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# Contribution by the Joint FAO/IAEA Division to Food and Agriculture

## A Status Report

*Report by the Director General*

The purpose of this report is to inform Member States about the present status of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture by outlining its accomplishments to date, its current programme and its future challenges. The paper has been prepared against the background of the on-going discussions in FAO on the follow-up to the report of an independent external evaluation of FAO, which was submitted to the FAO Conference in November 2007 and a notice of termination of the Arrangement establishing the Joint Division received earlier from FAO. [1] A formal decision by FAO on the future of the Joint Division is expected to be taken in 2009 as part of FAO Member States' deliberations on the recommendations of the independent evaluation.

## Introduction

1. The International Atomic Energy Agency, through a Joint Division established in partnership with the Food and Agricultural Organization (FAO), has fostered the development and application of nuclear techniques in food and agriculture in Member States for more than 40 years. The goal is to help countries use nuclear and related methods to increase food production, combat animal and plant diseases and protect the environment (http://www-naweb.iaea.org/nafa/index.html).

2. From small beginnings, the activities of the Joint Division have evolved from a programme promoting research and development of techniques for improving food production to one of "research

[1] A notice of termination of the Joint Division was sent to the IAEA Director General by the FAO Director-General on 29 November 2007. As a result of this notice, the existing cooperation arrangements between the Agency and FAO would lapse on 29 November 2008, a dead-line that has since then been extended until 9 December 2009.

for development", aimed at sustainable productivity increases coupled with improved product quality and safety.

3. Investments by Member States as well as by the Agency through the Joint Division have produced substantial dividends for many countries. Yet, more needs to be done to bring the benefits to more people in more countries. With high food prices and global climate change now affecting everyone, particularly the rural and urban poor, the challenges faced by Member States and the international community in delivering on the Millennium Development Goals through agriculture are on an unprecedented scale. Increased support for investments in nuclear applications in food and agriculture is necessary to meet these challenges.

# Table of Contents

# A. Global Food Security Crisis

1. In 1960, the world's population stood at around 3 billion people, average daily per capita food consumption was 2400 kcal (2050 kcal in developing countries), and the proportion of undernourished people in developing countries was 37%. (1)

2. At present, there are over 6 billion people in the world, but cereal yields have doubled, meat production has increased four-fold and milk output has tripled. The average person is much better fed (per capita food consumption 2800 kcal/day; 2650 kcal/day in developing countries), and lives longer and more healthily than ever before, while the proportion of undernourished people in developing countries has fallen to 17%. (2)

3. The main factors behind the increased supply and variety of food are improvements in agricultural productivity brought about by new and improved technologies and management practices, higher incomes which have boosted demand, especially for high value commodities, and the growth of trade and transport links.

4. Despite these achievements, more than 850 million people in developing countries (mainly in south and east Asia and sub-Saharan Africa) are still undernourished and 1.4 billion people live on less than US$1.25 a day, according to the World Bank. Improving both the productivity and competitiveness of agriculture in developing countries must therefore be at the heart of any strategy for hunger and poverty reduction.

5. After more than 20 years of neglect through poor national and international investment, the critical role of agriculture in promoting sustainable development is again receiving high level recognition. Fighting hunger and poverty was placed first among the UN's Millennium Development Goals (MDGs) and its importance has been recognized in numerous other reports. (3 - 6)

6. Several key challenges must be addressed.(7) *First*, the world's population is predicted to increase by another 3 billion people by 2050, yet opportunities for expanding the land area for crops or keeping livestock are becoming increasingly limited, as are the possibilities for tapping renewable fresh water resources. *Second*, low and declining soil fertility brought about by widespread land degradation limits yields in many developing countries, as does the limited availability of plant varieties that are both productive and well adapted to often harsh local conditions such as drought, salinity, frost and flooding. *Third*, animal and plant diseases and pests continue to extract heavy tolls on productivity, trade and livelihoods, while the increased use of agrochemicals and numerous outbreaks of food-borne diseases have raised both environmental and food safety concerns.

7. In addition, there is a need to increase the resilience of current food production systems to climate change, to manage the balance between crops grown for food and those used to produce bio-fuel, and to deal with soaring prices of food and agricultural inputs which disproportionately affect the poor.

8. In April 2008, the Secretary General of the United Nations established a High Level Task Force on the Global Food Security Crisis. (8) It produced a Comprehensive Framework for Action (CFA) to deal with both urgent needs and sustainable longer-term food security. This was followed in June 2008 by a High-Level Conference on Food Security and the Challenges of Climate Change and Bio-energy convened by FAO. (9)

9. Both the High-Level Conference and the CFA called for urgent action to boost food production to meet immediate needs and to complement this with significantly increased investments in agricultural technology research and infrastructure.

## B. Nuclear Applications in Food and Agriculture

10. When the Agency was founded, nuclear applications in food and agriculture were in their infancy and restricted to industrialized countries. They involved the use of a few isotopes and X-rays in laboratories to conduct metabolic and genetic studies in plants, insects and animals. Applications of nuclear techniques in farmer fields and in developing countries in general were largely non-existent.

11. Parallel advances in other technologies and methodologies have improved the development and application of nuclear technologies. Nuclear and isotopic techniques provide unique or substantial complementary value in addressing food security. Nuclear techniques are of great socio-economic importance as they are the only solution in certain areas, and combined with modern biotechnologies, are essential in providing more efficient ways of improving food availability, accessibility and affordability.

12. The result has been a vastly improved understanding of the processes that underpin the transformation of biophysical resources into food and the development of new and innovative technologies. Nuclear applications improve agricultural sustainability through the use of integrated approaches that increase the efficiency of crop and livestock production systems. In addition, they conserve natural resources and enhance food quality and consumer protection.

## C. The Role of the Agency's Partnership with FAO

13. It is now 50 years since the Agency and FAO established focal points for international cooperation on nuclear science and its applications in food and agriculture. It is also 50 years since the Agency initiated its technical assistance programme and research contracts with laboratories and scientific institutions in Member States.

14. The two organizations are well matched. FAO brings to the table its comprehensive knowledge and networks on food and agriculture, a terrain otherwise foreign to the IAEA. The Agency, in turn, contributes technical know-how in the area of nuclear technology and applications, an area not easily accessible (and in fact peripheral) to the FAO. Each was thereby able to advance its own expertise through partnership with the other, and together they were able to deliver accomplishments that each would have been unable to achieve in isolation. Although the Joint Division, which emerged in 1964, is wholly located in Austria, FAO unmistakably carries the primary responsibility in the partnership, while that of the Agency is by definition a secondary one. The partnership's potential is by no means exhausted.

15. The aim of the Joint Division is to help Member States in applying nuclear techniques to enable farmers, food processors and government agencies to provide people with more, better and safer food, while conserving the natural resources (soil and water) and biodiversity on which these products depend.

16. The focus on coordination and support of research, practical application of techniques and exchanging scientific information has remained largely unchanged. However, the range of services provided to Member States has constantly evolved.

17. The work of the Joint Division has been underpinned by the determined pursuit of sound science, objectivity and balance, and the conviction that nuclear science, technology and research are key drivers of development. Nuclear applications are fostered only where they really add value (or have significant prospects of doing so), and have high applicability globally or regionally. Nuclear techniques are proposed as adjuncts to – and not substitutes for – other techniques and are most effective when used by people with knowledge in the relevant agricultural specialities.

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

**Establishment:** October 1964 by FAO and IAEA and includes the FAO/IAEA Agriculture and Biotechnology Laboratory.
**Location:** Vienna, Austria and FAO/IAEA Agriculture and Biotechnology Laboratory in Seibersdorf, Austria.
**Mandate:** Nuclear and isotopic techniques provide unique or substantial complementary value in addressing food security and safety. The existence of a Joint Division has allowed a coordinated approach to the use of nuclear techniques in the field of agriculture.
**Staff:** The Joint Division staff consists of 71 IAEA positions, and 24 FAO positions. Its programme and budget are approved by the policy making organs of both FAO and the IAEA.
**Budget:** The total budget of the Joint Division is over €14 million per annum, of which ca. €2.2 million is provided by FAO. In addition some $10-15 million is provided annually by the Department of Technical Cooperation of IAEA to fund ca. 220 national and regional technical cooperation projects in food and agriculture.
**Activities:** About 25 training courses and ca. 20 workshops and seminars are held annually involving more than 500 trainees. Between 30 and 40 FAO/IAEA Coordinated Research Projects are coordinated at any given time, involving the participation of approximately 400 research institutions and experimental stations in Member States.
**Partnership organizations:** these include: Arab Organization for Agriculture Development (AOAD), African Union/Interafrican Bureau for Animal Resources (AU-IBAR), Consultative Group on International Agricultural Research (CGIAR), International Centre for Research/Development on Livestock in the Sub-humid zone (CIRDES), European Food Safety Authority (EFSA), International Relief & Development (IRD), International Centre for Theoretical Physics (ICTP), International Center for Soil Fertility and Agricultural Development (IFDC), Inter-American Institute for Cooperation on Agriculture (IICA), International Treaty on Plant Genetic Resources (ITPGR), North American Plant Protection Organization (NAPPO), World Organisation for Animal Health (OIE), Programme Against African Trypanosomiasis (PAAT), Pan African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC), Technical Cooperation Network on Plant Biotechnology in Latin American and the Caribbean (REDBIO), United Nations Fund for International Partnerships (UNFIP), United Nations Trust Fund for Human Security (UNTFHS), United States Agency for International Development (USAID), United States Department of Agriculture (USDA), Africa Rice Center (WARDA), World Health Organization (WHO).

# D. Results of FAO-IAEA Cooperation with Member States

## D.1. New & Better Measurement Techniques, Agricultural Products and Practices

18. Development-oriented research supported by the Joint Division through Coordinated Research Projects and at its FAO/IAEA Agriculture and Biotechnology Laboratory at Seibersdorf has produced many scientific and technical outputs. These include:

- Isotopic techniques to optimize plant nutrient uptake from fertilizers and other sources, minimize groundwater pollution and improve soil fertility;

- The use of fallout radionuclides to understand the factors causing soil erosion and identify cost-effective practices to reduce it;

- The use of optimal radiation doses to induce mutations in food and industrial crops that result in varieties with higher yields and enable crops to thrive in harsh environments;

- The development of techniques using gamma-rays to sterilize the Mediterranean fruit fly, and a number of major insect pests;

- Reductions in the population of the deadly tsetse fly, the parasitic carrier of sleeping sickness, by using radiation to sterilize males;

- The development of highly sensitive techniques for measuring the levels of hormones that regulate reproduction in livestock and identifying diseases such as rinderpest, foot-and-mouth, brucellosis and Rift Valley fever that kill farm animals;

- Understanding of the optimal radiation doses for destroying bacteria, insects and other organisms that cause spoilage in food and human diseases;

- Validated methods of analysis and sampling to determine and control radionuclide, pesticide, veterinary drug and mycotoxin contaminants in foods.

## D.2. Increasing Evidence of Agricultural and Socio-Economic Benefits

19. Since the mid–1960s, the Joint Division's research-for-development activities have delivered continuous results that have improved people's lives while helping to protect the environment.

*Some of the most notable and sustainable impacts are:*

- The huge savings in fertilizer applications made possible by using isotopes to more effectively determine optimal placement and timing of use, or to let plants fix nitrogen from the atmosphere. The economic benefit from fertilizer savings totals at least US$6 billion per year;

- The millions of hectares of higher yielding, more disease resistant and drought tolerant food and industrial crops grown all over the world from using mutation-assisted breeding. The economic benefit in terms of annual crop value and additional income to farmers totals billions of dollars per year;

- The eradication of screwworm from the Libyan Arab Jamahiriya using the SIT. This has brought estimated benefits of US$280 million annually;

PIC 1. A new mutant rice variety of significantly high yielding in Vietnam

- Removal of the tsetse fly from the Island of Zanzibar, which increased the contribution of livestock from 12% to 34% for agricultural GDP;
- The creation of fruit fly free areas in Mexico, Central America, Peru, Chile, the Patagonia and Mendoza Provinces of Argentina, the Arava Valley shared by Israel, Jordan and the Palestinian Authority, and the Hex River Valley in South Africa. This brought benefits of hundreds of millions of dollars per year in terms of reduced production losses, increased exports and more jobs;
- The widespread use of immunoassay technology which provided the technological platform to monitor the effectiveness of national vaccination programmes carried out under the Pan African Rinderpest Eradication Campaign (PARC). The net annual economic benefit to the region is estimated at US$920 million.

PIC. 2. Better irrigation management by using a soil moisture neutron probe.

## D.3. Enhanced Technical and Managerial Skills and Competences

20. Capacity-building by the Joint Division has led to increased use of nuclear techniques by Member States. Examples include:

- 41 countries use nuclear tracer techniques to track soil movement, assess soil erosion and develop cost-effective soil conservation measures (up from 15 in 2000);
- 95 Member States use isotopic and nuclear techniques to identify land and water management practices to improve nutrient and water use efficiency for crop productivity and environmental sustainability (up from 75 in 2000);
- The carbon isotope discrimination technique to improve soil quality and land productivity by assessing crop genotypes for drought and salinity tolerance and evaluating soil organic carbon accumulation and storage is being used in 64 Member States (up from 27 in 2000);
- The number of crop varieties developed through mutations officially released by Member States has risen to 2672 in 2008 (up from 2250 in 2000);
- More than 70 Member States successfully employ Joint Division-developed or validated animal diagnostic and monitoring tests to assist their national disease prevention, control and eradication programmes;
- There has been significant growth in the number of Member States employing a Joint Division-developed genetic sexing strain of Mediterranean fruit fly in programmes for controlling this pest, and in the number of sterile medflies being produced globally (over 3.5 billion per week in 2008 compared with one billion per week in 2000);
- 30 countries are using the sterile insect technique (SIT) against other key insect pest species and are embarking on area-wide pest management approaches promulgated by the Joint Division instead of field-by-field operations (up from 15 in 2000);

- The number of food irradiation facilities in Member States has risen to 192 in 2008 (up from 32 in 2000).

## D.4. Greater Support for Agricultural Development

21. Recent examples of the commitments of governments, private sector bodies and lending institutes to invest in nuclear applications include:

- The decisions in 2007 of 58 Member States to cooperate with the Agency through the Joint Division in 119 agricultural development projects through the Technical Cooperation Programme (up from 35 countries and 47 projects in 2003); a further 210 concepts for future projects have been submitted for the 2009 cycle of the programme;

- The decision by African Heads of State and Government in 2005 to establish the Pan African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC). Subsequently, the African Development Bank agreed to invest US$80 million in tsetse and trypanosomiasis control activities;

- A multilateral approach to reducing or eliminating the prevalence of fruit flies in Central America which led to investments in the production of fruit and vegetables of US$150 million. All exports of tomato and bell pepper from Nicaragua, El Salvador and Guatemala now come from the fruit fly low prevalence areas established; and

- Notification by Argentina, Brazil, China, Colombia, India, Ghana, Guatemala, Mexico, Nigeria, Sri Lanka, Thailand and the Philippines, that new or additional irradiation facilities are being built or planned for future phytosanitary treatments of foodstuffs, especially fruits, which are being increasingly traded on the international market. The facilities represent investments ranging from US$15-20 million for electron beam and US$50-70 million for $^{60}$Co sources by governments and the private sectors of the countries concerned.

## D.5. Increased Acceptance of Joint Division Recommended Norms and Procedures by International Standard Setting Bodies

22. In recent years, the international regulatory framework surrounding the protection of human, animal and plant life and health has become increasingly important in determining the conditions under which agricultural trade takes place. The Joint Division has responded by providing scientific and technical information to the three international standard-setting bodies named in the World Trade Organization's Agreement on Sanitary and Phytosanitary Measures. These are: the FAO/WHO Codex Alimentarius Commission, the International Plant Protection Convention and the World Organisation for Animal Health (Office International des Epizooties, OIE).

23. Information from research and technical cooperation projects and expert group meetings, as well as the experience of the Joint Division's own technical staff, has contributed substantively to a number of international standards and guidelines in food safety as well as animal and plant health (Annex 1).

## D.6. Scientific and Technical Information

24. Over the past five years, results from coordinated research and technical cooperation projects, in-house research at the FAO/IAEA Agriculture and Biotechnology Laboratory at Seibersdorf,

meetings and international symposia have led to the publication of several thousand peer-reviewed scientific papers, articles and numerous textbooks (Annex 2).

25. In addition, a number of databases and decision-support systems are now available to Member States (Annex 3).

## D.7. New Ideas and Directions for Scientific and Technological Research

26. The Joint Division has been instrumental in stimulating funding for and implementation of a number of initiatives with transnational impact at both research and development levels.

27. For example, isotopes and neutron moisture probes are now part of almost all national research efforts to optimize plant fertilizer uptake, minimize soil erosion and groundwater pollution and improve soil fertility and water management practices. Likewise, Joint Division-supported research encourages the use of mutations in plant breeding and genetics programmes for producing better varieties of food and industrial crops.

28. In animal production, the Joint Division's work transformed feed supplementation strategies for animals kept on low quality diets by small-scale farmers managing integrated crop-livestock production systems. The immunoassay and molecular techniques it helped to develop are now widely used by artificial insemination services to small-scale dairy farmers and by veterinary authorities to diagnose diseases and monitor the success of eradication efforts.

29. The Joint Division's work on food irradiation stimulated interest in applying the process commercially and developing international standards to regulate and promote its use.

# E. Recent Successes

30. The following is a snapshot of some recent successes achieved by Member States in partnership with the Agency through the Joint Division:

- Turkey has significantly boosted potato output through a system called drip irrigation-fertigation which involves adding water and fertilizer to the crop together. The system was developed through research using isotopes.

  Thirty Member States have introduced this practice.

- China successfully used nuclear tracer techniques to assess the extent of land degradation and soil erosion and implemented soil conservation measures to combat it.

  Similar successes have been reported by Chile, Morocco, Romania and Vietnam, and 40 Member States are currently using Joint Division guidelines to tackle this problem.

- Vietnam developed better varieties of rice using mutation induction. Since 1997, 3 new rice varieties, known for both their high food quality and tolerance to salinity, have been released by the Government of Vietnam to farmers in the Mekong Delta. These varieties have raised farmers' incomes by US$350 million per year and one is among the top five export varieties in Vietnam.

Just over 100 Member States are using mutation induction to improve food and industrial crops.

PIC. 3 Helping Member States to improve their local animal breeds

- Diagnostic tests were developed for Contagious Bovine Pleuropneumonia (CBPP) and Rift Valley fever (RVF) through research supported by the Joint Division and subsequently approved for use by the World Organisation for Animal Health (OIE). Use of the CBPP test in Botswana helped to eliminate the disease in 2005 and protected beef exports to the European Union worth US$90 million per year.

  Close to 50 Member States are using the tests developed for CBPP and RVF.

- In early 2008, the Animal and Plant Health Service of Peru declared that the regions of Tacna and Moquegua were free of Mediterranean and *Anastrepha* fruit flies. This transboundary expansion of the fruit fly free area from Chile was achieved through the area-wide integrated application of the SIT. It is the culmination of 20 years of effort by governments and institutions in Chile and Peru, the IAEA, FAO, the Inter-American Development Bank and others.

  Over 20 Member States are using SIT on crop pests. Other countries are using radiation for biological control purposes.

# F. Future Challenges

31. In order to face the challenges referred to in Section A above, substantial leaps must be made in agricultural productivity and quality to meet rapidly growing demand and increasing household and market requirements.

32. There is considerable scope for wider dissemination of techniques and approaches available today to deal with problems in food and agriculture. Adapted to local circumstances, these techniques and approaches will contribute relatively quickly to boosting productivity.

33. Farmers face new challenges such as the growing unpredictability of water supplies, dramatic changes in land use such as deforestation and land degradation and changing distributions of animal and plant pests and diseases. Fruit fly pests, for instance, are becoming established in previously inhospitable areas, while outbreaks of Rift Valley fever and other diseases, which also affect humans, are becoming more numerous.

34. Climate change may also affect food safety as a growing number of pests and diseases could lead to higher levels of pesticides and veterinary drug residues in food. Changes in rainfall, temperature and humidity can lead to foods becoming more easily contaminated with fungi that produce potentially fatal mycotoxins.

35. Research is essential to identify ways of adapting agriculture to changing environmental conditions, as well as mitigating the contribution to climate change made by specific practices or systems (e.g. methane from cattle and nitrous oxide from fertilizer use), while boosting and sustaining the productivity of smallholder farmers and enhancing agriculture's contribution to economic growth and poverty reduction.

36. The Agency through the Joint Division will continue to assist Member States in protecting their food and agricultural systems and the wider environment by providing objective and science-based information on crop, soil and water management to help ensure that climate change dimensions are incorporated into national development plans for using nuclear technology.

37. It will foster applications of existing techniques for emerging issues facing food security, for example dealing with a wider spectrum of animal and plant pests and diseases than at present.

38. The Joint Division will promote the international validation and acceptance of techniques such as isotope ratio mass spectrometry for establishing the geographic origins, authenticity and traceability of agricultural resources, products, pests and disease agents and food constituents.

39. The Joint Division will continue facilitating transboundary agricultural trade by providing technical support for the development and harmonization of international sanitary and phytosanitary standards and their use by developing countries to facilitate their access to international markets and foreign exchange.

40. Subject to greater international consensus on bio-fuel production, the Joint Division may join with public and private sector partners in using nuclear techniques to better develop plant varieties with increased biomass for sustainable production of second-generation biofuels from non-food plant materials and inedible by-products.

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9. *High-Level Conference on World Food Security: the Challenges of Climate Change and Bioenergy (2008)*. (Available at: http://www.fao.org/foodclimate/hlc-home/en/).

# Annex 1: International standards and guidelines with technical inputs from the Joint FAO/IAEA Division:

**In food safety:**

- Codex General Standard for Irradiated Foods;
- Codex Recommended International Code of Practice for Radiation Processing of Food;
- Codex General Methods for the Detection of Irradiated Foods;
- Codex Guideline Levels for Radionuclides in Foods Contaminated Following a Nuclear or Radiological Emergency for Use in International Trade, revised in 2007;
- Codex Guidelines on the Use of Mass Spectrometry (MS) for Identification, Confirmation and Quantitative Determination of Residues;
- Guidelines for the Single Laboratory Validation of Analytical Methods for Trace-Level Concentrations of Organic Chemicals;
- Revised Codex Guidelines on Good Laboratory Practice in Pesticide Residue Analysis, and
- Codex Guidelines on Estimation of Uncertainty of Results.

**In animal health:**

- OIE Guidelines on the Adoption of Diagnostic Tests as Prescribed, Recommended or Alternative Tests;
- OIE Guidelines for Establishing Quality Systems in Veterinary Diagnostic Testing Laboratories;
- OIE Guidelines for the Validation of Serological and Polymerase Chain Reaction (PCR) Diagnostic Procedures;
- OIE Guidelines for the surveillance of rinderpest;
- OIE Guidelines on the rinderpest declaration pathway - freedom from rinderpest disease and freedom from rinderpest infection; and
- Developed and Validated Diagnostic Tests included in the OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals (2008) for the following transboundary animal diseases: foot-and-mouth disease, rinderpest, peste des petits ruminants, contagious bovine pleuropneumonia, Rift Valley fever, bovine brucellosis, and surra (Trypanosoma evansi).

**In Plant Health, International Standards for Phytosanitary Measures (ISPMs) on:**

- Guidelines for Export, Shipment, Import, and Release of Biological Control Agents and Other Beneficial Organisms which includes the release of sterile insects;
- Requirements for the Establishment of Pest Free Areas;
- Guidelines for Pest Eradication Programmes;
- Requirements for the Establishment of Pest Free Places of Production and Pest Free Production Sites;
- Guidelines for the Use of Irradiation as a Phytosanitary Measure;
- Requirements for the Establishment of Areas of Low Pest Prevalence;
- Establishment of Pest Free Areas for Fruit Flies (Tephritidae); and
- Recognition of Pest Free Areas and Areas of Low Pest Prevalence.

## Annex 2: Scientific publications over the past five years:

- Several 1,000 peer-reviewed scientific papers and review articles in international and national journals and conference proceedings;

- A textbook on "Maximising the Use of Biological Nitrogen Fixation in Agriculture"; guidelines on "Nitrogen Management in Agricultural Systems", "The Use of Sulphur Isotopes in Soil-Plant Studies" and "Neutron and gamma Density Probes: Their Use in Agronomy"; a handbook for "The Assessment of Soil Erosion and Sedimentation using Environmental Radio-nuclides"; FAO bulletins on "The Use of Phosphate Rocks for Sustainable Agriculture" and "Deficit Irrigation Practices"; and a manual on "Field Estimation of Soil Water Content; A Practical Guide to Methods, Instrumentation and Sensor Techniques";

- Textbooks on "Molecular Techniques in Crop Improvement", "Mutant Germplasm Characterization using Molecular Markers", and "Banana Improvement using Cellular and Molecular Biology using Induced Mutations"; and a manual on "Doubled Haploid Production in Crop Plants"; a yearly updated laboratory manual on "Mutant germplasm characterization using molecular markers";

- Textbooks on "Measuring Methane Production from Ruminants", "Quantification of Tannins in Tree and Shrub Foliage", "Applications of Gene Based Technologies for Improving Animal Production and Health in Developing Countries"; a manual on "Application of Radioimmunoassay in Improving the Reproductive Management of Smallholder Dairy Cattle"; a "Molecular Diagnostic PCR Manual"; and "Guidelines, Quality Assurance Procedures and Reference Standards for the Diagnosis and Surveillance of Animal Diseases"

- Textbooks on "The Sterile Insect Technique: Principles and Practice of Area-wide Integrated Pest Management", "Area-wide Control of Insect Pests: From Research to Field Implementation", and "Animal Trypanosomiasis: Vector and Disease Control Using Nuclear Techniques", "Trapping Guidelines for Area-wide Fruit Fly Programmes", a manual for "Product Quality Control and Shipping Procedures for Sterile Mass-reared Tephritid Fruit Flies"; and guidelines on "Packing, Shipping, Holding and Release of Sterile Flies in Area-wide Fruit Fly Control Programmes";

- Textbooks on "Principles and Practice of Method Validation", "The Use of Irradiation to Ensure the Hygienic Quality of Fresh Pre-cut Fruits and Vegetables and Other Minimally Processed Food of Plant Origin", and "Classification of Soil Systems on the Basis of Transfer Factors of Radionuclides from Soil to Reference Plants", a manual on "Dosimetry for Food Irradiation", and "Guidelines for the Single Laboratory Validation of Analytical Methods for Trace-level Concentrations of Organic Chemicals"

## Annex 3: Databases and decision-support systems:

- Phosphate Rock Decision Support System (PRDSS): provides information on influence of soil properties on the availability of phosphate from local phosphate rocks on crop growth;
- Mutant Varieties Database (MVD): provides data on officially released varieties, information on mutagens used and characters improved;
- International Database on Insect Disinfestation & Sterilization (IDIDAS): provides species-specific information for both disinfestation (trade and quarantine) and sterilization (SIT);
- Animal Disease Diagnosis System (ADDIS): a reference system to help diagnose, monitor and prevent rinderpest and other diseases;
- Tephritid Workers Database: provides information to fruit fly workers on directory of workers, and what they are doing, regional associations, a virtual fruit fly library, news and events, and links;
- World-wide Directory of SIT Facilities: provides information about all mass rearing facilities of sterile pest insects including production size, radiation process, quality control parameters, dosimetry, programme objective, trans-boundary shipment, field release data, and the facility address.
- e-learning courses on “dosimetry system for the SIT using Gafchromic® film” and “field cage comparative assessment of tsetse fly mating compatibility and competitiveness”;
- Clearances of Irradiated Food Database: a database of foods cleared for irradiation processing by country;
- Authorized Food Irradiation Facilities Database: a database of authorized food irradiation facilities by country; and
- Food Contaminant and Residues Information System (INFOCRIS): an interactive system focusing on food and environmental contaminants with emphasis on Codex Alimentarius standards