Improving Crops through Induced Mutations

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Introduction

The Plant Breeding Unit (PBU), part of the Agriculture and Biotechnology Laboratory of the Agency Laboratories, Seibersdorf, Austria is the laboratory arm of the Plant Breeding and Genetics (PBG) Sub-program of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. This division was set up in 1964 with a mission to use "Atoms for Peace" to achieve sustainable increases in food production, protection of the environment and the enhancement of food quality and safety. The PBG sub-program assists national plant breeding programs in using mutation techniques and modern biotechnologies to develop superior varieties of major and under-exploited food security and industrial crops. This is achieved through close collaborations with NARS in Africa, Asia, Middle East, Latin America and the Caribbean, advanced laboratories and the Consultative Group for International Agricultural Research (CGIAR) centres.

Mutation is a natural process that increases variation. This process can be accelerated by induced mutagenesis using either physical or chemical mutagens. More than 2,250 officially released mutant crop varieties are being cultivated by farmers in 59 countries of Africa, Asia, Australia, Europe, South America and North America. These mutants possess superior attributes in such agronomic traits as reduced plant height (defence against lodging), tolerance to abiotic stresses (e.g. salinity), pests and diseases resistance, increased tillering and several quality traits. Only one of these is cassava in spite of all its production constraints that have proved recalcitrant to conventional breeding methods. This poster highlights the activities in our sub-program as well as draws attention to opportunities for funding, training and induced mutation related services.

Activities of Plant Breeding Unit

The PBU contributes to the activities of the PBG sub-Program through the:
- Provision of training for Member States personnel;
- Services; and
- Research

Training

Individual and group training courses are provided to fellows and course participants from Member States in the application of mutations in plant breeding. Training programmes and modules covered include:

- Mutation induction for the broadening of genetic base of crop germplasm in seed and vegetatively propagated crops
- DNA marker techniques for identification/characterization or pedigree analysis of and races/genotypes/mutants
- *In vitro* culture in combination with mutation induction.
- Anther culture techniques in combination with mutation induction

Interregional Group Training Courses hosted by PBU

- FAO/IAEA Interregional Training Course on Induced mutations and related techniques: 1977 – 1997; 15 TCs x 20 participants = 300 scientists from developing countries.
- FAO/IAEA Interregional Training Course on Mutant germplasm characterization using molecular markers: 2001-2003; 3 TCs x 20 participants = 60 scientists from developing countries.
- TOTAL: 18 TCs – 360 scientists

Regional Training Courses

- About 400 scientists trained from 1979 till date

Services

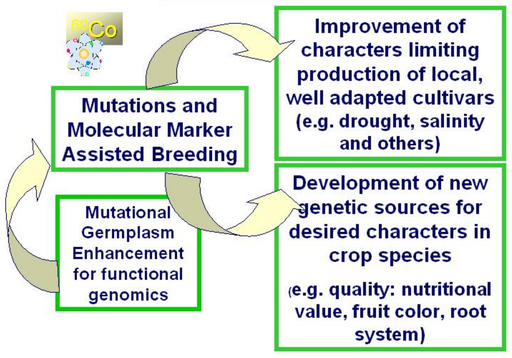
Mutation Induction
Irradiate plant propagules for scientists from Member States using our Cobalt-60 source located at the Agency's Laboratories at Seibersdorf, Austria.

DNA fingerprinting
Provide DNA fingerprinting services for crop mutants with promising agronomic traits. These data can provide diagnostic molecular markers for use in marker-assisted breeding. In addition genetic fingerprints protects breeders' intellectual property rights.

Ploidy Determination
Apply flow cytometry in the determination of the ploidy levels of plants. Genetic improvement involving hybridisation across ploidy levels (diploid, aneuploid or polyploid) is important in wide crossing involving polyploid plant species such as rice wild relatives and bananas.

Mutant germplasm database and repository
The recently launched FAO/IAEA Mutant Variety Database (**http://www-mvd.iaea.org/MVD/default.htm**): provides information on officially released crop mutant varieties, the mutagen used and characters affected. DNA fingerprinting data are used to define and verify mutant stocks.

Research: Application of induced mutations, molecular markers and related biotechnologies to crop improvement



Mutation induction coupled with selection remains the "cleanest" and most inexpensive way to create varieties by changing single characters without affecting the over all phenotype. Mutation induction involves the treatment of plant propagules with mutagens (chemical or physical). This is followed by selection for desirable changes in the resulting mutants. Breeders use mutation induction to broaden the genetic base of germplasm, and use the mutant lines directly as new varieties or as sources of new variation in breeding programs.

The efficient exploitation of induced mutations is dependent on a number of related biotechnologies. Tissue culture technologies are of particular relevance in rapidly creating stable genetic stocks, true breeding mutant lines and segregating populations that can be used in pure and applied genetic studies

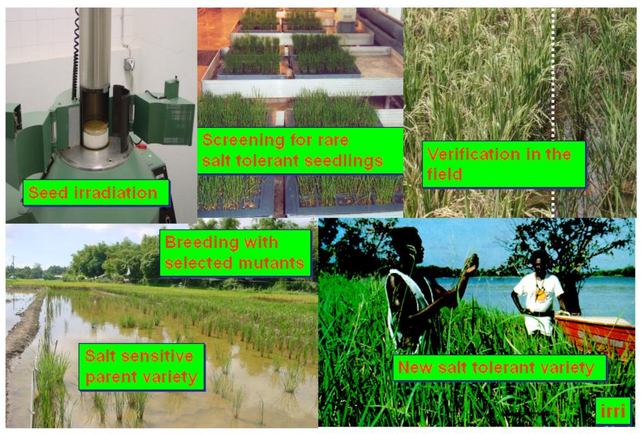
Linking mutant phenotype to gene sequence mutation leads to early selection for the desirable allele

The selection process is made more efficient through molecular genetic fingerprinting of the mutant variety and the parent. Mutants are fingerprinted in order to develop molecular tags which could be used in marker aided selection or for protecting the IPR of the breeder. In the figure, a missing allele (arrowed) distinguishes the mutant from the parent. A marker that distinguishes a parent from the mutant can be used in early screening of segregating populations. This way, unwanted progeny are discarded early in the selection process thereby saving the time and expense that would have been invested in waiting until phenotypic data can be collected.

Research Activities

In addition to Member States' specific problems, we have focused attention on removing certain production constraints to rice and banana through the application of induced mutations. Molecular genetic assays are used for developing molecular tags for marker aided selection while *in vitro* techniques are also used for speeding up the crop improvement process, for germplasm conservation as well as for safe across the border transport of disease-free plants. Rice and banana have been selected as they are contrasting crop types, one is annual and seed propagated, the other a vegetatively propagated fruit. Also, studying their different production constraints enrich our perspectives for research and technology transfer.

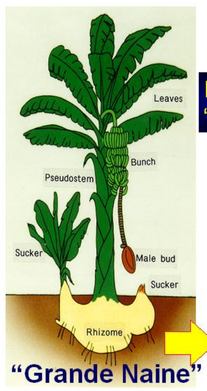
Developing salt tolerant rice through induced mutations



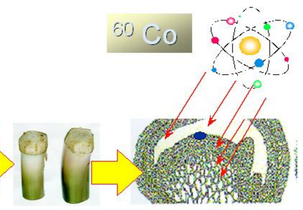
- Salinity is the most widespread soil problem in rice-growing countries, there being approximately 400 million ha of salt-affected land in the world. Out of this, 56 million are found in South and Southeast Asia. It is estimated that 10 million ha are now being lost every year as a result of salinity and /or water logging
- One of the highlights of our induced mutageneis research is the development of salt tolerance in rice. The work is being done in collaboration with the International Rice Research Institute (IRRI), Manila, Philippines. The progeny from gamma-irradiated rice seeds was tested for salt tolerance. The salt tolerant mutant lines are of particular interest as they show no negative traits and have therefore been taken up enthusiastically by IRRI plant breeders.

Improving bananas through induced mutations

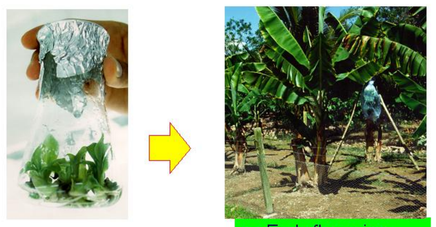
Bananas, including the dessert banana and cooking plantains, are important as food security and cash crop for over 400 million people in the developing tropical countries of the world. PBU has traditionally worked on this crop and one of the highlights is the release of a banana mutant, "Novaria" in Malaysia



Mutation induction of "Grande Naine" meristems



'Novaria'- A banana mutant variety derived from mutation induction of 'Grande Naine'. Released in Malaysia in 1993



Improved Characters

- Early flowering
- Short stature
- High yield potential
- Good flavor

Black Sigatoka ***Mycosphaerella fijiensis***

Biotic stresses constitute the major production constraints for banana. The most important banana disease is the fungal disease, banana leaf spot commonly referred to as the black sigatoka disease (BSD) caused by *Mycosphaerella fijiensis*. The extensive leaf necrosis could reduce yield by up to 50%.

Several banana mutants with high levels of tolerance to "juglone", a synthetic toxin that mimics the effects of BSD, have been developed in our Unit. Molecular fingerprints of these are being developed while multiplying them for shipment to BSD "hot spots" for field testing.

Plant Breeding and Genetics Sub-Program of the FAO/IAEA Joint Division

Tools of implementation

In addition and complementary to research activities at PBU, our sub-program undertakes the following:

Technical Co-operation Projects (TC)
1977-2003
- **Total implemented projects - 191**
- **Active projects - 34**
- **Total budget - US$ 35 million**

Co-ordinated Research Projects (CRP)
1983-2003
- **Implemented CRPs - 28**
- **RCMs - 79**
- **Participating institutes - 375**
  - **developing countries - 235**
  - **developed countries - 140**

Cassava Mutants?

- **Tekbankye**, a cassava mutant with excellent cooking qualities has been released in Ghana. Is the result of a TCP.

New and emerging cassava-targeted initiatives

- Cassava is one of the crops being used to investigate mutation frequencies at the DNA sequence level in a new CRP.
- Another CRP dedicated exclusively to cassava and banana starts early next year. Will develop baseline data on cassava induced mutagenesis as well as facilitate the development of molecular tags.

For information on:
- Participation in TCPs or other forms of assistance, please visit the IAEA's Department of Technical Cooperation web pages at http://www-tc.iaea.org/tcweb/default.asp.
- Participation in CRPs, contact any Technical Officer of the PBG sub-Program (http://www.iaea.org/programmes/nafa/d2/index.html)
- Training courses are usually announced at http://www.iaea.org/programmes/nafa/d2/index.html