwide are in danger of having no access to food, the result of more frequent extreme weather conditions, depletion of the agricultural landscape by conflicts and wars, and the devastating loss of agriculture by insect infestations and diverse plant diseases.

Many food producing countries are however facing challenges in correlating traditional ways of food production to meet the demand of growing world population. For example, both China and USA were able to increase its crop yield per unit area in the past through the use of planting technologies (Mok et al., 2020) but much less so over the past 10 years due to deteriorating farming conditions and supply chain disruptions. As a whole, countries can no longer rely on traditional farming techniques and should look for more creative and technologically advanced methods to produce food.

In Singapore, rapid economic development has seen its population increased by 87% from 3.047 million to 5.7 million in 2019. This increase has been met by a rapid decline in the amount of land allocated for agriculture from 25% in 1965 to less than 1% in the 2020. To compensate the limited food supply from local production (around 10%), Singapore imports foods from more than 170 countries (Chen et al. 2019). In view of the changing external environment conditions (drop in food production from global warming and supply chain disruptions from infectious diseases or geopolitical tensions), Singapore's food security is increasingly vulnerable (Mok et al., 2020).

Therefore, technology innovations are key to enhance food security in Singapore. Such technologies may include vertical farming, aquaponics and internet-driven agriculture, as well as platform technology to develop alternative and unconventional food sources.

To this end, the Singapore government announced in 2019 the "30 by 30" strategy which aims to produce 30% of nutrition needs from local food production by 2030 with adoption of new urban technologies to maximise yields from the limited land spaces.

Changing Farming Landscape

Urban farming has evolved in the past decades from two-dimensional greenhouses to three-dimensional vertical farms to environmentally controlled indoor plant factories (Mok et al., 2020).

Vertical farming refers mainly to the cultivation of vegetables and fruits in vertically stacked layers in urban areas in which the conditions of different floors can be controlled (Fig. 1). Due to its limited land space, vertical farming is especially relevant to the primary production in Singapore but is also suitable for other cities to meet the demand of consumers towards fresher and nutritious vegetables and fruits.

Figure 1. *Vertical Farming of Leafy Vegetables*

Vertical farms can be more sustainable and efficient. For example, a combination of recycled water, air-temperature and humidity control, solar panel lighting or controlled 24 hour LED lighting to minimize seasonality. In certain cases, plants are grown under soilless conditions with nutrients fed through a solution that flow past the plant roots (Mok et al., 2020). Sky Green, Singapore's first commercial vertical farm utilizes customizable modular towers to house the vegetables which are in turn planted on rotating racks powered by recycled water-pulley system that deploy rainwater collected from its overhead reservoirs. The rotating system helped to ensure equal distribution of sunlight, air flow and irrigation.

There are numerous benefits and opportunities to vertical farming that could significantly change the agricultural landscape. Firstly, due to its vertical nature, productivity per unit area of cultivated land is enhanced by as high as 14 times for lettuce grown in vertical farms compared to traditional farming (Mok, 2020). In addition, vertical farming could also produce multiple types of crops simultaneously compared with mostly single type from the traditional farming.

Vertical farming is also resistant to climate changes and natural disasters, as the crops grown indoors are protected from the external environment with the ideal conditions required for optimum growth.

Traditional farming consumes huge amount of fossil fuels during transportation and storage. As vertical farms are located in the city areas, they can reach to consumers faster and requires much less transportation and storage therefore generating much less carbon footprint.

Future Direction of Vertical Farming and Nutrition

Sustainable urban farming also requires system efficiency, including controllable conditions for superior plant performance (high yield, high nutrients, strong resilience), reduced energy consumption, and zero waste circular economy systems. For vertical farming, the energy efficiency would make it sustainable in long run and also help to reduce production cost. Currently, vertically grown crops have a higher energy consumption compared to conventionally grown ones. Proper energy usage and planning would be needed for vertical farming to be fully feasible.

From a perspective of systems approach, a few areas are essential to support the costly and energy-demanding vertical farming in city areas including the tropical Singapore. These may include: 1. integrated vertical farming technologies for higher yield and nutrient dense vegetables. 2. Circular farming system through zero-waste technologies. 3. Integration of smart material-based and digitalized energy systems. 4. Comprehensive monitoring systems for yield and nutrient optimization.

A breakdown of Singapore food consumptions shows that the population is increasingly health conscious and eating more healthily. Therefore, vertical farming not only focus on quantity but the quality of the produce (Chen et al. 2019).

The increasing global demand for urban farming urgently needs integrated innovative agri-food technologies for greater sustainability and food security. A sustainable agri-food system for Singapore and beyond needs an eco-urban farming system that integrates improved plant nutrient values enhanced yield, higher performance in energy saving, and circular farming system. The integrated systems approach will result in a controlled enhancement in urban food production thereby addressing global sustainability challenges in agriculture and food security.

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Coordinated Research Projects (CRPs)

Project Number	Ongoing CRPs	Project Officers
D22006	Enhanced Biotic-stress Tolerance of Pulses Towards Sustainable Intensification of Cropping Systems for Climate-change Adaptation (2019–2024)	A. Hingane S. Sivasankar
D24014	Development of Integrated Techniques for Induced Genetic Diversity and Improvement of Vegetatively Propagated and Horticultural Tree Crops (2021–2025)	I.K. Bimpong S. Sivasankar
D24015	Radiation-induced Crop Diversity and Genetic Associations for Accelerating Variety Development (2022-2027)	S. Sivasankar
D23033	Integrative Approach to Enhance Disease Resistance Against Fusarium Wilt (Foc TR4) in Banana – Phase II	C. Zorrilla S. Sivasankar
E43041	Application of Nuclear Techniques to Improve and Evaluate Nutritional and Health Benefits of Underutilised Crops	K. Bimpong V. Owino

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

Project Officer: A. Hingane, S. Sivasankar

The objective of the CRP is to enhance the productivity of three important pulses - chickpea, cowpea, and lentil - which contribute to 40% of the worldwide pulses production, using mutation induction and genomics technologies. The project focuses on improving the resistance of chickpea to the pod borer *Helicoverpa armigera*, cowpea to the bod borer *Maruca vitrata*, and lentil to the disease *Stemphylium blight*. The CRP was started in 2019 and has resulted in the development of a large number of mutant populations for the desired traits of all three pulse crops over the past four years. This initiative has provided the opportunity to collaborate with the National Agricultural Research System of the Member State countries and the CGIAR centres. Standardized screening protocols are being developed for the target pests and diseases in all three pulse crops. Promising mutants with tolerance to the pod borer in chickpea and cowpea, as well as Stemphylium blight in lentil, have been identified. These mutants will be further evaluated and developed into genomic resources, leading to the release of new varieties.

Project Counterparts from ICRISAT are working to identify superior lines and candidate genes for pod borer (*Helicoverpa armigera*) resistance in chickpea. Based on three seasons of evaluation they have identified few promising mutant lines (M4), namely, ICCL 86111-B-8-4, ICCL 86111-B-688-10, ICCL 86111-B-638-8, ICCL 86111B-834-2, ICCL 86111-B-862-6, ICCL 86111-B-713-3, ICCL 86111-B-1066-2, ICCL 86111-B-1072-3, and ICCL 86111-B-1002-2, exhibiting lowest percent larval survival and larval weight gain under lab bioassay (Figure:1) and least pod damage under field conditions when compared to ICCL 86111(Non-mutant) and ICC 3137 (Susceptible check).

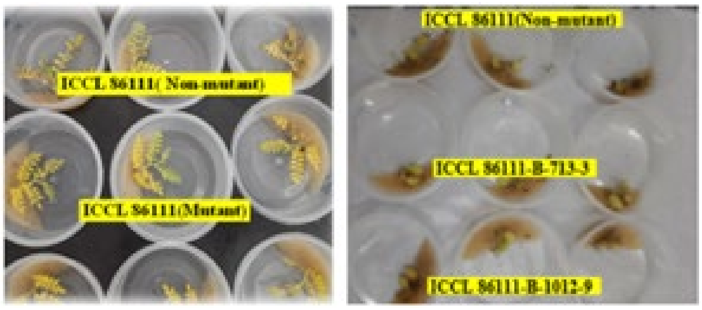
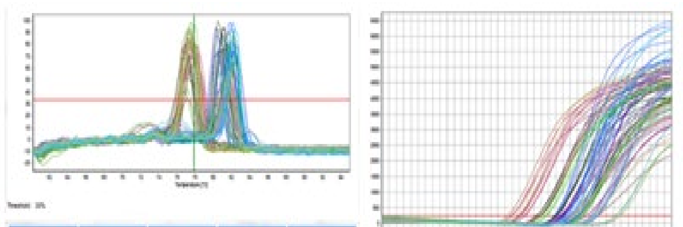


Figure 1. *Antibiosis studies for pod borer in mutant and non-mutant lines by leaf and pod bioassays*

Researchers at the Bhabha Atomic Research Centre(BARC) in India have identified three cowpea mutant lines at M5 that demonstrate resistance to *Maruca vitrata*, the pod borer. These lines are expected to undergo further evaluation in State and National trials before ultimately being released as new varieties. The scientists have generated sufficient seeds of these mutants for multi-location trials and have started summer sowing trials at the target locations. They have also conducted gene expression studies on cowpea, focusing on genes related to insect resistance pathways.



Genotype	ISS1	PAL1	GGPS1	ICD1
VCP22	5.24	2.6	2.57	2.93
LOLA	1	1	1	1

Figure 2. *DGE analysis, CT and melt curve analysis of pod borer resistance genes*

This work was presented at the International Conference on Pulses (ICPulses 2023) in New Delhi, India in February 2023 and won the award for the best poster (Figure: 3).

Figure 3. *Results of mutants with resistance to the cowpea podborer, Maruca vitrata, presented at the International Conference on Pulses (ICPulses 2023) in New Delhi, India, in February 2023*

The CRP participants from Namibia at the University of Namibia are also working to induce pod borer (*Maruca vitrata*) tolerance through mutation induction and has identified promising M3 and M4 mutants . They have identified mutants with phenotypic characteristics associated with *Maruca* pod borer tolerance such as wider angle between pods, inflorescent located above foliage etc. Interestingly they have also identified photo-insensitive mutants during off-season generation advancement under long day conditions, which opens up opportunities for cowpea to be cultivated in non-traditional cropping systems in Namibia.

CRP D24014: Development of Integrated Techniques for Mutation Breeding in Vegetatively Propagated and Horticultural Tree Crops

Project Officer: K. Bimpong, S. Sivasankar

The CRP will provide outcomes that can guide National Agricultural Research Systems (NARS) in Member States to accelerate the development of new varieties of vegetatively propagated crops (VPCs) and horticultural tree crops (HTCs) through the use of efficient state-of-the-art technology packages.

The CRP aims to develop new genetic resources and technologies for accelerated breeding in VPCs and HTCs through induced genetic diversity, chimera-free regeneration, and functional genomics. It will lead to the generation of (a) stable mutant clones that are free-of-chimeras and characterized at the genetic and molecular levels for traits of interest; and (b) publication of protocols for phenotyping and genomic analyses for Member States.

The CRP includes 13 participating countries from Member States where the crops are grown extensively, some advanced institutions and the CGIAR research centres with the respective mandates. Each country will bring together researchers covering the fields of micropropagation, advanced functional genomics for variant discovery and the use of nuclear techniques to induce genetic diversity at the cell or tissue level in selected VPCs and HTCs to address the research objectives.

CRP D24015: Radiation-Induced Crop Diversity and Genetic Associations for Accelerating Variety Development

Project Officer: S. Sivasankar, C. Zorrilla

CRP D24015 was approved in October 2021 and was launched in April 2022 with its first Research Coordination Meeting.

Breeding with induced genetic diversity has remained a highly effective avenue for the improvement of both simple and complex crop traits in Member States of the FAO/IAEA. Mutation breeding has mainly relied on gamma rays, but most recently the ion beam, electron beam, proton beam and space irradiation (cosmic rays) are coming into increasing use at least in some Member States, though the effect of these different sources on the plant genome remain to be assessed systematically. Newer genomic technologies that establish genetic associations for marker and candidate gene discovery also remain yet to be applied to mutation breeding for increased precision and breeding efficiency.

Mutant populations generated from induced genetic variation are traditionally used directly as source germplasm for breeding and variety development. However, they can also render themselves to the establishment of genetic associations for marker-assisted breeding and gene editing. Theoretically, mutant populations can also be used for genomic predictions for increased efficiency of the breeding process.

The overall objective of this CRP is to strengthen the ability of the Agency and its Member States to develop and test emerging technologies in mutation induction, genomics and big data to facilitate the accelerated development of crop varieties for food security and climate-change adaptation.

CRP D23033: Integrative Approach to Enhance Disease Resistance Against Fusarium Wilt (Foc TR4) in Banana – Phase II

Project Officer: C. Zorrilla, S. Sivasankar

The CRP D23033 was approved in September 2022 and has opened calls for proposals from mid-October to mid-December. This project is expected to launch with its first Research Coordination Meeting in April 2023.

This CRP is aimed at improving disease resistance in banana and developing microbes with enhanced beneficial activities through induced mutagenesis for the management of Fusarium wilt (*Foc* TR4) disease. Specific research objectives are (1) to generate induced genetic diversity in bananas using physical mutagenesis for developing resistance; (2) to generate functional genomics tools and methodologies for understanding the mechanisms of disease resistance using available resistant germplasm that will contribute to markers development and gene editing; (3) to develop rapid and reliable diagnostic protocols for field detection of the pathogen; and (4) to develop protocols for physical mutagenesis of microbes for enhanced biocontrol and plant growth promotion activities, and evaluation against the disease.

CRP E43041: Application of Nuclear Techniques to Improve and Evaluate Nutritional and Health Benefits of Underutilized Crops

Project Officer: K. Bimpong, V. Owino

Malnutrition as a result of nutrient deficiencies, especially for micronutrients (e.g., iron, zinc, calcium, vitamin A, thiamine, riboflavin) and essential amino acids, is associated with almost 50% of mortality among children under 5 years of age, especially in Low- and Middle-Income Countries.

For example, iron deficiency affects at least 30% (2 billion) of the world's population; it is associated with anaemia, decreased work capacity, impaired immune and endocrine function, and impaired physical and cognitive development in children. Uunderutilized crops can be used to enhance nutrition security as they have higher concentration of nutrients, including protein, vitamins, and minerals.

Mutation breeding is a routine method in plant breeding and has contributed to the development of new varieties with desired traits. However, nutritional benefits of most nutrient-enhanced underutilized crop varieties have not been evaluated adequately since the focus of mutation induction has been on enhancing crop yield. This CRP aims to fill this gap by generating robust evidence on the nutritional value and health efficacy of underutilized crops among vulnerable groups in Asia and Pacific, Africa, Latin America, and Europe. This approved CRP is an innovative cross-disciplinary approach to improving and evaluating the nutritional benefits of underutilized crops between NAFA-Plant Breeding and Genetics (PBG) and NAHU- Nutritional and Health- Related Environmental Studies (NAHRES).

Forthcoming Events

Third Research Coordination Meeting (RCM)

Development of Integrated Techniques for Mutation Breeding in Vegetatively Propagated and Horticultural Tree Crops, D24014

Vienna, Austria, 10-14 July 2023

The CRP uses both induced genetic variation and functional genomics technologies to address constraints associated with vegetatively propagated and horticultural tree crops. Research will focus on induction of genetic diversity, chimera-free regeneration, and functional genomics to accelerate breeding in cassava, olive, and potato/sweet potato. In addition, the CRP aims to develop disease-resistant and stable clones of mutants for Cassava Brown Streak Disease (CBSD), Olive Quick Decline Syndrome (OQDS) and all major diseases in potato/sweet potato.

The CRP started in 2020 and had its second virtual RCM on November 14-18, 2022, and this will be the first time the CRP participants will meet together in person. The meeting will provide an opportunity for participants to share their work progress to date and also discuss the status of preparation and production of a book(s) planned for 2023 but postponed to 2024 from the CRP output. The meeting is also expected to discuss the progress of work by participants using the Gamma Greenhouse at Nuklear Malaysia for their research activities. The final report of the meeting will be compiled and shared with the management.

Past Events

First Research Coordination Meeting (RCM)

Radiation-induced Crop Diversity and Genetic Associations for Accelerating Variety Development (D24015)

Virtual. 6-8 March 2023

The first research coordination meeting for CRP D24015 was held virtually in March 2023 after a previous workplan discussion in April 2022 immediately after the launch of the CRP. The meeting in March 2023 took stock of research status in each participating project of the CRP and good progress was noted.

The meeting was attended by the Chief Scientific Investigators (and teams in some cases) of the 14 projects in the CRP, and presentations were made on each project. Projects within the CRP are: (1) Characterization of biological and genomic variations in space-induced mutagenesis for accelerating breeding in wheat (China); (2) Comparative study of high energy pulsed electron beam and gamma ray mutagenesis and characterization of an electron beam mutant through genomics approach in groundnut (*Arachis hypogaea* L.) (India); (3) Decoding the complex molecular machinery associated with drought and salinity tolerance in rice using advanced molecular tools (India); (4) Characterization of mutations and genomic rearrangements in plants upon exposure to various sources of ionizing radiations (France); (5) Mutation Breeding for Quantitative Traits with Genomic Selection (United Kingdom); (6) Development of Irradiation Techniques and Useful Mutants of some Crops used by Proton Beam (Republic of Korea); (7) Cloning and Functional Analysis of a Drought-Tolerant Cotton Mutant Obtained from Space Mutagenized Seeds (China); (8) Study of Genetic Associations of Black Seed Coat Trait in Mutant Soybean Line DT26BS (Viet Nam); (9) Exploiting Induced Mutations to Unearth Molecular Associations for Resistance to Marusa Pod Borer and Striga Restistance in Cowpea, *Vigna unguiculata* (Nigeria); (10) Mapping of Genetic Associations of Number of Pods Per Plant and Number of Seeds Per Pod in Cowpea (Ghana); (11) Marker assisted pyramiding of gamma-ray induced resistance in sorghum for durable resistance to *Striga hermonthica* (Burkina Faso); (12) Developing a molecular diagnostics toolkit to improve malting barley using a fast-forward genetics approach (Australia); (13) Molecular analysis of 'genetic imprints' across rice genome and enhancement of germplasms induced by circumlunar space flight of Chang'e 5 (China); (14) Development of Shatterless Sesame (*Seamum indicum* l.) Varieties by Mutagenesis and Determination of Genetic Associations for Reduced Shattering (Niger)

First Research Coordination Meeting (RCM)

Integrative Approach to Enhance Disease Resistance Against Fusarium Wilt (FoC TR4) in Banana – Phase II (D23033)

Virtual. 15-19 May 2023

CRP D23033 was approved in September 2022 and opened a call for proposals from mid-October 2022 to January 2023.

This CRP project was launched with its first Research Coordination Meeting in May 2023.

This CRP is aimed at improving disease resistance in banana and developing microbes with enhanced beneficial activities through induced mutagenesis for the management of Fusarium wilt (*Foc* TR4) disease. Specific research objectives are (1) to generate induced genetic diversity in bananas using physical mutagenesis for developing resistance; (2) to generate functional genomics tools and methodologies for understanding the mechanisms of disease resistance using available resistant germplasm that will contribute to markers development and gene editing; (3) to develop rapid and reliable diagnostic protocols for field detection of the pathogen; and (4) to develop protocols for physical mutagenesis of microbes for enhanced biocontrol and plant growth promotion activities, and evaluation against the disease.

A total of 13 Institutions from Asia, Africa and Latin America participating in this CRP discussed the workplan of the project with special emphasis on activities for the first year and strategies to achieve the objectives of the project. As well, collaboration links were established among participants. A total of 16 researchers (10 male and 6 female) from participating institutions were part of this meeting.

First Workshop on Plant Mutation Breeding at the International Plant and Animal Genome Conference (PAG) hosted by PBG

In January 2023, PBG hosted the inaugural "**Plant Mutation Breeding**" workshop at the **International Plant and Animal Genome Conference** in San Diego, USA (PAG 30, January 13-18, 2023). The workshop was organized by Norman Warthmann and Isaac Kofi Bimpong from Plant Breeding and Genetics at the Joint FAO/IAEA Centre.

On behalf of Shoba Sivasankar, Section Head of Plant Breeding and Genetics at the Joint FAO/IAEA Centre, Technical Officer Isaac Kofi Bimpong provided the opening talk, which was followed by four further talks on the subject of plant mutation breeding.

Plant Breeding and Genetics at the Joint FAO/IAEA Centre, Isaac Kofi Bimpong (Presenting Author), Shoba Sivasankar, Norman Warthmann, Joint FAO/IAEA Centre, Vienna, Austria.

Mutation Breeding for Stress Resilience in Cereals, Antonio Costa De Oliveira, Federal University of Pelotas, Pelotas-RS, Brazil

The Sequence of Mutants in the Model Rice Variety Kitaake Facilitates Rapid Functional Genomic Studies, Pamela Ronald, Joint BioEnergy Institute (JBEI), Emeryville, CA and Rashmi Jain, University of California, Davis, Davis, CA

Mutation Breeding in the Age of Next-Generation Sequencing and Genome Editing, Zhanguo Xin, Yinping Jiao, Gloria Burow, Chad Hayes, Junping Chen and Doreen Ware, (1)USDA-ARS, Lubbock, TX, (2)Texas Tech University, (3)USDA ARS NEA Plant, Ithaca, NY

Speed Breeding to Accelerate the Discovery and Utilisation of Desirable Mutations, Lee Hickey, The University of Queensland, Brisbane, QLD, Australia https://plan.core-apps.com/pag_2023/event/3cee484866e6d00c5e492240c4d29b9e

PAG is the most significant annual conference on the genetics and genomics of plant and animal research and breeding. PBG intends to establish this workshop at PAG as yearly networking hub for the Mutation Breeding community supporting our capacity building for Member States.

Technical Cooperation Field Projects

Project Number	Country/Region	Title	Technical Officer(s)
BDI5005	Bangladesh	Enhancing Productivity of Staple Crops Using Nuclear-derived Technologies	I.K. Bimpong with SWMCN
BKF5024	Burkina Faso	Improving Food Crops through Mutation Breeding and Best Soil and Nutrient Management to Ensure Food Security	F. Sarsu with SWMCN
BOL1012	Bolivia	Strengthening National Capacities on Irradiation Technology	C. Zorrilla with NAPC
BOT5019	Botswana	Improving Selected Legumes and Cereals against Biotic and Abiotic Stresses to Improve Food Production and Security	I.K. Bimpong
BOT5024	Botswana	Improving Selected Legumes and Cereals against Biotic and Abiotic Stresses for Enhanced Food Production and Security	I.K. Bimpong with SWMCN
BUL5016	Bulgaria	Improving the Productivity and Quality of Economically Important Crops through Mutation Breeding and Biotechnology	C. Zorrilla
CAF5013	Central African Republic	Improving Productivity of Maize and Developing Resistant Armyworm Maize Varieties Using Radio-Mutagenesis Techniques	S. Sivasankar
CAF5015	Central African Republic	Improving Productivity of Maize and Developing Resistance to Fall Armyworm Using Radiation-Induced Novel Genetic Diversity — Phase II	F. Sarsu
CHI5052	Chile	Using Nuclear Techniques to Improve the Adaptation and Productivity of Forest Species Facing Climate Change	C. Zorrilla
CHI5054	Chile	Use of Irradiation and Isotopic Techniques to Improve Native and Agricultural Plant Genetics	C. Zorrilla
COL5026	Colombia	Enhancing Crop Productivity of Creole Potato Using Nuclear and Related Techniques	I.K. Bimpong with SWMCN
CPR5024	China, People's Republic of	Enhancing the Accelerated Application of Mutant Germplasm and High-Efficiency Breeding in Crops	N. Warthmann
CUB5023	Cuba	Strengthening National Capacities for the Development of New Varieties of Crops through Induced Mutation to Improve Food Security While Minimizing the Environmental Footprint	C. Zorrilla with SWMCN
ECU5034	Ecuador	Improving the Resilience of Bananas to their Major Diseases through Mutation Breeding Techniques	S. Sivasankar
ERI5011	Eritrea	Developing Improved Banana and Maize Varieties through Mutagenic Nuclear Techniques	I.K. Bimpong
ERI5013	Eritrea	Improving Food Crop Varieties through Mutation Breeding and Related Technologies	I.K. Bimpong
GHA5038	Ghana	Using Irradiated Pollen for the Development of Provitamin A Rich, Drought Tolerant and Cassava Mosaic Disease Resistant Cassava Mutants	C. Zorrilla
GHA5039	Ghana	Mainstreaming Nuclear Based Climate Smart Agriculture Technologies into Sustainable Production	C. Zorrilla with IPC *and* SWMCN
HAI0007	Haiti	Building National Capacity in Nuclear Technology Applications	I.K. Bimpong with NAPC
HON5009	Honduras	Improving Genetic Resistance of Coffee-to-Coffee Leaf Rust through Mutation Breeding	F. Sarsu

Project Number	Country/Region	Title	Technical Officer(s)
INS5044	Indonesia	Using Nuclear Technology to Support the National Food Security Programme	S. Sivasankar with SWMCN
IRA5015	Iran, Islamic Republic of	Enhancing Capacity of National Producers to Achieve Higher Levels of Self-Sufficiency in Key Staple Crops	F. Sarsu with FSC *and* SWMCN
IRQ5023	Iraq	Utilizing Nuclear Technology to Improve Key Legume Crops for Climate Change Adaptation	I.K. Bimpong
IVC5040	Cote d'Ivoire	Improving Agricultural Production of Maize, Rice and Cassava through Cultivation of Induced Mutant Adaptable to Climatic Changes	I.K. Bimpong
JAM5013	Jamaica	Improving Crops by Using Experimental Mutagenesis and Diagnostic Technologies	S. Sivasankar
JAM5014	Jamaica	Establishing a Self-Contained Gamma Irradiation Facility for the Introduction of Sterile Insect Technique and Experimental Mutagenesis and Diagnostic Technologies	S. Sivasankar with IPC
KAM5007	Cambodia	Improving Cotton for Enhanced Resilience to Climate Change	F. Sarsu
KEN5038	Kenya	Using Nuclear Techniques to Evaluate and Improve the Impact of Mutated Forages on the Performance of Smallholder Dairy Cows	I.K. Bimpong with APH
KUW5005	Kuwait	Implementing Mutation Induction to Improve Barley Production under Harsh Environmental Conditions – Phase III	F. Sarsu
KUW5006	Kuwait	Improving Barley and Sorghum Production Under Harsh Environmental Conditions Using Mutation Breeding Techniques	S. Sivasankar
LAO5006	Lao PDR	Enhancing Crop Production with Climate Smart Agricultural Practices and Improved Crop Varieties	F. Sarsu with SWMCN
LES5012	Lesotho	Improving Productivity of Potato and Sorghum through Mutation Breeding and Best Soil, Nutrient and Water Management Practices	I.K. Bimpong
LIR5003	Liberia	Enhancing Rice Productivity Using Induced Mutation and Speed Breeding for Food Self–Sufficiency and Income Generation	I.K. Bimpong
MAG5026	Madagascar	Enhancing Rice and Maize Productivity through the Use of Improved Lines and Agricultural Practices to Ensure Food Security and Increase Rural Livelihoods	F. Sarsu with SWMCN *and* IHS
MAK5010	Macedonia	Improving Dry Bean Productivity and Tolerance to Diseases and Drought by Use of Nuclear Techniques	F. Sarsu
MAL5032	Malaysia	Strengthening National Capacity in Improving the Production of Rice and Fodder Crops and Authenticity of Local Honey Using Nuclear and Related Technologies	C. Zorrilla with FSC *and* SWMCN
MAR5029	Mauritius	Improving Landraces of Crucifers (Cauliflower and Cabbage) and Carrot through Mutation Breeding and Biotechnology — Phase II	F. Sarsu
MAU5009	Mauritania	Improving Rice and Sorghum through the Application of Nuclear Techniques	I.K. Bimpong
MHL5003	Marshall Islands	Enhancing Food Productivity by Promoting New Mutant Varieties and Traditional Varieties	C. Zorrilla
MLI5031	Mali	Improving Rice Productivity through Mutation Breeding and Better Soil, Nutrient and Water Management Practices	I.K. Bimpong with SWMCN
MLW5005	Malawi	Developing Drought Tolerant, High Yielding and Nutritious Crops to Combat the Adverse Effects of Climate Change	C. Zorrilla

Project Number	Country/Region	Title	Technical Officer(s)
NAM5017	Namibia	Improving Crops for Drought Resilience and Nutritional Quality	C. Zorrilla with SWMCN
NAM5020	Namibia	Enhancing Staple Crop Yields, Quality, and Drought Tolerance through Broadening Genetic Variation and Better Soil and Water Management Technologies	F. Sarsu with SWMCN
NEP5006	Nepal	Enhancing Productivity of Corps and Fruit Employing Nuclear and Molecular Techniques	I.K. Bimpong
NER5024	Niger	Improving Key Staple Crops towards Food Security	S. Sivasankar
NER5025	Niger	Improving Food and Biological Hazard Detection, Food Preservation and Mutation Breeding	I.K. Bimpong with FSC
NHE5001	Vanuatu	Enhancing the Productivity and Quality of Crops through the Application of Mutation Breeding Techniques	L. Jankuloski
NIC5011	Nicaragua	Broadening the Genetic Variation of Vegetative Propagated Crops Using Nuclear Techniques	C. Zorrilla
PAK5053	Pakistan	Strengthening and Enhancing National Capabilities for the Development of Climate Smart Crops, Improvement in Animal Productivity and Management of Soil, Water, and Nutrient Resources Using Nuclear and Related Techniques	F. Sarsu with SWMCN
PAL5011	Palestine	Enhancing Food Security via Nuclear Based Approaches	I.K. Bimpong with SWMCN
PAR1005	Paraguay	Establishing National Capabilities in Irradiation Technologies for the Treatment of Patients with Burns and the Introduction of Mutation Breeding for Enhanced Quality and Productivity of Crops	S. Sivasankar with NAPC
PAR5012	Paraguay	Evaluation of Varieties and Advanced Mutant Lines against Biotic and Abiotic Stress Conditions to Mitigate the Effects of Climate Change in Crops	C. Zorrilla
PER5034	Peru	Improving Yellow Potato and Coffee Crops through Mutation Breeding Techniques	F. Sarsu
PHI5036	Philippines	Providing an Innovative Platform for Germplasm Utilization for Rainfed and Irrigated Lowland Rice Ecosystems — Phase	S. Sivasankar
QAT5008	Qatar	Developing Best Soil, Nutrient, Water and Plant Practices for Increased Production of Forages under Saline Conditions and Vegetables under Glasshouse Using Nuclear and Related Techniques	F. Sarsu with SWMCN
RAF5083	Regional Africa	Enhancing Crop Productivity through Climate Smart Crop Varieties with Improved Resource Use Efficiency (AFRA)	F. Sarsu
RAS5077	Regional Asia	Promoting the Application of Mutation Techniques and Related Biotechnologies for the Development of Green Crop Varieties (RCA)	I.K. Bimpong
RAS5088	Regional Asia	Enhancing Crop Productivity and Quality through Mutation by Speed Breeding (RCA)	F. Sarsu
RAS5094	Regional Asia	Promoting Sustainable Agricultural and Food Productivity in the Association of Southeast Asian Nations Region	C. Zorrilla with FSC *and* SWMCN
RAS5098	Regional Asia	Improving the Resilience of Crops to Climate Change through Mutation Breeding — Phase II (SAPI)	C. Zorrilla
RAS5099	Regional Asia	Developing Climate Smart Crop Production including Improvement and Enhancement of Crop Productivity, Soil and Irrigation Management, and Food Safety Using Nuclear Techniques (ARASIA)	I.K. Bimpong with SWMCN
RER5024	Regional Europe	Enhancing Productivity and Resilience to Climate Change of Major Food Crops in Europe and Central Asia	F. Sarsu

Project Number	Country/Region	Title	Technical Officer(s)
RLA5084	Regional Latin America	Developing Human Resources and Building Capacity of Member States in the Application of Nuclear Technology to Agriculture	S. Sivasankar with SWMCN *and* APH
RWA5001	Rwanda	Improving Cassava Resilience to Drought and Waterlogging Stress through Mutation Breeding and Nutrient, Soil and Water Management Techniques	F. Sarsu with SWMCN
SAF5016	South Africa	Promoting Mutation Breeding of Vegetables to Improve Rural Livelihoods — Phase I	N. Warthmann
SIL5021	Sierra Leone	Improving Productivity of Rice and Cassava to Contribute to Food Security	I.K. Bimpong with SWMCN
SRL5050	Sri Lanka	Supporting Genetic Improvement of Tea	S. Sivasankar
SUD5041	Sudan	Enhancing Productivity and Quality of High Value Crops through Improved Varieties and Best Soil, Nutrient and Water Management Practices	F. Sarsu with SWMCN
SWA5002	Eswatini, Kingdom of	Improving Adaptability of Cowpea to Climate Change through Mutation Breeding	F. Sarsu
SYR5026	Syrian Arab Republic	Using Accelerated Mutation Breeding of Staple Crops for Enhanced Resilience to Climate Change through Speed Breeding, Phenotyping and Genotyping	F. Sarsu
TOG5004	Togo	Improving Crop Productivity and Agricultural Practices through Radiation Induced Mutation Techniques	I.K. Bimpong with SWMCN
TUN5031	Tunisia	Developing Cereal and Legume Mutants for Improving Food Security and Farmers' Resilience to Climate Change	A. Hingane
UGA5043	Uganda	Improving Cassava and Rice Disease Resistance through Mutation Breeding Techniques	I.K. Bimpong
URT5037	Tanzania, United Rep. of	Developing Rice Varieties with Resistance to Rice Blast and Salinity Tolerant Using Mutation Breeding and Biotechnology Techniques	F. Sarsu
VEN5023	Venezuela	Improving Banana Productivity through Mutation Breeding Techniques for Enhanced Disease Resistance	S. Sivasankar
YEM5015	Yemen	Enhancing Sorghum and Legume Crop Productivity through Induced Mutations with Supportive Breeding and Biotechnologies	L. Jankuloski
YEM5016	Yemen	Enhancing Sorghum and Legume Crop Productivity through Induced Mutations with Supportive Breeding and Biotechnologies — Phase II	F. Sarsu
ZAI5029	Congo, Democratic Republic of the	Enhancing Crop Productivity of Soybean and Maize through Improved Mutant Varieties and Lines	I.K. Bimpong
COD5030	DR Congo	Improving Staple Crop Productivity and Quality through Biotechnology and Nuclear Techniques — Phase IV	I.K. Bimpong
INT5158	Interregional	Strengthening Member State Capacities to Combat Banana Fusarium Wilt (TR4) through Early Detection, New Resistant Varieties, and Integrated Management	S. Sivasankar

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

Forthcoming Events

National Training Course

Mutation Breeding Techniques and Crop Improvement, MAU5009

Nouakchott in Mauritania, 12 - 19 June 2023

Project Officer: I. K. Bimpong

The training objective is to enhance the understanding and research capabilities of the participants in advanced technologies involved in plant mutation breeding, specifically in speed breeding and related enabling techniques in developing rice and sorghum crops for the country. The training course will cover topics such as mutation induction, breeding schemes, early and late generation selection methods for targeted stresses, multi-location and farmer field trials, introductory to protocols in the laboratory, greenhouse and field conditions for successful implementation of breeding programmes, informal and formal seed systems for the multiplication and dissemination of seed for upscaling and cultivation. The course will include lectures, demonstrations and practical sessions on various protocols on mutation breeding and selection. The course is design for researchers, plant breeders who are working on mutation induction of cereals. Twenty one participants (20 males and 1 female) are expected to join the training.

National Training course

Mutation induction and crop improvement in cowpea and sorghum for adaptation to extreme climatic conditions; BOT5024

Gaborone, Botswana, 19 - 23 June 2023

Project Officer: I. K. Bimpong

The purpose of the training course is to provide participants with opportunities to strengthen their capacity in plant mutation breeding techniques, specifically in selection and phenotyping processes and related techniques in developing cowpea and sorghum crops for the country.

The course will cover topics such as mutation breeding, concepts, and methodologies, including optimization of irradiation treatments, lab, screenhouse and field-based screening protocols in developing new and improved mutant varieties/lines for improving crop resilience to drought stress. Other courses such as selection of mutant lines for registration and release as variety and seed systems will be part of the training. Approximately 15 participants are expected to join the training.

National Training Course

Mutation induction, selection in the 2 crops (Sweet potato and Sorghum) for adaptation to extreme climatic conditions; LES5012

Maseru, Lesotho, 19 to 23 June 2023

Project Officer: I. K. Bimpong

The project, LES 5012 “Improving Productivity of Potato and Sorghum through Mutation Breeding and Best Soil, Nutrient and Water Management Practices ” aims to strengthen participant researcher capacity in plant mutation breeding techniques, for selection and development of improved crops for the country. The training course will cover topics such as mutation induction, calculations of radiosensitivity test /curves, basics of experiment design, early and late generation testing of mutant lines/populations, basic statistics, single/multiple site analysis and interpretations, correlation and simple linear regression. The rest includes introductory molecular biology, basics of linkage analysis, QTL mapping and marker assisted breeding. The course is design for breeders, agronomist and other crop specialist involved in mutation breeding programmes. Approximately 14 participants (9 males and 5 females) are expected to join the training.

National Training Course

Application of Marker Assisted Mutation Breeding and Basic Bioinformatics for Improvement of Namibia Staple Food Crops

Windhoek, Namibia, 19-23 June 2023

Project Officer: F. Sarsu

Project Objective for NAM5020: Improve farmers’ income and livelihood through developing high yielding and drought tolerant crop varieties through mutation breeding and associated biotechnologies in Namibia.

Course Objective: Providing protocols for DNA analysis to detect mutation in induced mutation breeding program for sorghum, cowpea and groundnut, including genotyping using SSR marker, PCR and page gel techniques, data handling, application MAS to crop improvement program, prepare a workplan for application of MAS into Namibian Breeding Program for Improvement of Namibia Staple Food Crops.

National Training Course

Nutritional Quality Assessment Techniques Developing Drought Tolerant High Yielding and Nutritious Crops to Combat the Adverse Effects of Climate Change – MLW5005

Lilongwe, Malawi, 03-07 July 2023

Project Officer: C. Zorrilla

The project aims at developing new drought resilient mutant soybean and groundnut varieties, using nuclear technology to contribute towards achieving food, nutrition, and income security of the nation, as highlighted in the Country Programme Framework (CPF) for 2016–2021 as one of the major areas of cooperation with the IAEA. Mutagenized populations, which were generated by exposing seeds (M0) to the mutagen, were planted under irrigation at a horticulture department research farm to produce M1 plants, and later M2 seed. The M2 plants have been used to develop M3 seeds, which will be used in screenings for various properties, including drought tolerance, disease resistance and nutritional quality traits. As well, new mutants of groundnut, pigeon pea and soybean have been generated.

This training will provide basic understanding of biochemical analyses used for nutritional quality evaluation. As well as to provide an overview of equipment and materials needed for measuring relevant nutritional parameters such as total proteins, total oils, and oleic acids. A total of 17 participants (8 female, 9 male) are expected to be trained in this course.

The training will be held at the Chitedze Research Station, with participation of breeders and technicians involved in mutation breeding as well as other breeding groups interested in this topic.

Regional Training Course

Genomic selection to maximize genetic gain in mutation breeding programs

Kinshasa/DRC, 10-22 July 2023

Project Officer: F. Sarsu

Project Objective for RAF5083: Support AFRA States in developing and disseminating new and improved mutant crop varieties with improved yield, quality, and tolerance to biotic and abiotic stresses to contribute food security in Africa.

Course Objective**:** To strengthen Member States' capacities on application of mutation breeding, rapidly advancing genomic technologies, genomic predictions of mutant populations/lines to be used for increased efficiency of the breeding process, acceleration of crop improvement and enabling long-term increases in the "genetic gain" of breeding programs working on staple food crops in Africa. To provide techniques/technologies to young scientist in Africa to expedite the breeding process and developing and disseminating new and improved mutant crop varieties with improved yield, quality, and tolerance to biotic and abiotic stresses. to release mutant varieties to applied to mutation breeding for increased precision and breeding efficiency.

National Training Course

Improving Cassava Resilience to Drought and Waterlogging Stress through Mutation Breeding

Kigali, Rwanda, 17-22 July 2023

Project Officer: F. Sarsu

Project Objective for RWA5001: To enhance human and infrastructural capacities of the country to improve cassava through mutation breeding and combined biotechnologies to contribute to food security and improve livelihood of smallholder cassava farmers in Rwanda. This is the first mutation breeding program in the country.

Course Objective: Basic introduction of application of induced mutation in cassava breeding to help CP to prepare explant for irradiation and provide on screening of mutants for biotic/abiotic stress in lab, greenhouse and field conditions, cassava mutation breeding cycles from irradiation to release a variety and provide protocols to use laboratory, greenhouse, and field conditions to conduct a successful cassava breeding program.

National Training Course

Mutation induction and crop improvement in rice for adaptation to extreme climatic conditions, MLI5013

Bamako, Mali, 17 to 28 July 2023

Project Officer: I. K. Bimpong

The project, MLI 5031 5009 "Improving Rice Productivity through Mutation Breeding and Better Soil, Nutrient and Water Management Practices" aims to strengthen participant researcher capacity in plant mutation breeding techniques, specifically in selection and phenotyping processes and related techniques in developing rice and sorghum crops for the country.

The course will cover topics such as breeding scheme for mutation breeding program, Experimental designs and randomization, Stage one trial generation, selection methods for simple and few (monogenic) traits and for complex (polygenic) traits. The rest includes multi-location trials and understanding of GxE, and farmer field trials; selection of line/s for registration and release as variety and seed systems; and basics in molecular markers and gene mapping. The course will comprise of lectures, demonstrations, and practical sessions on various protocols on mutation breeding and selection methods. The course is design for participants who have basic knowledge in mutation breeding techniques. Fifteen participants are expected to join the training course.

National Training course

Mutation induction and Selection in Rice; LIR5003

Monrovia, Liberia, 1-12 August 2023

Project Officer: I. K. Bimpong

Since this project is the first mutation breeding programme for Liberia, the aim is to continue to create awareness on the importance of nuclear techniques in food and agriculture. This training is a follow up to last year training held virtually. The main theme of the training will include mutation induction, breeding schemes, early and late generation selection methods for targeted stresses, introductory to protocols in the laboratory, greenhouse and field conditions for successful implementation of breeding programmes, informal and formal seed systems for the multiplication and dissemination of seed for upscaling and cultivation. The course will include lectures, demonstrations, and practical sessions on various protocols on mutation breeding and selection methods. The course is design for researchers, plant breeders who are working on mutation induction of cereals (rice and sorghum). Fifteen participants are expected to join the training.

Regional Training Course

Mutation by Speed Breeding (MbyS) for Abiotic Stress Tolerance,

Jakarta, Indonesia, 07-18 August 2023

Project Officer: F. Sarsu

Project Objective for RAS 5058: Enhancing crop productivity and quality is the eternal subject in the Asia Pacific Region to satisfy the demand of population growth and climate change. Plant mutation breeding has played important roles in the past 60 years to breed new mutant varieties, elite lines, and mutant germplasm. The current project is combining mutation induction with speed breeding methods to develop a new approach, named mutation by speed breeding (MbyS), and the approach is extended to other Government Parties (GPs) through regional training courses, expert missions, or technical meetings.

Course Objective: To develop capacities in speed breeding techniques are being utilized to develop genetically stable lines to shorten breeding cycles to development of tolerant crop varieties for abiotic stresses. Participants are expected to enhance their knowledge, experience, and skills in establishing national plant breeding programmes using speed breeding technique, such as double haploid, marker assisted selection and artificial growth environments to shorten breeding cycle to develop genetically stable lines to breed new crop varieties with tolerance to abiotic stresses to contribute food security in the region.

Regional Training Course

Banana breeding for resistance to Fusarium wilt (*Foc* TR4) using tissue culture and nuclear techniques as part of the breeder's toolbox

Strengthening Member State Capacities to Combat Banana Fusarium Wilt (TR4) through Early Detection, New Resistant Varieties, and Integrated Management – INT5158

Bahia, Brazil, 28 August – 01 September 2023

Project Officer: C. Zorrilla, S. Sivasankar

The project INT5158 is aimed at developing capacities for disease management against *Foc* TR4 and the development of new resistant banana varieties using mutation breeding and combined biotechnologies to contribute to prevent the spread of this disease and reduce farmers losses.

This event is focused on the thematic area of the project related to Mutation Breeding. A maximum of 16 participants are expected from Member States such as Bolivia, Colombia, Costa Rica, Ecuador, Mexico, Peru, Venezuela, and Brazil that have initiated efforts to conduct mutation breeding.

The purpose of the event is to develop capacities on breeding methods used to develop resistance to *Fusarium oxysporum* f.sp *cubense*, Tropical Race 4 (*Foc* TR4) with especial emphasis on breeding using nuclear-induced mutations to generate new genetic diversity; and *in vitro* techniques used for multiplication of banana and plantains.

The training will be held at the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) that will share experiences and train on the implementation of mutation breeding as part of a banana and plantains breeding programme.

Regional Training Course

Speed Plant Breeding Techniques for Climate-Ready Crops- RAF5083

Tunis, Tunisia, 04-15 September 2023

Project Officer: F. Sarsu

Project Objective for RAF5083: To support AFRA States in developing and disseminating new and improved mutant crop varieties with improved yield, quality, and tolerance to biotic and abiotic stresses to contribute food security in Africa.
Course Objective : To develop Member States' understanding and research/laboratory capacities in basic aspects of crop mutation breeding, speed breeding techniques, such as double haploid, marker assisted selection and artificial growth environments, phenotypic

and genotypic linkage for selection of mutant plant population/mutant line, among others, is being utilized to develop genetically stable lines to shorten breeding cycles to development of tolerant crop varieties for biotic/abiotic stresses- Climate-Ready crops to contribute food security in Africa.

Advanced Regional Training Course

Mutation Breeding and Combined Biotechnologies, RAS5099

National Center for Nuclear Sciences and technologies (CNSTN), Tunisia, 14-15 September 2023

Project Officer: I. K. Bimpong

The training course will be implemented under the regional project, RAS5099 referred to as "ARASIA project", and will provide participants with knowledge, and skills in the application of mutation breeding and combined biotechnologies. The training aims to incorporate advanced and enabling technologies, to hasten the pace and precision in developing new and improved mutant varieties. The course curriculum will comprise of mutation breeding, concepts and methodologies, screening protocols for biotic and abiotic stresses in the laboratory, screenhouse and field conditions, selection methods for abiotic and biotic stresses, modalities for informal and formal seed systems for multiplication and dissemination for upscaling and cultivation, molecular biology, molecular markers and genome variations, genomics and transcriptomics, linkage analysis, , genome wide association analysis and introduction to bioinformatics. The course will involve lectures, demonstrations, and practical sessions on various protocols of mutation enhancing approaches and enabled biotechnological tools. The course is design for breeders, pathologist and tissue culture specialist in Member States involved in mutation breeding programmes and will be attended by approximately 20 participants from the Member States.

National Training Course

Developing Drought Tolerant High Yielding and Nutritious Crops to Combat the Adverse Effects of Climate Change – MLW5005

Lilongwe, Malawi, 25-29 September 2023

Project Officer: C. Zorrilla

The project aims at developing new drought resilient mutant soybean and groundnut varieties, using nuclear technology to contribute towards achieving food, nutrition, and income security of the nation, as highlighted in the Country Programme Framework (CPF) for 2016–2021 as one of the major areas of cooperation with the IAEA. Mutagenized populations, which were generated by exposing seeds (M0) to the mutagen, were planted under irrigation at a horticulture department research farm to produce M1 plants, and later M2 seed. The M2 plants have been used to develop M3 seeds, which will be used in screenings for various properties, including drought tolerance, disease resistance and nutritional quality traits. As well, new mutants of groundnut, pigeon pea and soybean have been generated.

The training course on Plant Mutation Breeding and Associated Biotechnologies included lectures, practical sessions, audio-visual tools, and discussions. The topics covered included mutation induction, radiosensitivity test, and biotechnological techniques associated to mutation breeding.

The training will be held at the Chitedze Research Station, with participation of breeders and technicians from other Research Stations and Institutions in the country interested in learning more about the potential of mutation breeding.

National Training Course

Mutation breeding and the use of molecular markers for drought tolerance in cereals

Kigali, Rwanda, 25-29 September 2023

Project Officer: F. Sarsu

Project is supported under Regional TC RAF5083: To support AFRA States in developing and disseminating new and improved mutant crop varieties with improved yield, quality, and tolerance to biotic and abiotic stresses to contribute food security in Africa.

Course Objective: Develop capacities in mutation breeding and molecular techniques in crop breeding specifically in cereal breeding mutation breeding programs. Developing and understanding on the use of molecular markers in mutation seed crops such as maize, sorghum and millets including concepts, applications, and data analysis.

Regional Training Course

Statistically Rigorous, Pre-field and Field Screening to Select Improved Mutant Lines to Release for Farmers, RAS5099

National Center for Agricultural Research and Extension (NCARE) Jordan, 24 September-5 October 2023

Project Officer: I. K. Bimpong

The project, RAS5099 "Developing Climate Smart Crop Production including Improvement and Enhancement of Crop Productivity, Soil and Irrigation Management, and Food Safety Using Nuclear Techniques (ARASIA)" aims to strengthen participant researcher capacity in technologies involved in plant breeding, specifically for related enabling techniques and statistical rigor in field-testing for the selection of improved varieties.

The course curriculum will include breeding informatics in plant breeding, use of software's to intermate parents, genealogy management, generation advancement, basics of experiment design and early generation testing, barcoding of plots/plants using any good software, digital data recording using field book, introductory R Language (Installing R and R studio, vectors and matrices, factors, data frame, plotting), stage 1 trials generation, multilocational trials, GxE and stability analysis, and concept of mega environment and location grouping.

The training course will comprise of lectures and demonstrations. The course is design for breeders, agronomist and other crop specialist from Member States involved in mutation breeding programmes. Approximately 20 participants are expected to join the training.

Regional Training Course

Molecular Markers and TILLING Applications for Crops Improvement

Katowice, Poland, 25 September-06 October 2023

Project Officer: F. Sarsu

Project Objective for RER5024: Supporting the production of major food crops with higher yields, improved quality, and better resilience to climate change through mutation breeding and combined biotechnologies to contribute to food security in Europe and Central Asia. Course Objective: Capacity development in genotypic screening for desired mutations in genes of interest, gene expression analysis – from qPCR to RNA-Seq, NGS Analysis and basics of informatics and the use of DNA markers, DNA sequencing and targeted induced local lesions in genomes (TILLING) in applications related to the improvement of mutant populations generated using nuclear techniques and chemical agents.

National Training Course

Improving Crop Adaptation to Drought Stresses using Nuclear-Derived Techniques, and Molecular-Breeding Method; ERI5011

Asmara, Eritrea, 9-20 October 2023

Project Officer: I. K. Bimpong

The training objective is to enhance the understanding and research capabilities of the participants in basic principles in mutation breeding and molecular techniques for improved mutation detection and selection. The course will cover topics such as mutation breeding, concepts and methodologies, including invitro techniques of mass propagation of plantlets for vegetatively propagated crops, optimization of irradiation treatments, lab, screenhouse and field-based screening protocols in developing new and improved mutant varieties/lines for improving crop resilience to drought stress.

Other courses such as selection of clone/s for registration and release as variety, seed systems and introductory molecular biology and techniques for improved mutation detection and selection will be part of the training. The course will include lectures, demonstrations and practical sessions on various protocols on mutation breeding and selection methods. The course is design for participants who have basic knowledge in mutation breeding techniques. Fifteen participants are expected to join the training course.

National Training Course

Molecular marker technologies for Identification of Mutations

Accra, Ghana, 16-27 October 2023

Project Officer: F. Sarsu

Project is supported under Regional TC RAF5083: To support AFRA States in developing and disseminating new and improved mutant crop varieties with improved yield, quality, and tolerance to biotic and abiotic stresses to contribute food security in Africa.

Course Objective: Enhance capacity building in molecular techniques in applied crop improvement, methods for detection of mutations in candidate genes and principles of RT-PCR. Lectures and practical sessions and data analyses will be included on genotyping using markers, PCR and page gel techniques, and application MAS to crop improvement program.

Regional Training Course

Mutation Breeding and Efficiency Enhancing Techniques for Resistance to Banana Fusarium Wilt Race TR4 in Latin America

Strengthening Member State Capacities to Combat Banana Fusarium Wilt (TR4) through Early Detection, New Resistant Varieties, and Integrated Management – INT5158

Vienna, Austria, 23 October to 3 November 2023

Project Officer: C. Zorrilla, S. Sivasankar

The project INT5158 is aimed at developing capacities for disease management against *Foc* TR4 and the development of new resistant banana varieties using mutation breeding and combined biotechnologies to contribute to prevent the spread of this disease and reduce farmers losses.

This event is focused on the thematic area of the project related to Mutation Breeding. The training will include basic concepts of mutation induction, radio-sensitivity testing, and hands-on practical sessions on screening methods for resistance *Foc* TR4 under greenhouse conditions, identification of symptoms in comparison other sources of stress; and basic molecular methods for detection of Foc TR4. The training will be held at the Plant

Breeding and Genetics Laboratory located in Seibersdorf where mutation breeding has been successfully applied to improve several crops and traits since the 1960's.

Regional Training Course

Accelerated Breeding Techniques for the Development of Crop Tolerance to Abiotic Stress

Ankara, Türkiye, 06-17 November 2023

Project Officer: F. Sarsu

Project Objective for RER5024: Supporting the production of major food crops with higher yields, improved quality, and better resilience to climate change through mutation breeding and combined biotechnologies to contribute to food security in Europe and Central Asia.

Course Objective: Capacity building in mutation breeding and related biotechnologies that to develop genetically stable lines to shorten breeding cycles to development of tolerant crop varieties for abiotic stresses to contribute food security. The training will include accelerated breeding techniques such as double haploids, embryo culture, rapid cycling methods, shuttle breeding to develop better-performing mutant crop varieties, phenotyping/genotyping methods for breeding abiotic stress tolerance.

National Training Course

Mutation Breeding and Invitro Mutagenesis Techniques Application in Vegetatively Propagated Crops

Abidjan, Côte D'ivoire, Date TBD

Project Officer: F. Sarsu

Project is supported under Regional TC RAF5083: To support AFRA States in developing and disseminating new and improved mutant crop varieties with improved yield, quality, and tolerance to biotic and abiotic stresses to contribute food security in Africa.

Course Objective: The purpose of this course is to provide participant's theoretical as well as practical information with mutation induction in vegetatively propagated crops, and application of in vitro techniques, micropropagation, and in vitro screening for biotic and abiotic stress tolerance in crop breeding. Additionally, the training will include the mutation breeding procedures/methodologies and handling of mutated population for vegetatively propagated crop and establishment of proper in vitro screening protocols for biotic-abiotic stress with special reference to issues relevant to crops.

Past Events

National Training Course

Phenotypic and Genotypic Selection of Mutant Population in Improvement of Namibia Staple Food Crops

Tsumeb, Namibia, 29 May-02 June 2023

Project Officer: F. Sarsu

Project Objective for NAM5020: Improve farmers' income and livelihood through developing high yielding and drought tolerant crop varieties through mutation breeding and associated biotechnologies in Namibia.

Course Objective: Assisting Namibian Breeders/Researchers with hands-on application of phenotypic and genotypic data handling and analysis in induced mutation breeding programs for cross-pollinated (maize and pearl millet) and self-pollinated (sorghum, cowpea and groundnut). The training will include economic traits and agronomic important data in plant breeding, phenotypic/genotypic data collection, analysis and interpretation, phenotypic and genotypic linkage for selection of mutant plant population, Marker-assisted selection (MAS) breeding program for a long-term and release/registration process of new crop varieties.

National Training Course

Improving Crop Adaptation to Abiotic Stresses using Nuclear-Derived Techniques, and Molecular-Breeding Method; BDI 5005

Bujumbura, Burundi, 22-26 May 2023

Project Officer: I. K. Bimpong

The purpose of the training course is to enhance the understanding and research capabilities of the participants in basic principles in mutation breeding and introductory to molecular techniques for improved mutation detection and selection in crops. The training course will consist of mutagenesis of crops, analysis of radiosensitivity graphs, introductory to some speed breeding techniques such as *In-vitro* haploidy, genotyping and marker-assisted-backcross.

The course curriculum will comprise of lectures, demonstrations and practical sessions comprising of screenhouse, labs and field-based screening protocols on mutation breeding. The course is design for young members of national project team who have no experience in mutation breeding and 23 participants (20 males and 3 females) are expected to join the training.

National Training Course

Screening for water stress tolerance

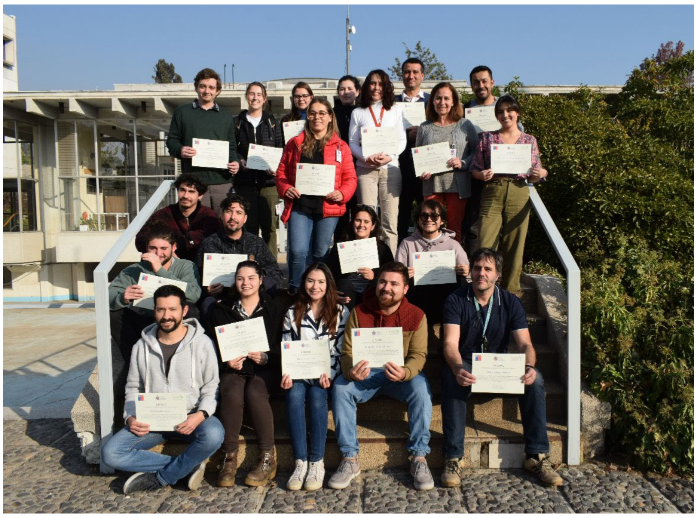
Use of Irradiation and Isotopic Techniques to Improve Native and Agricultural Plant Genetics – CHI5054

Santiago, Chile, 15-19 May 2023

Project Officer: C. Zorrilla

The aim of the project is to conduct two pilot studies using nuclear techniques in plant breeding programmes on agricultural and native plant species that are propagated by seed and by vegetative means. Use of ionizing radiation to generate new phenotypes of high ornamental value starting from native species from arid and semiarid zones, which would allow the development of crops that are better adapted to water scarcity conditions. As well, use of ionizing radiation as a mutagenic agent to induce genetic variability is applied in cucurbit species to improve the drought tolerance trait of this species to make a more sustainable production of watermelon and melon feasible.

The objective of the course is to develop capacities in the participants to screen for water stress tolerance in using simple tools to record morphological and physiological parameters such as plant temperature with infrared imaging, chlorophyll measurement, foliar area, and soil moisture using tomato and sweet potato as model crops. As well, basic data management and statistical analysis will be included as part of the training. This training includes lectures and practical sessions that will contribute to the selection of water-stress tolerant mutant lines of *Lagenaria* and *Nolana*.



CHI5054. *Group photo of participants in the NTC in Screening for water stress tolerance, Santiago - Chile*

A total of 22 participants were trained in this course, 12 female and 10 male participants.

The training was held at the Chilean Commission of Nuclear Energy (CCHEN), with participation of Pontificia Universidad Catolica de Valpariso (PUCV), Advanced Centre of Fruit Cultivation Studies (CEAF), Instituto Forestal (INFOR), as well as some local Universities.

Regional Training Course

Methodologies for Improving Crop Resilience to Abiotic Stress through Nuclear Techniques and Seed Systems, RAS5099

Rice Research & Training Center, Cairo, Egypt, 24 April to 5 May 2023

Project Officer: I. K. Bimpong

The training course will be implemented under the regional project, RAS5099, to provide knowledge and expertise on mutation breeding, including micropropagation, pre-field and field screening to select improved mutant lines in crops and seed harmonization systems. The main theme of the training will consist of mutation induction, preparation of radiosensitivity curves using provided data and calculation of growth reduction rates, basics of experiment design and early generation testing of mutant lines/populations, basic statistics, single/multiple site analysis and interpretations, correlation and simple linear regression and seed systems. The rest includes introductory molecular biology, molecular markers, basics of linkage analysis, QTL mapping and marker assisted breeding.

RAS5099. *Regional Training Course on Methodologies for Improving Crop Resilience to Abiotic Stress through Nuclear Techniques and Seed Systems*

The training course will comprise of lectures, demonstrations, and practical sessions on various protocols to fasten the breeding process. The course is design for crop improvement specialist, in Member States involved in the ARASIA project. Approximately 22 participants (18 males, 4 females) are expected to attend.

Workshop
Banana Fusarium Wilt *Foc* TR4 Detection and Diagnostics Methodologies
Strengthening Member State Capacities to Combat Banana Fusarium Wilt (TR4) through Early Detection, New Resistant Varieties, and Integrated Management – INT5158

Virtual. 12 – 14 April 2023

Project Officer: Cinthya Zorrilla, Shoba Sivasankar

The project INT5158 is aimed at developing capacities for disease management against Foc TR4 and the development of new resistant banana varieties using mutation breeding and combined biotechnologies to contribute to prevent the spread of this disease and reduce farmers losses.
This event was focused on the thematic area of the project related to Detection and Diagnostics. More than 80 participants from 12 Member States (Bolivia, Brazil, Colombia, Costa Rica, Ecuador, Mexico, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, and Venezuela.) were part of this event.

This event had the participation of experts in the field that gave 7 presentations on main diagnostics methods available (molecular and microbiological); as well as a grasp on the utility of *Foc* genome sequencing for taxonomy and diagnostics. As well, discussions during the event focused on the advantages and disadvantages of currently available methodologies, the need for more research on the pathogen's taxonomy and genomics, and the approaches taken by some Member States for official diagnostics.

The results of this workshop will guide the future activities to be implemented under this project in the topic of Detection and Diagnostics.

Regional Meeting
Strengthening Member State Capacities to Combat Banana Fusarium Wilt (TR4) through Early Detection, New Resistant Varieties, and Integrated Management – INT5158

Virtual. 27 – 29 March 2023

Project Officer: C. Zorrilla, S. Sivasankar

The project INT5158 is aimed at developing capacities for disease management against *Foc* TR4 and the development of new resistant banana varieties using mutation breeding and combined biotechnologies to contribute to prevent the spread of this disease and reduce farmers losses.
A total of 35 participants, from 12 Member States (Bolivia, Brazil, Colombia, Costa Rica, Ecuador, Mexico, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, and Venezuela.) participated in the meeting.

The purpose of the meeting was to discuss, share experience and report on the progress made and achievements reached on the 3 aspects of the project: Vigilance, Detection and Diagnostics and Mutation Breeding activities conducted by Member States during the first year of the project; as well as to identify and address prioritized needs to include in future activities in our workplan.

Counterparts participated actively during the event and prioritized topics for future trainings were defined.

Mid-Term Project Coordination Meeting
RAF5/083 "Enhancing Crop Productivity through Climate Smart Crop Varieties with Improved Resource Use Efficiency (AFRA)"

Vienna, Austria, 27 February to 03 March 2023

Project Officer: F. Sarsu

Project Objective for RAF5083: Support AFRA States in developing and disseminating new and improved mutant crop varieties with improved yield, quality, and tolerance to biotic and abiotic stresses to contribute food security in Africa.

The meeting aimed to assess the progress made within the project towards achieving expected results. Also included efforts being made in participating member states and initiatives from prior TC Cycles. The meeting agreed priority activities to optimise the implementation of the project to December 2023, with emphasis on achieving set project results.

The meeting was attended 17 National Project Coordinators (NPCs) from Africa, national project activities and achievement were presented by each NPCs.

Virtual Training

Near-Infrared Spectrometry for Nutritional Quality Screening

Evaluation of Varieties and Advanced Mutant Lines against Biotic and Abiotic Stress Conditions to Mitigate the Effects of Climate Change in Crops – PAR5012

Virtual. 06-10 February 2023

Project Officer: C. Zorrilla

The project PAR5012 has the objective to develop mutant lines with tolerance to biotic and abiotic stresses, as well as improve nutritional quality in several crops including soybeans, beans, and Stevia.

This course presented the characteristics, advantages, limitations, and potential of NIR techniques with special emphasis on food applications for the analysis of ma This course presented the characteristics, advantages, limitations, and potential of NIR techniques with special emphasis on food applications for the analysis of major or minor compounds. This training provided basic understanding of the principles of Near-Infrared Spectrometry (NIRS), types of software and analysis available for chemometrics and calibrations, types of libraries and their utility, and examples of the successful application of NIRS.

A total of 11 researchers including 4 female and 7 male participants from the counterpart's team were trained.

The training was held virtually with the participation of a Professor of Food Science and Technology from the Ohio State University.

National Training Course

Plant Mutation Breeding Techniques and Associated Biotechnologies

Phnom Penh, Cambodia, 30 January- 03 February 2023

Project Officer: F. Sarsu, L. Jankuloski

Project Objective for KAM5007: Improvement farmers' livelihoods with increased cotton yields and quality and to reduce imports of raw materials in the garment industry.

Course Objective: Develop capacities to initiate/conduct mutation breeding programs in crops specifically in cotton including concepts, application, handling of mutant lines to select the mutant lines with desired traits, experimental design and seed multiplication/release a variety to contribute food security.

The training course was attended by 33 participants (23 males and 10 females) from different Research Institutes and Universities and was coordinated by Prek Leap National College of Agriculture.

Regional Training Course

Field Experimental Design and Data Analysis for the Advancement of Mutant Populations

Enhancing Productivity and Resilience to Climate Change of Major Food Crops in Europe and Central Asia – RER5024

Virtual. 30 January - 3 February 2023

Project Officer: F. Sarsu, C. Zorrilla

In recent years, the negative impact of climate change has become evident in agriculture. Environmental stresses seriously limit plant growth, crop yield and disease resilience. Increasing genetic diversity can play an important role in addressing the problems arising from unfavourable environmental conditions.

The main objective of this project is to improve yield and resilience to climate change of major food crops in Europe and Central Asia by inducing new genetic variation with nuclear techniques. This project includes a total of 26 countries. Some of them have experience applying mutation breeding to develop new improved varieties while others are starting to implement these techniques. A total of 25 participants, 18 female and 7 male participants from 11 countries attended this training.

The purpose of the event is to develop capacities and skills on statistical analysis and experimental design for crop improvement with emphasis on updating skills on data analysis using open-source software. This training was the second part of a training focused on statistical analysis for young researchers already involved or planning to start using mutation breeding techniques.

The trainers were experienced scientists from CIMMYT that demonstrated the use of open-source software such as R and RStudio to analyse results from different types of experimental designs.

Coordination and Review Meeting

Enhancing Crop Productivity through Climate Smart Crop Varieties with Improved Resource Use Efficiency (AFRA), RAF5099

Vienna, Austria, 30 January-1 February 2023

Project Officer: I. K. Bimpong

The regional project in Asia on the use of Nuclear Techniques to developing Climate Smart Crop Production including improvement and enhancement of crop productivity, soil and irrigation management, and food safety known as ARASIA had its second coordination and review meeting to discuss the workplan for 2023. All project countries were represented except for Syria.

The project is directed towards enhancement of human capacities in the development of new improved varieties with higher and more stable yield potential, superior quality, and resistance to drought stress and enhancement of food safety. The project focus is on the application of a comprehensive/multidisciplinary approach to develop technology packages based on the integration of crop legumes and cereals to improve new mutant lines/varieties with best fitting desirable traits (disease resistance, tolerance to drought, salinity, and heat stress with good yield) and their dissemination to farmers to contribute to food security in the region.

The following summarizes the highlight of the discussion points raised during the meeting; participants acknowledged the dates for the three regional training courses and two group scientific visits to be held in 2023; Farmers field day events was agreed to be held in three countries namely Jordan, Qatar and UAE to showcase improved mutant crops; Varietal development and selection using an agreed protocol and as per the countries national plan of action.

The rest includes Expert missions to Oman, Qatar, and Jordan to support members on the application of mutation breeding for crop improvement and procurement needs of member states. Participating countries includes Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, and Saudi Arabia. The rest includes United Arab Emirates and Yemen.

Conference

Scientific Exchange in the Frame of a Workshop at the Plant and Animal Genome (PAG) Conference

San Diego USA, 13-18 January 2023

Project Officers : I. K. Bimpong, N. Warthmann

Two Technical Officers (TOs) from the PBG section represented the Joint FAO-IAEA centre at the 30th PAG workshop at San Diego convention centre and held a held 2.5-hour workshop entitled “Plant Mutation Breeding” as scheduled, on January 17th, 2023, which was the first inaugural workshop for the subprogram. A presentation was delivered by five expert Scientist including one of the TOs. The talk by the TO (Kofi Bimpong) centred on the joint centre’s activities in relation to plant breeding and genetics and the way forward especially in this era of genomics. There was great interest in the “Plant Mutation Breeding” as evidenced by the participation as well as through the interactions, discussions and questions raised. It is recommended to repeat this activity in subsequent years.

Developments at the Plant Breeding and Genetics Laboratory (PBGL)

Induced Genetic Variation for Developing *Striga* Resistant Varieties of Sorghum (*Sorgum bicolor*)

Striga is a parasitic weed that affects various crops, including sorghum, and causes significant economic losses globally. Striga (Striga *hermonthica* (Del.) infested sorghum crops exhibit stunted growth, reduced yield, and poor quality, which can result in reduced income and food insecurity for farmers and communities.

Moreover, Striga control measures such as herbicides and cultural practices are costly, and their effectiveness may vary depending on the location and severity of the infestation. Therefore, developing Striga-resistant sorghum varieties through genetic improvement and breeding is a promising long-term solution to mitigate the economic impact of Striga on sorghum production. Such varieties would enable farmers to reduce their reliance on expensive Striga control measures and increase their productivity and profitability while ensuring food security for themselves and the wider community.

Figure 1. *Sorghum mutant population in controlled glass house conditions at PBGL, Seibersdorf*

Mutation breeding is a powerful technique that involves inducing and selecting mutations in plants to generate desirable traits such as disease and pest resistance. At PBGL we are working on developing striga resistant varieties of sorghum by mutation induction in collaboration with the Member States (MS) and has developed large population in glass house and field at Plant Breeding and genetics laboratory (PBGL), Seibersdorf (Figure 1 and 2).

To fast-track development of striga resistant mutant varieties of sorghum, we are advancing this population under speed breeding conditions for Rapid Generation Advancement (RGA) and will be using amplicon sequencing and ddPCR to facilitate the identification and selection of desirable mutations in the available population.

Efforts are also made to screen the putative striga resistant mutants from the member states under glass house conditions at PBGL, Seibersdorf (Figure 3).

Figure 2. *Sorghum mutant population grown in fields at PBGL, Seibersdorf*

Figure 3. *Screening of putative striga resistant mutants in glass house at PBGL, Seibersdor*

Crop Irradiation Services Provided to Member States

The table lists the irradiation requests that the PGL has received so far (2023-03-31). The PBGL has received 21 requests from 19 Member States across 26 different plant species covering a total of 65 accessions/varieties.

Table 1. Crop Irradiation Services

Request Number	Country	Request Type	Crop/Species
1722	Tanzania	TC	*Solanum scaborum*
1723	Germany		ornamental
1724	Belgium		*Fragesia angustissima*
1725	The Netherlands		*ornamental*
1726	Slovenia		*soybean, buckwheat*
1727	Hungary		*ornamental*
1728	Zimbabwe	TC	cowpea, maize, sorghum
1729	PBGL		sorghum
1730	Malawi	TC	groundnut, pigeon pea, soybean
1731	Niger	TC	sesame
1732	Senegal	TC	cowpea
1733	Ghana	TC	cassava, chrysanthemum, sorghum
1734	Ivory Coast	TC	cassava, plantain, yam
1735	PBGL		sorghum
1736	The Netherlands		ornamental
1737	UK		*Cannabis sativa*
1738	Bosnia and Herzegovina	TC	beans
1739	Switzerland		rice, wheat
1740	Liberia	TC	rice
1741	Austria	CRP	olive
1742	Namibia	TC	groundnut, soybean, sorghum, bambara groundnut

Individual Training

During 2023 the PBGL hosted one intern, six fellows, and two PhD students as summarized in **Table 2.**

Table 2. Individual Training Activities at the PBGL

Name	Country	Status	Topic	Period
Mr Yonis Alberto MORALES REYES	Honduras	Fellow	Genetics of qualitative and quantitative (mutant) traits; intro Next Generation Sequencing: Molecular Bio Lab procedures and NGS data analysis	6 months
Ms Aneera Devi PURMESSUR MAYAPUTH	Mauritius	Fellow	Radiosensitivity, DNA extractions & QC, PCR, KASP marker, Genetic/genomics/NGS, advanced mutation breeding	3 months
Ms Tonike MALEMA	Malawi	Fellow	Mutation breeding, mutation induction, radiosensitivity, screening methods	2 months
Mr Gerhard Shangeshapwako HAITEMBU	Namibia	Fellow	Mutation breeding, mutation induction, development & handling of mutant populations, detection & selection of mutant plants Radiosensitivity, DNA extractions & QC, PCR, KASP marker, Genetic/genomics/NGS, advanced mutation breeding	3 months
Mr Raymond MASSAQUOI	Sierra Leone	Fellow	Irradiation and methods for radiosensitivity assay of rice and cassava, selection of mutant lines	3 months
Mr Mohammad RAHEMI	Iran	Fellow	DNA extractions & QC, PCR, KASP marker, Genetics/genomics/NGS	4 months
Mr Radisras NKURUNZIZA	Uganda	PHD-Consultant	Mutation breeding for Fusarium wilt resistance in African cooking banana	1 year
Mr Hassan MDUMA	United Republic of Tanzania	PHD-Consultant	Mutation breeding of African cooking banana for Fusarium Wilt resistance	1 year
Ms Emma Ramirez	USA	Intern	Designing, phenotyping, and molecular diagnostic analysis for banana fusarium wilt resistance screening experiments	1 year

In Memoriam

Dr Alexander Micke

Dr Alexander Micke, Section Head of Plant Breeding and Genetics during the period from 1969 to 1991, passed away in June 2023 at the wonderful age of 94 years. His contributions to the fledgling Section in its early years helped lay the basic foundations and research directions in plant mutation breeding for crop improvement towards food and nutritional security at the Joint FAO/IAEA Centre over the 22 years of his leadership.

It was during Dr Micke's leadership of the Section that the first "Mutation Breeding Newsletter" was published in 1972 facilitating information exchange in plant mutation breeding and related biotechnologies. Also, it was during his tenure that the first FAO/IAEA Interregional Training Course in mutation plant breeding, "Use of Radiation and Mutagen Treatments for Crop Improvement", was held. New facilities for developing *in vitro* culture techniques for mutation breeding were also established at the Seibersdorf laboratory in 1984 during his time.

Several Coordinated Research Projects were implemented during Dr Micke's time at the Section. These and the technology transfer projects at the time together led to many important results. Examples are the development of four improved mutant rice varieties with improved nutritional value in Bangladesh and the Philippines, a mutant rice variety in Hungary, "Nucleoryza", grown on large commercial scale, increased content of lysine in barley following mutation induction, a pearl millet variety in India resistant to downy mildew, improved rice and jute varieties released in Burma, promising mutants in vegetatively propagated plants such as compact fruit trees, and disease resistant varieties of turf, forage grasses and sugar cane.

Important international symposia organized during Dr Micke's tenure to highlight critical topics in plant mutation breeding included the "FAO/IAEA International Symposium on the Nature, Induction and Utilization of Mutations in Plants" held in July 1969 in Pullman, Washington; the "FAO/IAEA International Symposium on Plant Protein Resources: Their Improvement through the Application of Nuclear Techniques", held in June 1970 in Vienna; the "FAO/IAEA International Symposium on the Use of Induced Mutations for Improved Disease Resistance in Crop Plants" held in January/February 1977 in Vienna; the "FAO/IAEA/GSF International Symposium on Seed Protein Improvement in Cereals and Grain Legumes" in September 1978 at Neuherberg, Germany; the "FAO/IAEA International Symposium on Induced Mutations as a Tool for Crop Plant Improvement", held in Vienna in March 1981; and the "FAO/IAEA International Symposium on Plant Mutation Breeding for Crop Improvement" held in Vienna in June 1990.

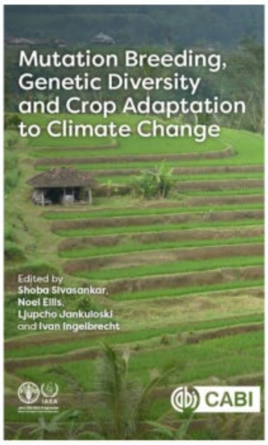
During the first international symposium in 1969, a report from the Section showed that at least 77 new improved varieties of agricultural and horticultural crops had been developed by mutation induction in Member States. The symposium in 1990 that gathered plant breeders from 46 countries to assess the contribution of plant mutation breeding to crop improvement over the past 25 years reported that the number of crop mutant varieties had increased to nearly 1500 across at least 90 different cultivated plant species.

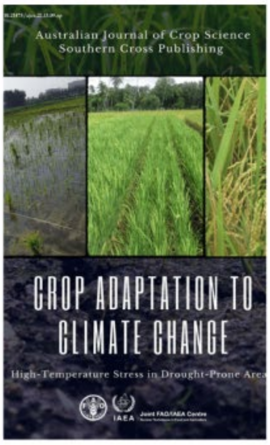
I remember Dr Micke as a courageous and optimistic personality and a committed and valued colleague. I pay sincere homage here to his foundational leadership of the Plant Breeding and Genetics Section during his 22 years at its helm.

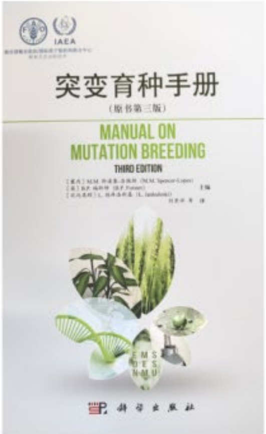
Shoba Sivasankar

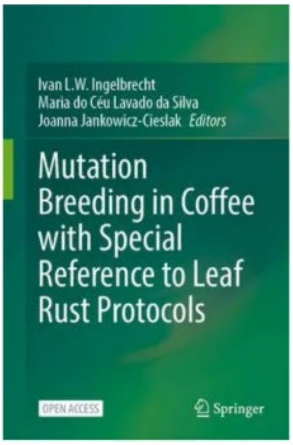
Publications

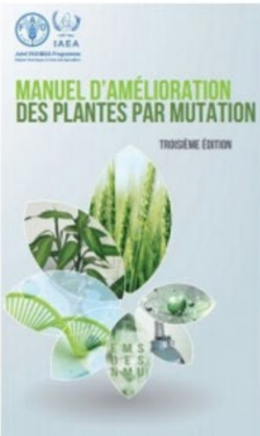
Books

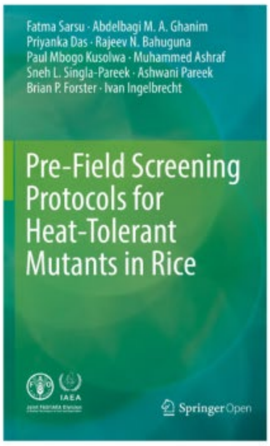


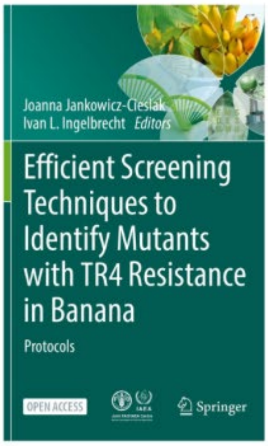


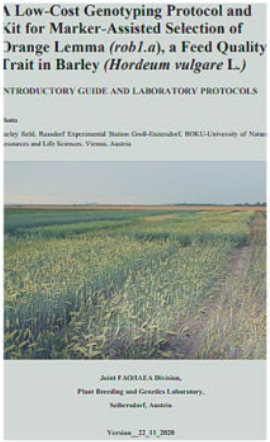


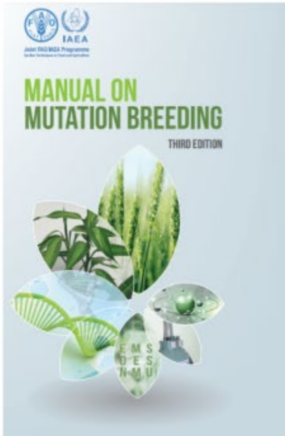












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Efficient Screening Techniques to Identify Mutants with TR4 Resistance in Banana
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ASHRAF M, HAMEED A, ZIAL-UL-QAMAR, SARSU F (2021) Correlation of yield with early seedling performance and physio-biochemical traits in Basmati rice 78 mutants subjected to heat stress. In Sarsu et al (eds) 2021. Crop Adaptation to Climate Change: High-Temperature Stress in Drought-Prone Areas. Southern Cross Publishing, Australia, pp 79-90.

Conference Abstracts and Posters

2023

SUBRAMANIAN N, PILLAI S, ROONEY W, BAGAVATHIANNAN M, SIVASANKAR S (2023) Utilization of electron-beam mutagenesis for sorghum crop improvement. Global Sorghum Conference 2023, June 5-9, Montpellier, France

SIVASANKAR S (2023) Innovative plant breeding for climate-resilient crops. Invited plenary lecture at the 5th Mindanao Summit of the The Philippine Phytopathological Society, Inc. - Southern Mindanao Division (PPS-SMD), June 9, 2023, Davao City, Philippines.

DHANASEKAR P, SOUFRAMANIEN J, DHOLE VJ, HINGANE AJ, SIVASANKAR S (2023) Physical mutagenesis for induction of resistance against *Maruca* pod borer in cowpea [*Vigna unguiculata* (L.) Walp]. Submitted to the International Conference on Pulses: "Smart Crops for Agricultural Sustainability and Nutritional Security" February 10-12, 2023, New Delhi, India.

SIVASANKAR S (2023) Induced genetic variation and mutation breeding for crop improvement at the Joint FAO/IAEA Centre. Invited talk at the 2nd International & 12th Biennial Conference of the Plant Breeding and Genetics Society of Bangladesh 2023, February 18-19, 2023, Dhaka, Bangladesh.

SIVASANKAR S (2023) The role of induced genetic variation in crop improvement towards food and nutrition security – a global context. Invited Keynote Lecture at the International Conference on Food and Nutrition Security (iFANS-2023) January 6-9, 2023, Mohali, India.

JANKOWICZ-CIESLAK, J., WARTHMANN, N., ENRIQUE MORALES ZAMBRANA, A., VILJOEN, A., INGELBRECHT, I. (2023) Induced Mutagenesis of Banana for Resistance to Fusarium Wilt Tropical Race 4. The Plant & Animal Genome Conference (PAG), January 13 - January 18, San Diego, CA, USA.

WARTHMANN, N., MURRAY, K.D., MORALES ZAMBRANA, A.E., CONDE M.V., MORALES., L., ALI, A., GHANIM, A.M., BOREVITZ, J.O., INGELBRECHT, I. (2023) Mainstreaming Genomics: Protocols for Genome Re-Sequencing at the Population

Scale. The Plant & Animal Genome Conference (PAG), January 13 - January 18, San Diego, CA, USA.

NKURUNZIZA, R., JANKOWICZ-CIESLAK, J., INGELBRECHT, I.L.W., WERBROUCK, S. (2023) In vitro tissue culture and genotyping innovations to accelerate mutation-assisted breeding of Coffea arabica. COPYTREE (European Network for Innovative Woody Plant Cloning - Cost Action 21157), Faculty of Chemistry, Universidad de Santiago de Compostela, 17 - 18 April, 2023, Spain.

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SAIF, A.A., AL-SHAMIRI, A., ALSAGIR, M., JANKULOSKI, L. (2021) Evaluation and Selection Disease Resistant Wheat Mutants to Yellow Rust Disease *Puccinia striiformis f. sp.triticii* Using Gamma-Irradiation Technique in Yemen. 15th Arab Conference on the Peaceful Use of Atomic Energy. 12–16 December 2021. Aswan, Egypt.

TILL, B.J., HAWLICZEK, A., JANKOWICZ-CIEŚLAK, J., GUPTA, P., HOWARD-TILL, R., OSORIO, C.E., BOLIBOK-BRĄGOSZEWSKA, H. (2021) High-Throughput Discovery of Induced and Natural Mutations in Plants. Application Genetics of Plants – Challenges of the 21st Century, 22–24 September 2021, Warsaw, Poland.

AZIZ, S., KANTOGLU, Y., TOMLEKOVA, N., STAYKOVA, T., GANEVA, D., SARSU, F. (2021) Molecular Characterization of Tomato Genotypes (*Solanum lycopersicum* L.) by Simple Sequence Repeat (SSR) Markers. Presented at the 5th Balkan Scientific Conference on Biology (BalkanBio'2021), Plovdiv, Bulgaria: Zenodo. http://doi.org/10.5281/zenodo.4650460

News Highlights

- Crop Seeds Return from Space in IAEA/FAO Project to Help Feed a Warming World (**15 April**)
- IAEA and FAO Engage Youth in STEM with First-of-a-Kind Space-Themed Event (**28 March**)
- Seeds in Space: 'Cosmic crops' for food security and climate change adaptation (**27 March**)
- Cosmic crops poised for harvest on Earth (**27 March**)
- Creating 'cosmic crops' for food security and climate change adaptation (**27 March**)
- IAEA and FAO Launch 'Seeds in Space' Youth Comic Book Competition (**16 March**)
- Climate Change Is Launching a Mutant Seed Space Race (**5 March**)
- Seeds Undergo Radiation in Space to Explore Biology and Genetics for Enhanced Food Security (**11 January**)

Websites and Links

- Plant Breeding and Genetics Section: https://www.iaea.org/topics/plant-breeding
- InfoGraphic on Mutation Breeding: https://www.iaea.org/newscenter/multimedia/videos/using-nuclear-science-to-boost-plant-biodiversity
- Mutant Variety Database: http://mvd.iaea.org
- Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture: https://www.iaea.org/about/organizational-structure/department-of-nuclear-sciences-and-applications/joint-fao/iaea-centre-of-nuclear-techniques-in-food-and-agriculture
- Plant Breeding Publications: Plant breeding publications | IAEA
- Food and Agriculture Organization of the United Nations (FAO): Home | Food and Agriculture Organization of the United Nations (fao.org)

Impressum

Plant Breeding and Genetics Newsletter No. 51

The Plant Breeding and Genetics Newsletter is prepared twice per year by the Plant Breeding and Genetics Section, Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture, Seibersdorf.

International Atomic Energy Agency
Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Printed by the IAEA in Austria, July 2023

23-03450