Nuclear techniques in agriculture

Technical co-operation projects supported by UNDP in Asia and the Pacific Region are yielding important results

by L. LaChance, J. Aslam, and C. Langer

Applications of isotopes and radiation in agriculture have been one of the most important areas of technical co-operation at the IAEA. During the last decade, about 20% of all disbursements related to this field, making it the leading area of activity in the IAEA's technical co-operation programme.

In the Asia and Pacific region, the field of agriculture is one of the three most important areas of activity, following those related to applications of isotopes in industry and hydrology and to nuclear engineering and technology. The Agency is currently executing 48 projects in 13 of the 15 Member States of the region which receive IAEA technical assistance.

Problems being addressed through country projects include crop production, fertilizer and soil management practices, control of agricultural insect pests, environmental impact of pesticide residues, and animal production and health. Four country projects are supported by the United Nations Development Programme (UNDP), one each in China, Indonesia, Republic of Korea, and Thailand, as well as two regional projects. All UNDP-supported projects are run by the Food and Agriculture Organization (FAO)/IAEA Joint Division of Nuclear Techniques in Food and Agriculture in close collaboration with the IAEA's Department of Technical Co-operation. Thus, three international organizations — UNDP, IAEA, and FAO — work together. With the exception of those in China, all multi-disciplinary UNDP projects were approved after completion of 20-30 smaller IAEA technical co-operation projects relating to the application of nuclear techniques in agriculture.

This article highlights some important country projects in the Republic of Korea, China, Thailand, and Indonesia, as well as two projects in the region.

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Republic of Korea: Improving food and agricultural production

Following the completion of a number of IAEA technical co-operation projects in the Republic of Korea, a UNDP project was initiated in June 1986. The counterpart is the country's Rural Development Administration and six institutions within its administration. The budget for this project, which concludes this year, is US $634 000, plus Government support of approximately 6 billion Won.

Under this project, 33 expert missions have been undertaken, 19 fellows have been trained overseas, eight Korean scientists have gone on scientific visits, and a well-equipped radioisotope research laboratory has been established with Korean funds. Sixteen major activities in three fields — plant breeding, soils science and plant nutrition, and pesticide research — were conducted at six participating institutes. Research was mainly directed at the application of radiation techniques to induce useful and desirable mutation in crops of commercial interest; the efficient use of nitrogen fertilizer, its behaviour in soils and plants under different climatic conditions; the establishment of effective methods to measure root activity utilizing radioisotope techniques; the use of radiolabelled chemicals to study the dynamics of pesticides used in rice ecosystems; and the development of safer and easier to use agricultural chemical formulations.

Plant breeding and sericulture. In the plant breeding and sericulture fields, seven sub-projects were carried out at five institutes. Investigations were carried out on cereal crops (rice, barley, and wheat); legumes (soybeans); oil crops (sesame); horticultural crops (garlic, Chinese cabbage, and apple); sericulture (mulberry and silkworm). Lines of rice and barley were obtained that had early maturity, short stem, and resistance to disease and insect pests. Furthermore, a sesame variety, *Ansangae*, with high yield and resistance to disease was developed and released to the farmers.

Soil sciences. In soil fertility and plant nutrition, results were obtained on the efficient use of nitrogen fertilizer, particularly for upland crops, and nitrogen losses due to run-offs and leaching, using fertilizer labelled with nitrogen-15. Similarly, results were obtained using phosphorus-32 to improve agronomic practices by increasing the efficient use of phosphate by crops such as rice, soybean, and lettuce grown particularly on sloping lands. These studies are also expected to contribute towards decreased use of phosphate fertilizers, especially in newly reclaimed upland soils where high rates have been applied to maintain crop production on the limited arable land available. Further studies on constraints that limit crop production (particularly related to root structure and function, and cold and other environmental stresses) have also been initiated.

Pesticides. In the pesticide area, data were obtained on behaviour and terminal residues of carbon-14-labelled mancozeb and its degradation products on tomato plants, essentially tracing the level and fate of a highly toxic residue, ethylenethiourea. Two radiolabelled pesticides, carbofuran and BPMC, were used in rice production systems to study the dynamics, distribution, and terminal residues of these widely used chemicals. Carbon-14-labelled BPMC was also used to determine bioaccumulation in fish. A modest start was made in the application of controlled-release technology. Work emphasized delivery systems in flooded rice and involved the development of a new slow-release formulation composed of herbicide, polyethylene, and ethyl vinyl acetate. Such formulations would improve the safety of the chemicals and contribute substantially to the protection of the environment.

Throughout the project, the combination of manpower training, expert assistance, and equipment and supplies made an important contribution to the development of Korean agricultural research.

China: Radiation and isotopes in food and agriculture

This project is located at the Southwest Agriculture University, Chonqing, Sichuan. It is essentially an "institution building" project to assist the university's faculty in introducing teaching and research programmes involving the use of radiation and isotopes in food and agriculture. In comparison with other agricultural establishments in China's coastal regions — some of which started work on the application of nuclear techniques in agriculture many years ago and have made considerable progress — the Southwest Agricultural University has initiated such efforts more recently. However, Sichuan Province, where the university is located, is one of the major provinces for agricultural production. It supplies farm products not only to its own 100 million population, but also to other provinces in China. Thus, the location of this project for introducing new technologies for increasing agricultural production is appropriate.

This project, budgeted at US $415 000 for 1988–90, has provided valuable training for the faculty by arranging a group scientific visit to leading research institutes in the Netherlands, Italy, the Federal Republic of Germany, and Austria, including the Agency's Laboratories at Seibersdorf outside Vienna. Scientific equipment valued at US $147 000 has been provided and presently eight young scientists are to be trained abroad.

The project is to be concluded by end 1990 with the provision of expert services in plant nutrition and mutation breeding, and the organization of two training courses on mutation breeding and food preservation.

Thailand: Improving food in agricultural production

This 5-year project initiated in January 1986 with UNDP funding of US $1.5 million was designed to consolidate previous IAEA technical co-operation activities, and to act as a catalyst to promote the use of nuclear and related techniques by appropriate agricultural institutions. The Thai Department of Agriculture is the Government's implementing agency, in association with the Departments of Land Development and Livestock, and the Universities of Chang Mai, Khon Kaen, Chulalongkorn, and Kasetsart, and the Office of Atomic Energy for Peace. Over 50 research activities in the fields of animal production and health, soil fertility, and plant breeding have been initiated.

The project was designed to initiate research and to improve the economy of agricultural production in Thailand. A UNDP mid-term review, in 1988, was conducted by a team of three experts, one each from the United Kingdom, India, and Thailand itself. The review concluded that "the project was soundly based" and that progress has been made in achieving the original objectives in three aspects of Thai agriculture. In many cases, laboratory work has been intensified and extended to field conditions, the review noted.

Animal reproduction. The review team also concluded that the project had already resulted in genuine economic impact on village animal production systems. The studies have shown that progesterone measurement using radioimmunoassay techniques is invaluable for monitoring reproductive functions of cattle and buffalo. Thus, animals can be checked for the presence of cyclic ovarian activity and earmarked for breeding at the most appropriate time. Animals which do not conceive can also be identified at an earlier stage so that remedial actions can be instituted. The village farmers are enthusiastic in their adoption of the techniques and services provided by the research team.

An additional spin-off has been the information generated on the important causes of reproductive inefficiency under traditional management systems. This project has now been integrated in the Government's ongoing programmes for upgrading and improving the cattle and buffalo population.

Plant breeding. In plant breeding, a notable success was obtained in cowpea with resistance to virus and root rot combined with early maturity and higher yield.

Soil sciences. In the soil fertility and crop production sector, results have been obtained using nitrogen-15 to increase efficiency of fertilizer use by crops, especially in rainfed areas involving rice–soybean–cereal intercropping or soybean–rice sequential cropping systems. Studies using phosphorus-32 to analyse the efficiency of local rock phosphates as fertilizers have produced promising results which will reduce the dependency on imported phosphate fertilizers in the future.

Similarly, biofertilizer studies using nitrogen-15 have provided valuable information related to the use of *Azolla* as a green manure in flooded rice culture, a system which would reduce the dependence on chemical nitrogen fertilizers. The research has yielded a considerable amount of data which have subsequently been published. Results have further been presented at national workshops held in November 1988 and December 1989.

So far, the project has provided fellowship training for 29 scientists, and scientific visits for three others. It has also featured a number of technical meetings, including the First Symposium on Ruminant Reproduction and Parasitology held in Chiang Mai in November 1989, which was attended by 74 participants from various institutions and universities. A workshop on Induced Mutations in Plant Breeding was also held in Chiang Mai for specialists.

This project is scheduled to be completed at the end of 1990. A follow-up project to capitalize on the gains made in the current project is at an advanced stage of processing for UNDP support.

Indonesia: Increasing agricultural production

Before this project began, a 5-year preparatory phase was instituted from 1982 to 1987. Under this phase, facilities for undertaking isotope and radiation-aided research, as applied to practical agricultural problems, were strengthened at the Centre for the Application of Isotopes and Radiation (CAIR). Effective use was made of these methodologies in support of plant breeding, in soil, fertilizer and crop management practices, in insect-pest control, including the effective and safe use of pesticides, and in animal nutrition and reproduction.

Some of these methodologies are already being used by farmers. For example, improved varieties of wetland rice, soybean, upland rice, and mungbean are being cultivated; animal feed supplements in the form of solid molasses and mineral blocks made from agro-industrial by-products have been developed; better soil-moisture control and nitrogen-fertilizer practices as applied to multiple and sequential cropping routines under rainfed conditions have been introduced; and *Azolla* is being used as a source of biologically fixed nitrogen in rice paddies. Entomological research has provided valuable dispersion data on insect-pests in rice, and soybean varieties are being screened for insect-pest resistance. In these areas, effective co-operation has been established between CAIR, other national agricultural research institutes of the Ministry of Agriculture, and the universities.

The rice mutant variety, *Atomita-1*, was officially released in 1982 and *Atomita-2* in 1983. Both new varieties indicated resistance to BPH (brown planthopper) biotype 1. This success was followed by the release, in 1987, of the soybean mutant variety, *Muria*, which offers such characteristics as early maturity, high yield, and tolerance to rust disease.

The second phase, with a total budget of US $470 000, began in 1988. This phase aims to consolidate achievements made so far, focusing in particular on animal production and health components.

A number of promising mutant lines of rice, soybean, and mungbean have been put into official field testing at various locations by the Directorate of Food Crops Production, Ministry of Agriculture. Results of studies (using nitrogen-15) on increasing the efficiency of utilization of soil resources in multiple cropping systems involving soybean–rice–maize have proved useful. They have now been formulated into a package of technology aimed at reducing the amounts of nitrogen fertilizer applied to achieve and sustain maximum crop production. Similarly, the data from studies of the *Azolla–Anabaena* symbiotic system as a potential source of nitrogen for lowland rice culture have been assessed. This technology is now ready for testing at various locations at the farmers' level.

More recently, a novel system involving a rice–*Azolla*–fish combination is being tested using nitrogen-15, with the aim of introducing it into rural farming systems in the future.

One of the most spectacular achievements under the project has been the development of urea–molasses–multinutrient blocks (UMB) for cost-effective supplementary feeding of livestock. It has been conclusively demonstrated that UMB feeding increases production (growth, milk) and reproductive efficiency in animals using low-quality roughage diets. Based on data obtained during extensive field trials, the technology for making the blocks has been simplified so that it can be adapted to local conditions.

The technology has now been introduced to groups of farmers in West and Central Java, in collaboration with the Directorate General of Livestock Services and the respective provincial livestock services. The farmers are enthusiastically adopting this method of supplementary feeding for their livestock, and some of them are producing the UMB themselves using indigenous technology.

Insecticide residues have been studied in rice/fish cultures with the objective of devising pesticide application schemes and pesticide formulations which will allow maximum yields of fish (the major economic output) and rice. This has led to significant progress in developing a technology for the controlled release of pesticides. Basically, this involves partial immobilization of the

pesticide using irradiated natural rubber latex. Another example is the protection of soybean from damage caused by bean flies, where preliminary field tests of latex formulations indicated much greater efficiency as compared to ordinary formulations.

Regional UNDP projects

Two regional UNDP projects in agriculture are under way, each only starting recently. One is directed at increasing the yield and nitrogen-fixation capabilities of common grain legumes. It will increase the capability of the participating countries to raise the yield of grain legumes, particularly chick peas, soybean, ground nut, mungbean, and cow peas, while minimizing the use of nitrogen fertilizers, thus making these legumes available to poor farmers at affordable prices. It is based on the observations that some varieties of legumes fix many times more nitrogen from the atmosphere than others. This project will identify these varieties in the above grain legumes, in order to recommend them to farmers and to plant breeders for inclusion in their breeding programmes.

Participating countries include Bangladesh, China, India, the Republic of Korea, Malaysia, Pakistan, Sri Lanka, and Thailand. Institutes are being approached also in the Philippines and in Indonesia. Total funds amount to US $970 000 over 5 years.

The other regional project covers food irradiation, specifically process control and acceptance. The objective is to assist national authorities in developing countries of the IAEA's Regional Co-operative Agreement (RCA) to ensure effective transfer of food irradiation technology to the food industry, as well as development of human resources in this field, in order to achieve practical applications. Research and development will be conducted and the results will be made available to entrepreneurs interested in food irradiation processing. Training will be provided to scientists, engineers, and food control officials to effectively control the process according to the standards and code of practice of the Codex Alimentarius of the FAO and World Health Organization.

Participating countries include Australia, Bangladesh, China, Indonesia, India, Japan, the Republic of Korea, Malaysia, Pakistan, Philippines, Thailand, Sri Lanka, and Viet Nam. (Australia and Japan are participating at no cost to the sponsoring organizations.) An appropriation of US $650 000 has been made for a period of 4 years.

Successful co-operative formula

Experience with these projects indicates that a successful formula for improving agricultural research and productivity is emerging. First, the Agency responds to requests from Member States by providing training, expert advice, and equipment to counterpart institutes in various agricultural disciplines. Also, research contracts are awarded to build up research expertise. As many as 30 individual country projects over a long time may be required. Subsequently, when a substantial number of scientists have been trained and functional institutional infrastructures have been put into place, national institutions can then absorb larger UNDP support, which pulls together a number of scientific disciplines into an integrated programme. This has worked extremely well in Asia. Hopefully, the formula will work as well elsewhere. One prerequisite is smooth co-operation between organizations, institutes, and scientists, and excellent co-ordination at the national level.

The results of these UNDP-supported projects, as well as the Agency's earlier efforts, demonstrate the value of long-term continuity in assistance and pursuance of valid objectives.

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