Transferring technologies for agricultural development in the Third World

An overview of approaches followed by the agriculture laboratory of the IAEA's Laboratories at Seibersdorf

by J.I. Richards

A report by the World Food Council of the United Nations recently concluded that global hunger and malnutrition keep deteriorating. Famine is now threatening more than 30 million people with starvation as a result of natural disasters (mostly drought or flood) and continuing social and political emergencies (civil unrest and war).

Less visible but no less tragic is the continuing crisis of chronic malnutrition. It affects one in five people overall and 50 of the world's poorest countries. Almost 200 million children under 5 years of age suffer from protein-energy malnutrition, and 40 000 of them die each day from malnutrition causes.

Incongruously, despite the situation, there is continued rapid population growth in the developing world. Many developing countries, especially in Africa, are no more successful in controlling their population growth today than in the past and the region still has a growth rate in excess of 3% a year.

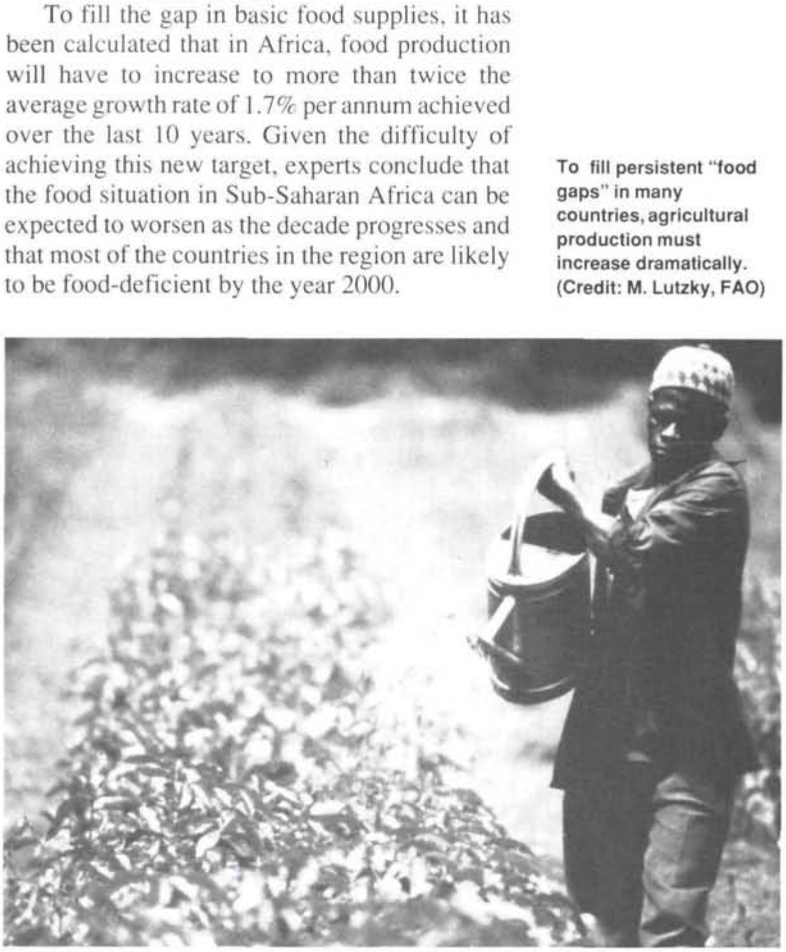
The consequences of this are all too clear:

There is greater pressure on land resources; fallow periods are shorter; overstocked grasslands are becoming exhausted; forests are being eaten away by expanding croplands and increased gathering of fuelwood; the ecological balance is being disrupted; soils are being degraded and water sources are drying up or becoming polluted; yields are being reduced; incomes are falling and unemployment rising; and the desert and poverty are taking over the countryside.

As a result, the "food gap" between domestic supplies and the fast-growing demand is widening inextricably. Although international aid has mitigated the consequences of this, it is obviously not a viable solution. Today, it only serves as a derisory palliative and is likely to lead only to a population which is permanently dependent on handouts.

To make things worse, the least developed countries, and others having both low incomes and food-deficits, have seen their share of food aid steadily decline over the last 2 to 3 years. This is because industrialized countries that are major food donors are re-directing their static or depressed food aid programmes to Eastern Europe and the former USSR at the expense of those to the Third World.

To fill the gap in basic food supplies, it has been calculated that in Africa, food production will have to increase to more than twice the average growth rate of 1.7% per annum achieved over the last 10 years. Given the difficulty of achieving this new target, experts conclude that the food situation in Sub-Saharan Africa can be expected to worsen as the decade progresses and that most of the countries in the region are likely to be food-deficient by the year 2000.



To fill persistent "food gaps" in many countries, agricultural production must increase dramatically. (Credit: M. Lutzky, FAO)

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In its bid to address this depressing situation, the United Nations General Assembly in December 1990 adopted an "International Development Strategy". Its purpose is to alleviate hunger and poverty through the promotion of human resource development. Likewise, the UN Conference on Environment and Development in June 1992 declared that "States should cooperate to strengthen endogenous capacity-building for sustainable development by improving scientific understanding through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion, and transfer of technologies, including new and innovative technologies".

At the IAEA, one of the three major objectives of the medium-term plan (1993-98) is the "enhancement of the transfer of nuclear technology and know-how to developing countries". For its part, the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture already is managing more than 500 research contracts and providing technical supervision of the IAEA's technology-transfer activities in 250 agriculture projects supported by the Department of Technical Co-operation. Through these avenues, the competence of research scientists in developing countries is being improved so that they are better able to identify and resolve the problems affecting agricultural productivity.

The Agriculture Laboratory of the IAEA's Seibersdorf Laboratories works with the Joint Division in this endeavour. Its areas of specialization are: soil fertility, irrigation and crop production; plant mutation breeding; pesticide analysis and formulation; insect and pest control; and animal production and disease diagnosis.

The Agriculture Laboratory has a staff of more than 70 highly qualified and experienced international personnel and a regular annual budget in excess of US $4 million. It does not pretend to have the facilities or staff to compete with national or international laboratories, however, and its work should not be confused with that of a research laboratory. Rather, its mandate is a distinct one in the UN system: to provide three basic services to counterparts in developing countries in an effort to ensure effective transfer of appropriate nuclear and related technologies for agricultural research. These services address research and development, training, and technical support.

Key elements of R&D services

Four major elements are involved in the Laboratory's provision of services in the area of research and development:

● ***Definition of problems for which technology is required.*** The type and scale of problems in any given country are important to define clearly before appropriate technologies can be identified or developed. In IAEA-supported agricultural projects, there is close collaboration with scientific counterparts in developing countries and with the Joint FAO/IAEA Division's technical and project officers, who have first-hand knowledge of the country and the agricultural problems being investigated. They also are familiar with the technical competence of the staff for whom the technologies are required, the local physical infrastructure (laboratories, quality of electrical and water supplies, availability of power and air conditioning), instrument repair/maintenance facilities, and local environmental factors (climate, dust, thunderstorms, etc.).

This background information has enabled the Agriculture Laboratory to focus its attention on assisting counterpart scientists address well-focused research topics in five areas:

Soil science: maximizing the use of atmospheric nitrogen in crops and trees through plant selection and optimal plant-bacteria conditions; and optimizing the use of nitrogenous and phosphatic fertilizers and water for maximum productivity and profit while minimizing their negative impact on the environment. *(See box on page 13.)*

Plant breeding: the creation of crop varieties with improved productivity characteristics and enhanced resistance/tolerance to diseases. *(See related article beginning on page 25.)*

Agrochemicals: development of new pesticide formulations which are target-specific and long acting with minimum impact on the environment. *(See box on page 12.)*

Entomology: reduction in the indiscriminate use of insecticides for controlling agriculturally important insect pests through the development and promotion of an environmentally-friendly target-specific system, the sterile insect technique (SIT). *(See box on page 16.)*

Animal production: improvement of livestock productivity by proposing alternative management strategies in animal feeding and breeding; and definition of the incidence and prevalence of major livestock diseases and monitoring the efficacy of vaccination or other campaigns for disease control/eradication. *(See article beginning on page 34.)*

● ***Identification, modification, and standardization of appropriate technology.*** The Laboratory's procedure for identifying appropriate technologies conform to a number of international guidelines formulated recently: (1) use should be made of transparent, user-friendly technologies to promote sustainable agricultural development; and (2) the IAEA should promote only those nuclear technologies which have a clear advantage in developing countries over other technologies.

With these guidelines, existing available technology (equipment, methodology, chemicals, biologicals) can be identified, and modified if required, and subsequently standardized to conform to international or IAEA norms.

● ***Development and standardization of "custom-made" technology.*** All too often, appropriate technology does not exist "on the shelf" and has to be "custom-made" or developed. This is achieved in a number of ways. One is through active collaboration with national, international, or commercial laboratories or organizations, whereby certain portions or the whole technology development (biologicals, equipment, methodologies) are contracted out. The Agriculture Laboratory currently liaises with more than 40 such groups worldwide. The second way is through the development of appropriate technology by and between scientists in the Agriculture Laboratory working with scientists from other disciplines, such as those in the chemistry and physics laboratories, and with skilled staff in the mechanical and instrumentation workshops. In both cases, the technology has to conform to international or IAEA norms.

Examples of technologies undergoing R&D at the Laboratory include:

Soil science: methodologies (DNA probes, GUS-gene and other molecular biology techniques) for investigating the ecology of nitrogen fixing microbes in pasture and grain legumes; development of optimal emission- and mass-spectrometers for nitrogen-15 and carbon-13 analysis to identify plant genotypes with superior nutrient uptake/utilization traits.

Plant breeding: mutation breeding techniques using ionizing radiation (gamma radiation and fast neutrons) and chemical mutagens for inducing genetic variation and providing increased opportunity for selecting plants with improved productive traits; *in-vitro* propagation techniques to facilitate the production of large numbers of treated plants and speed up the genetic confirmation and agronomic evaluation of new genotypes (plantains, bananas, cassava, yam, etc.).

Agrochemicals: slow (controlled) release formulations of herbicides in aquatic systems; development of pesticide impregnated screens for tsetse fly control; formulation and testing of effective pesticides and attractant "cocktails" against the screwworm fly under simulated environmental conditions; development of analytical methods for pesticides and their residues.

Entomology: the SIT (mass rearing, shipment, and release of insects) for the control/eradication of tsetse fly and Mediterranean fruit fly; advanced technologies in genetics and molecular biology, insect nutrition, and dietetics to make SIT applicable to more insect pests in larger areas at lower cost.

Animal production: kit technologies for the measurement of reproductive and metabolic hormones in livestock through radioimmunoassay; measurement of nutritional metabolites that limit the productivity of farm animals using colorimetric techniques; diagnosis of infectious diseases in livestock using enzyme-linked immunosorbent assays (ELISA).

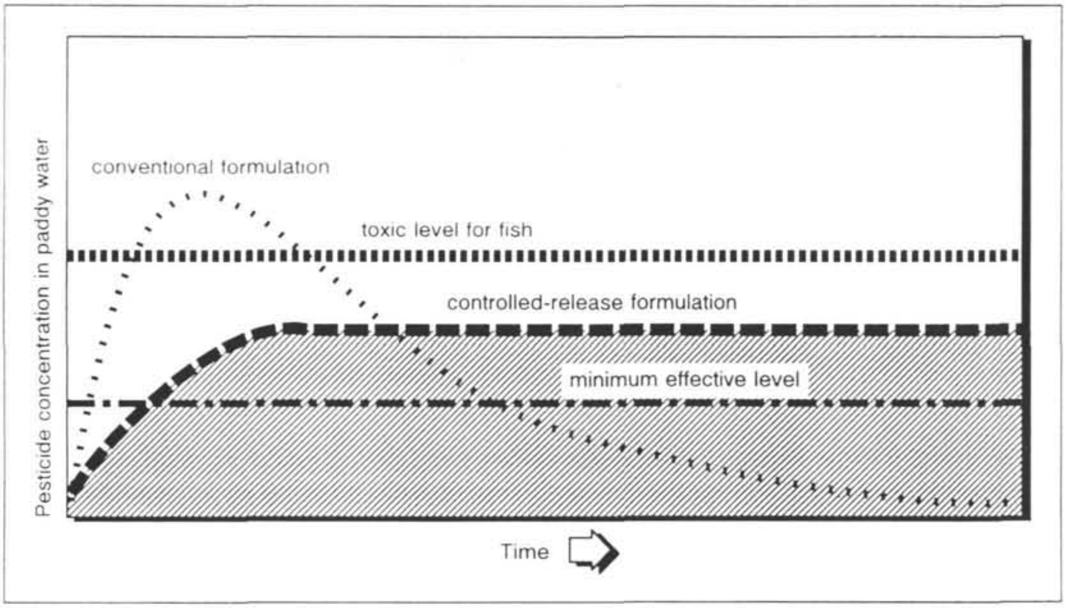
● ***Validation and field testing.*** Before any technology is distributed to counterparts in IAEA-supported projects, it is checked and validated by selected field laboratories. They are asked to use the new technology (or where appropriate compare it with an existing technology) and complete comprehensive questionnaires on its performance (sensitivity, accuracy, relevance of generated data), robustness, user-friendliness, and other factors. Based on their responses, the technology is then further modified and eventually enters the pool of "green light" technologies to be promoted for use by scientists in developing countries.

A much forgotten aspect of field testing—and subsequently of technology transfer—relates to the physical distribution of new technologies. Some might be sent only once, but more commonly, the technologies are shipped on a regular basis. This entails satisfying both the necessary "in-house" bureaucratic route, and the often problematic, time-consuming, and constantly changing international airline and sea-freight regulations governing packaging and packing materials, radioactive materials, import regulations, and customs clearance procedures of national governments. Whereas the IAEA's appropriate offices assist in this task, the Agriculture Laboratory is responsible for ensuring rapid, safe, and legal delivery of technologies that it develops.

Forms of scientific training

Clearly there is little point in providing technologies that people are not trained to use correctly. Recipients must know how to use, handle, and maintain these new technologies, and how to assess the quality of their operation and to interpret the data they generate. Training of scientists and technical support staff thus constitutes one major component (and some believe the main one) of technology transfer.

Agrochemicals: Improved formulations



Weeds are undesirable plants that grow in almost all cultivated crops. They compete with cultivated plants for nutrients, light, water, and space and reduce the yield of the crop and producivity of the land. In order to increase crop yields farmers control weeds by pulling them out by hand, machine, or by applying herbicides.

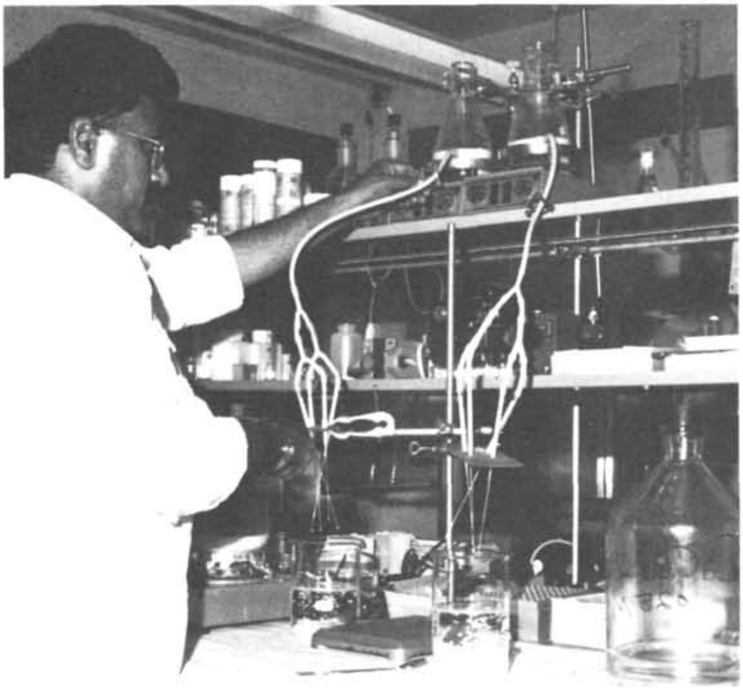
However when a herbicide (like other pesticides) is applied to a crop, a lot of it is lost during and soon after application. During application some herbicide is carried away from the target area by wind; some herbicide deposited on soil or plants is washed away by rain; and some is broken down by the action of light and oxygen in the environment. Thus, only a fraction of the applied herbicide is left to protect the crop.

In anticipation of these losses, high doses are applied to ensure adequate herbicidal activity. However, the initial high dose can harm non-target species such as fish, birds, and other animals. Also, since the herbicide is subject to degradation due to environmental effects, it does not last long and repeated applications become necessary.

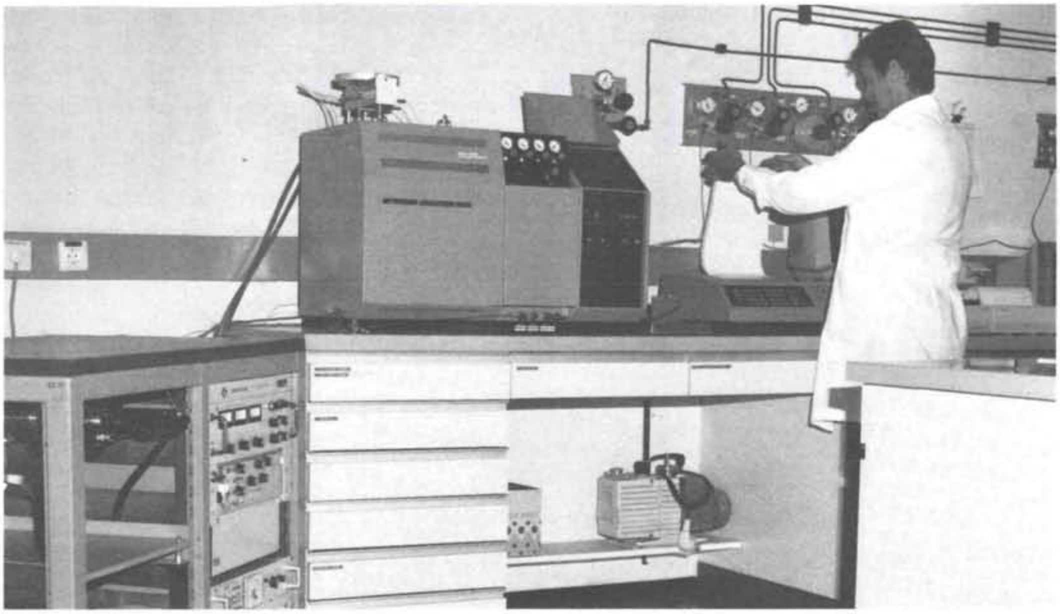
These problems can be overcome by using controlled-release formulations in which the herbicide is trapped in an inert matrix and is released in quantities slightly in excess of minimum effective herbicide levels. This prevents the loss of the herbicide from the action of water, light, and other environmental effects, thus making it active for a longer period of time. The duration of the effect of pesticides can be controlled by proper selection of the inert matrix and design of the formulation.

Several controlled-release formulations of herbicides have been prepared at the IAEA's Seibersdorf Laboratories. Some of these have contained herbicide labelled with a radioactive isotope in order to study the rate of release of the herbicide from the formulations. Based on this information, a few formulations were selected for biological tests in the greenhouse and in several collaborating countries. The herbicidal efficacy and environmental safety of controlled-release and commercial formulations were conducted in rice crops, as well as in rice-fish and rice-shrimp mixed ecosystems. The tests indicated that these formulations controlled weeds more efficiently and were less phytotoxic to rice plants than the commercial formulations. Similarly, tests carried out on *Azolla*, a water fern found extensively in Southeast Asia in mixed culture with rice plants, showed that the application of controlled-release herbicides effectively controlled weed growth but had relatively little toxic effect on *Azolla* compared with commercial herbicide formulations. — *contributed by Dr Manzoor Hussain, Head of the Agriculture Laboratory's Agrochemicals Unit.*

A scientist at the IAEA's Seibersdorf Laboratories preparing a controlled-release formulation of herbicides.



Soil science: Focus on grain legumes



Analysing plant samples at the Seibersdorf Laboratories Soil Science Unit.

Grain legumes such as common bean, soybean, pea, cowpea, and groundnut are among the world's most important crops, and a particular focus of work in the Soil Science Unit of the Agriculture Laboratory.

The crops are particularly nutritious—rich in protein, minerals and vitamins—and they make up a large proportion of the human diet. Other species such as forage legumes (alfalfa, clover etc.) and tree legumes (including *Leucaena, Gliricidia, Acacia, and Mimosa*) play a highly significant role in sustainable livestock practices of peasant farmers in the developing world. Leguminous crops, with the help of root nodulating Rhizobium bacteria, are able to derive nitrogen from the atmosphere in order to build-up tissue protein. This process, called biological nitrogen fixation, is able to supply nitrogen for plant growth, thus reducing the need for nitrogen fertilizer and its associated energy costs. Some of this nitrogen remains in the soil after cropping and enhances soil fertility. Nitrogen fixation may assume greater importance in future efforts to reduce excessive use of nitrogen fertilizer and associated environmental pollution of groundwater with nitrates and of the atmosphere with nitrogen oxides.

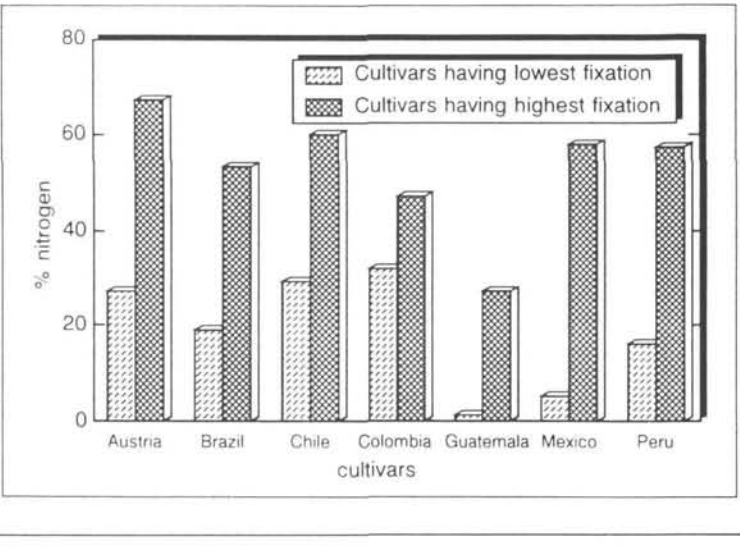
Not all legumes or rhizobial bacteria are equally efficient in fixing atmospheric nitrogen. The nitrogen-15 isotope technique has been found to be the most reliable method to quantify biological nitrogen fixation under greenhouse and field conditions. Largely developed at the Agriculture Laboratory at Seibersdorf, the technique has now been transferred to most developing countries. It is being used in a number of FAO/IAEA technical projects to enhance biological nitrogen fixation, saving nitrogen fertilizer and large amounts of foreign exchange.

Current research is focusing on the improvement of both yield and nitrogen fixation in grain legumes through a multidisciplinary research approach. Also, studies are being pursued on measuring the nitrogen fixation capabilities of some nitrogen fixing tree species commonly used in agroforestry systems and on factors which influence the amount of nitrogen fixed, for restoration/maintenance of soil fertility, soil conservation, and fuelwood production.

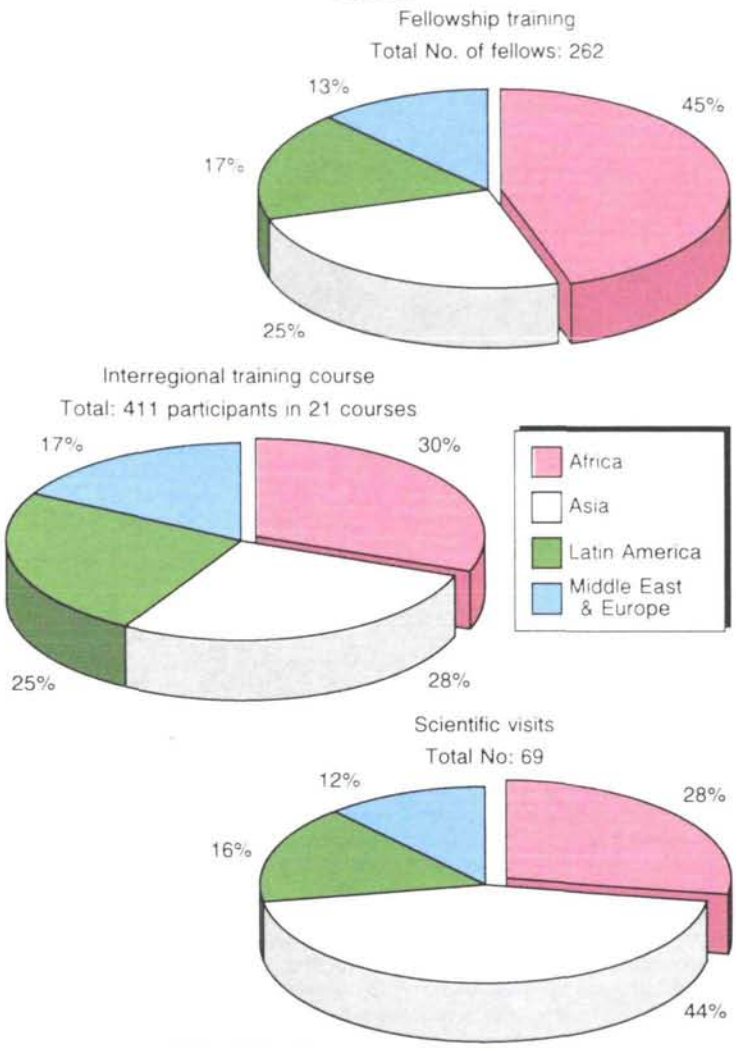
In support of the more than 100 research contractors participating in the FAO/IAEA international and regional networks, the Soil Science Unit analyses some 15 000 samples every year mainly for nitrogen isotope ratio. Analytical services are also provided to developing Member States in receiving IAEA technical assistance but lacking appropriate analytical facilities. The Unit plays a leading role in the development of new isotopic measurement techniques and equipment and the refinement of those in use for routine purposes.

In the next biennium, it is also planned to provide Member States with quality assurance services; this will give scientists confidence to regularly employ transferred technology and provide an international seal of approval to scientific data and associated conclusions generated by the nitrogen-15 technology.—*contributed by Dr Felipe Zapata, Head of the Agriculture Laboratory's Soil Science Unit.*

Percentage of nitrogen derived from the atmosphere by common bean cultivars



Scientific training at the Agriculture Laboratory in Seibersdorf, 1985-92



Scientific training activities in agriculture

The Agriculture Laboratory is a focal point of scientific training under IAEA projects and programmes.

Overall, three types of training related to the application of nuclear and related techniques in agriculture are offered to suitably qualified applicants from the IAEA's Member States. These are:

- Fellowship Training ("hands-on" training for junior scientists and technical support staff);
- Training Courses ("awareness" training for junior scientists);
- Scientific Visits ("awareness" training for senior scientists).

Over the past 7 years, more than 700 scientists from developing countries have participated in these IAEA training programmes for agricultural development. — *contributed by Ms. M.E. Ruhm, Training Officer, IAEA Seibersdorf Laboratories.*

Each year, the Seibersdorf Laboratories train about 13% of all trainees supported under IAEA technical co-operation projects. *(See box and graphs.)* In general, two forms of training are followed, each catering to the needs of senior and junior scientists, as well as technical support staff:

- ***Techniques training.*** The Agriculture Laboratory provides "hands-on" training in specific technologies. Training lasts between 2 to 6 months depending on the complexity of the technology and the calibre of the trainee. Training is sharply focused, with supervision provided by a Laboratory scientist and guidance by the project's technical officer. Other competent training locations can rarely provide the trainee with such specific, project-related training, and the trainee tends to "fit in" with the normal research work of the laboratory.
- ***Research and "awareness" training.*** The Agriculture Laboratory also trains scientists in basic and applied aspects of research. Although scientists from countries with well-developed research infrastructures are seldom taught how to conduct research, they normally have a scientific research supervisor to guide them or to emulate. This is not the case in many developing countries. Consequently, there is a need to provide these scientists with training in definition of a research problem; experimental planning; sample numbers and sampling frequency; data analysis and interpretation; and publication of results and conclusions. Where appropriate, this training follows aspects of the Laboratory's "techniques training". It normally lasts 6 to 12 months, and involves the trainee in a reseach project which is directly related to one being supported by the IAEA in their countries.

"Awareness" training is conducted in two ways. One is through interregional training courses, two to four of which are hosted by the Agriculture Laboratory each year. The courses last 5 to 8 weeks and are ideally suited for young professional scientists who need familiarization with the technologies currently available and the present state of knowledge in a specific field of agriculture. Selection is normally very keen for the 16 to 20 course placements, and about 80% of applicants have to be turned away from each course.

The second extremely important form of "awareness" training is for senior professional scientists who visit Seibersdorf for up to 1 week to become familiar with new developments in nuclear and related technologies, to catch up on scientific literature often not available in their home countries, and to discuss new scientific directions with research personnel. Such visits also often lead to collaborative links between Seibersdorf and developing country laboratories. This in turn leads to more rapid scientific development and promotion of greater friendship and understanding.

Support services and feedback

At this stage of the technology-transfer process, one assumes that the technology is in place and that staff have received basic training. What more, one might ask, can be done to assist? Unfortunately, a number of problems invariably occur at this stage with the equipment or methodology. At the same time, a great deal of pressure is put on project participants by both the IAEA and local employer to demonstrate results.

Therefore, this is an extremely critical step in the technology-transfer process. Scientific counterparts must be given the assurance that the IAEA will provide appropriate guidance and support in the use of the newly transferred technology so that they can proceed with the project plan with confidence.

The Agriculture Laboratory provides two services which may help provide this confidence:

- ***Analytical support and quality assurance.*** Through its analytical support services, the Laboratory undertakes analyses of samples when the transferred technology is temporarily non-operational. In this way, interruptions are alleviated and the scarce funds invested in often very expensive agricultural projects are not lost.
- ***Quality assurance.*** The second service, that of providing quality assurance, arguably has been the most neglected aspect of the Agriculture Laboratory's support until recently. The major components of quality assurance are the provision of guidance or chemical/biological materials which enable scientific counterparts in the project to have confidence in the equipment, analytical procedures (quantitative and qualitative), and data generated by the transferred technology.

Ideally, this degree of confidence should conform to international standards and thus allow the data to be used for defining acceptance of an agricultural product for international trade; submission to editors for publication in international agricultural research journals; and establishing the laboratory as a national reference laboratory for the analysis in question. The materials provided include international reference materials, external quality assurance panels, standardized protocols on methods, and guidance on how counterparts should make and assess internal quality assurance parameters. The recipient is required to participate in external quality assurance initiatives; laboratories whose data do not fall within specified limits are informed and advised as to ways of improving their use of the technology. The Agriculture Laboratory is now addressing the whole issue of quality assurance with vigour in many areas of its support services. The effort is designed to improve the implementation of field projects.

Reporting and application. The Laboratory can only improve its services if it receives comments (both negative and positive) from its end-users either directly or through project technical officers. No successful transfer of technology laboratory is an island.

Whereas some believe that no correspondence from counterparts generally indicates satisfaction with the technology, it may not be the case that "no news is good news". For its part, the Agriculture Laboratory frequently appeals for feedback through various avenues, including articles such as this one.

Impact of technology transfer

In a number of areas, transferred nuclear and related technologies have had a major impact on agricultural development in Third World countries.

In soil science, for example, technologies for measuring nitrogen-15 have enabled scientists to develop optimal fertilizer practices for improved crop productivity in difficult agroecological systems.

In plant breeding, irradiation procedures for inducing plant mutations have contributed to the release of more than 1500 new crop varieties worldwide. Radioisotopic methods have been used in developing improved and environmentally stable formulations of insecticides (deltamethrin) against tsetse flies and of controlled release herbicides (e.g. butachlor) for controlling weeds in rice-fish ecosystems.

In entomology, apart from the employment of the sterile insect technique in the eradication of the New World Screwworm from North Africa, SIT has been successfully used to eradicate the Medfly from Mexico and the Melon Fly from Japan.

In areas of animal health, ELISA technology used for the seromonitoring of livestock vaccinated against rinderpest has contributed to the fact that no major outbreak of this disease has been reported in Africa recently.

Improving the programmes

In light of such successes, the IAEA is about to conduct a review of its traditional means and procedures for technology transfer in order to ensure that more programmes achieve high levels of quality. It already has singled out the development of human resources, quality control services, and the maintenance of nuclear instrumentation for more attention in this new strategy. Additionally, the Agency might consider taking a broader, more integrated approach to project design as a way to promote a more interdisciplinary approach to identifying and resolving problems affecting agricultural production.

In his address to a recent regional Conference for Africa, the Director General of the Food and Agriculture Organization appealed for greater understanding. "We automatically gauge our solidarity towards a particular country according to its conformity to our values," he stated. "Yet I would humbly and earnestly request that care, flexibility, and delicacy be used in such an approach to Africa."

Far too often, bilateral and international organizations have been too arrogant in promoting a "we know what is best for you" approach before they truly address the values that the recipients place on such initiatives. Similarly, prestige programmes often have been conducted that give kudos to national governments or support organizations rather than addressing the true needs of the people.

Clearly there must be greater emphasis on dialogue with countries before programmes are implemented. This should involve multidisciplinary yet integrated teams that assess the value and impact of programmes on agricultural production and productivity, the country, and its population.

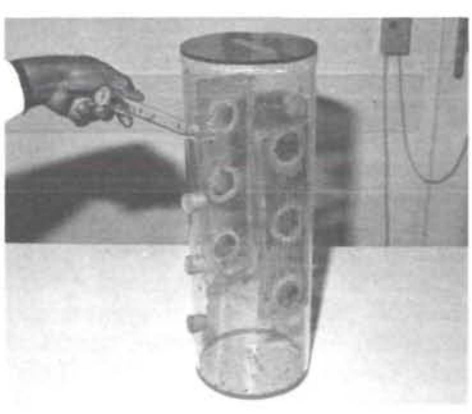
This will require far greater collaboration among UN and other organizations so that a concerted effort can be made by the international community to resolve the huge problems of hunger, malnutrition, and poverty facing the developing world. ❒

Entomology: The SIT and controlling insect pests

The primary research and development (R&D) activities of the Agriculture Laboratory's Entomology Unit are to make the sterile insect technique more reliable, efficient, and applicable for the control of insect pests in developing countries.

The technique, first tested less than 40 years ago, has revolutionized insect control and has made possible the total eradication of pest insects from large areas when used in conjunction with other methods in an integrated pest management approach. It is an environmentally friendly means of control. Its effects are so target specific that no other living organisms in the treatment area are affected.

While simple in technical concept (i.e., the mass rearing and release of sexually sterilized males that mate with and thereby render the wild females infertile) the SIT requires a complex operational organization including continual R&D back-up support. The Entomology Unit has provided such support to past eradication programmes organized by the Agency for the Mediterranean fruit fly in Mexico and Central America and the tsetse fly and screwworm in Africa.



Standard laboratory test to assess the mating competitiveness of sexually sterile tsetse fly males in relation to fertile males.

Tsetse flies, for example, have a low reproductive capacity. Relatively few sterile insects need to be released into the pest insect habitat to outnumber native fertile males. The Unit provides considerable numbers of tsetse fly pupae to IAEA projects in Africa and to collaborating scientists in IAEA Member States.

For the Mediterranean fruit fly, many hundreds of millions of highly viable insects must be produced for release each week. Costs have been reduced by designing equipment and developing diets that use locally available labour and materials. Recently geneticists in the Unit have developed strains of the fruit fly with lethal traits in the females that can be triggered by temperature. Since the sterile male is the active ingredient in a SIT programme, the females are unnecessary or even unwanted. Elimination of females in the embryo stage can save up to 40% of the rearing and release expenses. The released sterile female will still try to lay eggs and as a result damages fruit. Furthermore her presence detracts the sterile males from seeking wild females with which to mate.

Further development efforts have resulted in new genetic sexing (GS) strains of the fruit fly that are much more genetically stable than the original ones. Because of their extreme temperature sensitivity, which also affects the developmental stages after the embryo, special handling procedures have had to be developed to ensure consistent and reliable colony production. Behavioural studies in large cages and also with flies released in the field have shown that the newest GS strains are not only very stable, but they survive and behave as normal wild flies do under natural conditions; these characteristics are essential for the success of SIT pest control programmes. — *contributed by Dr R. Gingrich, Head of the Agriculture Laboratory's Entomology Unit. See the following article for a report on the successful use of the SIT in North Africa.*