Announcement of a new Coordinated Research Project (CRP)

“Integrated utilization of cereal mutant varieties in crop/livestock production systems”
D2.30.30

Summary
The CRP proposes to develop agronomic practices that maximise yield and nutritional value of cereals as dual purpose food and feed crops using a range of contemporary mutant varieties. Cereals are grasses with edible starchy grains and include many staple crops, e.g. barley, maize, rice, sorghum and wheat. They are harvested for their grain for human consumption, but may also be harvested throughout their life cycle as fodder for animals. Cereals are adapted to a wide range of growing conditions, barley, for example, is a useful food and feed crop in cool, dry conditions whereas maize, for example, fits into cropping systems with a warm wet season.

One of the first steps is to select existing mutant varieties in a range of countries. The type of mutant variety used will vary depending on the participating country. These will then be used in developing soil and water management practices that maximise biomass production. For fodder production, this often occurs before flowering, i.e. much earlier than standard harvests at grain maturity. The CRP will establish the baseline for agronomic practice for biomass production and feed value. It is important to note that in developed countries cereals are commonly separated into food and feed varieties, but this is a new concept for developing countries.

Farmers in developing countries need cereal crops that can be exploited for both food and feed, and have the ability to vary the use of the crop depending on circumstances. The crop may be harvested at any time as fodder (animal consumption). It may be sown and harvested early for rapid green fodder production or grown to maturity for grain yield (human consumption or feed). The CRP aims to develop soil and water management systems that maximise yields of dual purpose (food and feed) mutant cereal varieties.

The project is driven by plant breeding and managed by the Plant Breeding and Genetics Section of the FAO/IAEA Joint Division. Progress will be measured in terms of performance in the field (yield), and by animal and crop nutrition studies. The project involves three
FAO/IAEA disciplines: 1) plant breeding and genetics, 2) soil and water management, and 3) animal nutrition. It is recommended that participating Member States (MSs) have in place (or put in place) integrated programmes involving all three disciplines. It is anticipated that more countries will apply than can be handled in a well-focused CRP programme. However, to accommodate demand for mutant stocks, it was agreed, where appropriate, that germplasm containing a range of target mutant traits (awnless, hooded, low lignin, etc) would be made available to all interested countries for use in other national programmes.

**Basic CRP criteria**
The CRP will run for 5 years and should include up to 10 developing countries (Research Contract Holders), 5 Technical Contracts and 5 Agreement Holders. The work will focus on contemporary mutant varieties or advanced breeding lines of spring habit cereal crops (mutant traits may include: height, flowering time, lodging tolerance, biotic and abiotic stress tolerance, etc). Research Contract Holders will be selected from a wide range of cereal growing regions in Member States, and these would be encourage to have or put in place plant breeding, crop production, animal nutrition and crop nutrition networks. The FAO/IAEA laboratories at Seibersdorf will play a major role in secondary mutation induction for fodder traits, validating and disseminating protocols, and in germplasm development, characterisation and dissemination.

**Criteria for selection of Research Contract Holders**
- The participants are expected to provide and work with contemporary mutant varieties in a cereal crop.
- The participants should be able to establish integrated teams involving active cereal cropping and breeding programmes and soil and water management and animal nutrition in their own countries.
- The participating plant breeding groups are expected to test exotic mutant varieties and materials for crop management, adaptation and suitability as animal feed.
- Animal nutrition groups should have the capacity to conduct *in vitro* and *in vivo* feed quality evaluations.
- Soil science and crop nutrition groups should have the capacity to assess the agronomic performance of mutant cereal varieties under specific soil types, water availability and soil fertility conditions, including N-use efficiency studies.
• There should be strong links among plant production, plant breeding, animal nutrition, soil and water management, and animal science groups within the country.
• Participants should have the capacity to conduct on-farm participatory studies.
• Participants will agree to germplasm exchanges using the Standard Material Transfer Agreement of the International Treaty on Plant Genetic Resources for Food and Agriculture.

**Background Situation Analysis**

**Why cereals?**

Cereals are among the most important crops for human consumption and are grown in many regions of the world, they include: barley, maize, millet, oat, rice, rye, sorghum and wheat. Since these are staple crops they are grown on a regular basis and although the primary objective may be to produce grain for human consumption they are also utilised for animal feed either as fresh green fodder, straw, hay, silage or seed. The provision of fodder is a major limitation in animal production in developing countries. In developed countries cereal crops are divided into human and feed specific varieties, but this is not the case in many developing countries. As a consequence agronomic systems need to be developed to maximise biomass production and nutritional value in developing dual purpose cereals. Importantly, by assessing and managing soil fertility and water availability predictions can be made on when to grow and when to harvest the crop for maximum benefit. The development of soil and water management systems also provides farmers with options in making decisions on growing and harvesting for food, feed or both.

**Problems**

• Availability of good quality fodder is limited in developing countries. Presently crop residues from crops such as barley, maize, sorghum, legumes, wheat and millets are used as the main source of feed for animals.

• Few farmers utilize a strictly fodder crop in their production systems. Growing of food and cash crops is the primary goal of farmers in developing countries, who are mainly subsistence producers and only sell surplus production.
• Human activity has caused land degradation *e.g.* salinization and desertification and settlement expansion. Movement of people onto farmland also puts more pressure on marginal lands.

• Climate variability has affected productivity of grasslands and rangelands.

• Feed quantity and quality requirements of livestock producers are not fully met with current cereal varieties; the optimal potential of livestock systems is not realized.

• Awareness of the potential of cereals as a food and feed is lacking in developing countries and there is a need to capture this niche as a food and feed.

**CRP overall objective**

To increase crop and animal production by develop cropping systems for mutant cereal varieties for food and feed. To demonstrate the utility of dual purpose cereal crops for enhanced food security in small holder crop-livestock production systems in developing countries.

**Specific research objectives**

1. To develop crop management systems for cereal mutant varieties and advanced lines carrying mutant genes with respect to improved yield and quality.
2. To evaluate mutant cereal varieties for agronomic performance and feed quality.
3. To multiply seed of superior lines for fodder production trials.
4. To evaluate the nutritive value of new mutant lines in animal production systems.
5. To determine biomass, harvest index and nitrogen-use efficiency of mutant varieties and advanced lines.
6. To validate and publish protocols and guidelines for speeding up the establishment of useful mutants in desirable genetic backgrounds.
7. To perform pilot tests of superior mutant varieties/lines on-farm through participatory farmer approaches.
Expected research outputs

1. Development of dual purpose (food and feed) mutant cereal crops in developing countries.

2. Development of cropping systems for improved performance with respect to biomass production, application of appropriate soil and water management practices that maximise yield. Guidelines for crop management delivered to Member States.

3. Pilot tests on mutant varieties and advanced lines in on-farm trials performed.

4. Evaluate agronomic performance and nutritive value of mutant varieties and advanced lines.

5. Develop locally adapted breeding materials.

6. Determine the feeding value of mutant varieties and advanced lines in animal and crop production systems.

7. Determine and identify high biomass production, harvest index, soil and water management and nitrogen-use efficient in mutant varieties and advanced lines.

8. Deliver mutant genetic stocks to interested Member States, including those not participating directly in the CRP.

9. Develop protocols for mutant induction, mutation detection and mutant line development for plant breeding.

10. Publish and disseminate research results on high value food and fodder barley cropping systems.

11. Develop rapid selection procedures/protocols to develop and screen newly induced mutants.

Expected research outcomes

Outcomes will be measured against pre-CRP production values, such as yield per area and extent of cultivation.

1. Adoption of cereals as dual purpose crops in developing countries.

2. Increased availability of better quality and quantity of animal feed resources in Member States.

3. Food and feed resource-base enlarged in Member States.
4. Diversity and use of cereal mutant varieties increased.

5. Improved income and livelihoods of livestock and crop farmers.

6. Increased skills and capacity of researchers in manipulating induced mutations.

7. Increased collaboration between crop, soil and animal scientists in Member States for integrated food and feed production systems.
### Anticipated activities (to be discussed and adapted at the first Research Coordination Meeting, RCM)

<table>
<thead>
<tr>
<th>ACTIVITY WITH TIME FRAME AND RESPONSIBILITY</th>
<th>TIME FRAME</th>
<th>Responsibility</th>
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<tbody>
<tr>
<td>1. Identification and consolidation of available cereal mutant varieties, advanced mutant breeding lines and other mutant germplasm of participating countries.</td>
<td>0 to 24 months</td>
<td>Plant Breeding and Genetics Laboratory (PBGL)</td>
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<td>2. Evaluation of soil fertility status and soil type, chemical and physical characteristics</td>
<td>0 to 24 months (pre-season)</td>
<td>Soil and Water Management and Crop Nutrition Laboratory (SWMCNL) and Research Contract Holders</td>
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<td>3. Multiplication of relevant mutant varieties and advanced breeding lines and distribution to participating groups.</td>
<td>6 to 30 months</td>
<td>PBGL</td>
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<td>4. Evaluation of mutant varieties and advanced breeding lines, <em>in vitro</em> feed quality.</td>
<td>0 to 36 months</td>
<td>PBGL and Research Contract Holders</td>
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<td>5. Setting up of field plot experiments to assess the agronomic performance of cereal mutant varieties under different soil types and soil-water management adjustment.</td>
<td>6 to 60 months</td>
<td>SWMCNL and Research Contract Holders</td>
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<td>6. Further mutation induction of mutant varieties to induce traits for fodder quality (<em>e.g.</em> removal of awns in barley).</td>
<td>0 to 24 months</td>
<td>PBGL</td>
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<td>7. Multi-location testing (within and between countries) of mutant varieties and advanced lines for agronomic traits and feed quality.</td>
<td>24 to 60 months</td>
<td>Research Contract Holders</td>
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<td>8. Yield, N analyses, N-uptake and soil testing for N-use efficiency.</td>
<td>12 to 60 months</td>
<td>SWMCL and Research Contract Holders</td>
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<td>9. Development of single seed NIRS for pre-screening of new quality mutants.</td>
<td>36 to 60 months</td>
<td>Technical Contract Holder*</td>
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<td>10. Fodder quality evaluation (<em>in vitro</em>, <em>in vivo</em> and DNA analyses).</td>
<td>24 to 60 months</td>
<td>Animal Production and Health Section (NPHS) and Research Contract Holders and Technical contract Holder</td>
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<td>12. Fodder quality evaluation (N response)</td>
<td>48 to 60 months</td>
<td>SWMCNL and</td>
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<td>characteristics), yield time and percentage</td>
<td>months</td>
<td>Research Contract Holders</td>
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<td>13. Publication of results (for example a special issue of an international journal)</td>
<td>48 to 60 months</td>
<td>Research Contract Holders, Agreement Holders, Technical Contract Holders, and Joint FAO/IAEA</td>
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* Depends on collaboration with appropriate partners

**Participants**

Up to 10 research contracts will be awarded in diverse cereal production areas. In addition, it is foreseen that 5 technical contracts having possession of critical mutant varieties and advanced mutant breeding lines and mutation development, single-grain non-destructive NIRS, and advanced animal feed evaluation techniques will be awarded (potential countries: Australia, Canada, and UK). Scientific experts are required for: plant breeding, crop production, soil and water management and animal nutrition. Coordination and technical management will be handled by the scientific secretary in the Plant Breeding and Genetics Section.

**Participation of Agency’s laboratories**

Activities include:

1. Receive and disseminate plant genetic stocks (mutant varieties, advanced mutant breeding lines and other mutant stocks) among participating countries and other interested Member States.

2. Develop seed phenotyping for fodder quality.

3. Capacity building will be provided to participants within the framework of the PBGL training activities (TC-supported fellowships and scientific visits; internships; and cost-free experts visits link to RAS5064: Enhancing Productivity of Locally-underused Crops through Dissemination of Mutated Germplasm and Evaluation of Soil, Nutrient and Water Management Practices).

4. The Plant Breeding and Genetics Laboratory has on-going research in rapid backcrossing for the introgression of target mutants into desired barley breeding
material. This involves mutants for fodder barley. The introgression lines (BC4-6) may be available for inclusion in the CRP at the end of Year 2.

Assumptions

• Participating Member States are currently growing mutant cereal varieties.
• The genetic resources are transferable among countries.
• Each participating Member States will be able to form effective groups involving crop production, plant breeding, plant nutrition and animal nutrition.
• The project integrates well with on-going research and development activities throughout the period of CRP.
• Conflict between biofuel and food productivity for improved cereal lines will not occur.

Potential participating countries

Countries in Africa
Countries in Asia and Middle East.
Countries of Eastern Europe.
Countries in Latin America.
Countries in North, South and Central America.

Verifiable indicators

1. Demonstration of cereal mutant varieties as dual food and feed crops in developing countries.
2. Greater adoption of dual purpose cereal crops – greater acreage.
3. Development of crop management systems for improved fodder yield and quality under different soil types, water availability and agro-ecological zones.
4. The feed quality and performance of at least ten existing mutant varieties and/or advanced lines determined.
5. The feeding value of at least ten selected mutant varieties and/or advanced lines in animal production systems determined.
6. Biomass, harvest index and nitrogen-use efficiency of at least three mutant varieties and/or advanced lines per participating country determined.
7. Pilot tests on at least two selected lines in on-farm trials in at least five participating countries performed by the end of the project.
8. Research results on high value food and fodder cereals published in a special issue of a journal.
Parameters and methodologies to be used:

Plant breeding/crop production – development of mutant lines
Mutation induction and detection
Genotyping and phenotyping
Adaptability testing
Disease screening

Soil and water management – optimising agronomy
Physiologic, agronomic and N-fertilizer and water-use efficiency.

Animal Nutrition – evaluation of feed value
Chemical composition including amino acid composition
In vitro, in sacco, in vivo evaluation
NIRS
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<tr>
<td>• Informing potential participants on the initiation of the CRP (Agency)</td>
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<td>• Collection of proposals, appraisal and selection (Agency)</td>
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<td>• Award research contracts (mid 2012, Agency)</td>
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<td>• Formation of a consortium of participating scientists</td>
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<td>• Attraction of additional funding</td>
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<td>• Organization of the first coordination meeting (1st RCM, Agency)</td>
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<td>• Submission of annual progress reports by individual scientists (Partners)</td>
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<td>• Evaluation of scientific progress reports (Agency)</td>
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<td>• Organization of the second RCM (MS)</td>
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<td>• Submission of annual progress reports by individual scientists (Partners)</td>
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<td>• Implementation of revised work plans (Partners)</td>
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<td>• Submission of annual progress reports (Partners)</td>
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<td>• Evaluation of progress reports by individual scientists (Partners)</td>
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<td>• Organization of the third RCM (MS)</td>
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<td>• Organisation of final RCM and dissemination of results (Joint)</td>
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<td>• Preparation and publication of technical documents and scientific manuscripts, and conference presentations (Agency, Partners)</td>
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Additional Info:

Intellectual Property Rights

The CPR generally aims to use existing genetic variation or induced mutations for crop plant improvement. In addition, breeding lines from current plant breeding programmes will be requested for use in the project.

It is recognized that a robust, equitable, simple and open framework for accessing and distributing the (i) data, (ii) physical, and (iii) intellectual resources generated in this CRP is critical to its achieving the widest possible impact and the delivery of the outcomes envisaged.

Data used and generated will include gene and primer sequences, assessment of trait variation, assessment of agronomic benefit, assessments of heterosis effects and recombination maps. Physical resources include germplasm (plants or planting materials), induced mutants, and genomics resources such as the DNA, gene clones or markers. Intellectual resources include protocols and techniques useful in breeding, know-how on generation and applications of induced mutants and wild or local germplasm, and the application of targeted genes in plant breeding programmes.

There are legislation and intellectual property protocols in this area. Firstly, patents may be applied for technologies (e.g. new methods for screening), genes (e.g. mutated genes in biochemical pathways), and drugs or agrochemicals that interact in predictable ways with particular organisms. Plant breeders’ rights, giving breeders rights over their materials, are formalized by UPOV, the International Union for the Protection of New Varieties of Plants, as established by treaty in 1961 under an International Convention; for major crops with recognized, newly-developed cultivars (cultivated varieties), this means that farmers pay royalties to the breeders for rights to grow their seeds.

With respect to ‘research’, use of materials and intellectual property was traditionally regarded as free, a situation which has changed in recent decades. Similarly, germplasm of crops was traditionally exchanged globally between countries without payment. In recent decades, and following the Convention on Biodiversity, germplasm exchange between countries has become more restricted. Phytosanitary considerations have also played a part in limiting exchange. Recently, the International Treaty on Plant Genetic Resources for Food and Agriculture, entered into force in June 2004 enshrines the principles of asset and benefit sharing, and the crop species in this CRP are among the species covered. The position of induced mutation material is uncertain within the international frameworks. Unlike cultivars bred by crossing, mutants may only differ in one gene from the parental variety, although they would pass tests of distinctness, uniformity and stability demanded by UPOV.

Within this CRP, it is recognized that exchange of both information and germplasm will be important for the technologies developed to identify beneficial mutants in model crops to be transferred to the target crops of importance in developing countries. It is envisaged that useful germplasm generated in a given country would be important for another and as such, evaluated at multiple sites. In general terms, the CRP should have a standard Materials Transfer Agreement with the supplier retaining ownership of their materials, allowing the recipient to use it for research purposes and publications without restriction, and with defined routes should exploitation or new IP be developed using the materials.
The plant material used in the application has been collected before the Rio Biodiversity convention 1992 or has been obtained under the international material transfer agreements (MTA) and such material is free to be used for development of new cultivars released under the variety protection law (UPOV). In case plant material is covered by patent claims the rights and possible restrictions on use for breeding and industry will be clarified before major investments.

The source of some mutants in ‘good’ genetic backgrounds are advanced barley breeding lines held by Agri-Science Queensland, Department of Employment, Economic Development and Innovation (DEEDI), at the Hermitage Research Facility, 604 Yangan Road Warwick, QLD 4370, Australia. Access to these lines still needs to be negotiated.