This is No. 2 in the series: What Can Radioisotopes Do for Man?

Food Production - Present and Future Development

by Carl G. Lamm

This year the joint FAO/IAEA Division of Atomic Energy in Food and Agriculture celebrates its 10th anniversary. The aim of these two United Nations organizations is to ensure that the technical services of both FAO and IAEA are fully co-ordinated and their programmes are designed to assist developing Member States to apply isotopes and radiation techniques to the solution of food and agricultural problems. More precisely, the medium-term objectives of the Joint Division are to exploit the potential of nuclear techniques in research and development for increasing and stabilizing agricultural production, improving food quality, protecting agricultural products from spoilage and losses and minimizing pollution of food and the agricultural environment. This account of what radioisotopes can do for man in the agricultural field is therefore to a great extent a review of the activities of the Joint Division and a prediction of its future fields of emphasis, especially in the light of the present long-range and world-wide food crisis.

Atomic energy technology offers unique ways of looking into and solving agricultural problems. Sometimes the use of isotopes and radiation provides the only means of solving problems, and often progress is made faster by employing them.

The Joint Division's programme is problem-oriented, and special emphasis is placed on co-ordination and support of research directed at the solution of problems of practical importance for the economic growth of developing countries. At the present time, the Joint Division is responsible for some 20 co-ordinated research contract programmes comprising about 200 funded contracts and "cost-free" agreements. The objectives of each co-ordinated research programme are discussed and drawn up by specially convened panels of experts. Competent research institutes are then contacted and invited to take part in the programmes, which normally last 3-5 years.

Institutes in developing countries are normally given research contracts with nominal financial support, whereas institutes in the developed countries usually participate by signing "cost-free" research agreements. The participants in a co-ordinated research programme meet periodically to review the results achieved, and to discuss and decide on the coming research.

The Joint Division's programme provides for training through international training courses and fellowships and for various scientific meetings. Since 1964 some 80 publications have resulted from its activities.

In the Agriculture Section of the IAEA Seibersdorf Laboratory analyses are provided of stable and radioactive isotopes in plant and soil samples from the contractors; radiation and chemical treatments are administered to seeds sent in from the various co-operators. Certain insects for various research laboratories and field campaigns are reared and sterilized, etc. The laboratory has been increasingly requested to provide standard techniques and materials, and to write out and introduce simplified standard analysis procedures.

The application of nuclear technology in agriculture is concentrated in six major areas, highlights of which are given in the following chapters:

Soil Fertility, Irrigation and Crop Production

Labelling a nutrient element in a fertilizer with an isotope, stable on radioactive, makes it possible to follow its fate quantitatively in the soil and uptake in the plant after application. This technique allows one to determine directly in field experiments the efficiency of various fertilizing practices and to evaluate the availability of soil nutrients to the plants. Research co-ordination programmes have been confined to studies on fertilizer and water use efficiency of various food crops such as rice, wheat, maize, grain legumes, and the tree crops banana, citrus, cocoa, coffee, coconut and oil palm. Nitrogen and phosphorus have been the main nutrients studied, but a new programme will include trace elements like zinc, which become economically important with the introduction of high-yielding varieties and intensive agriculture.

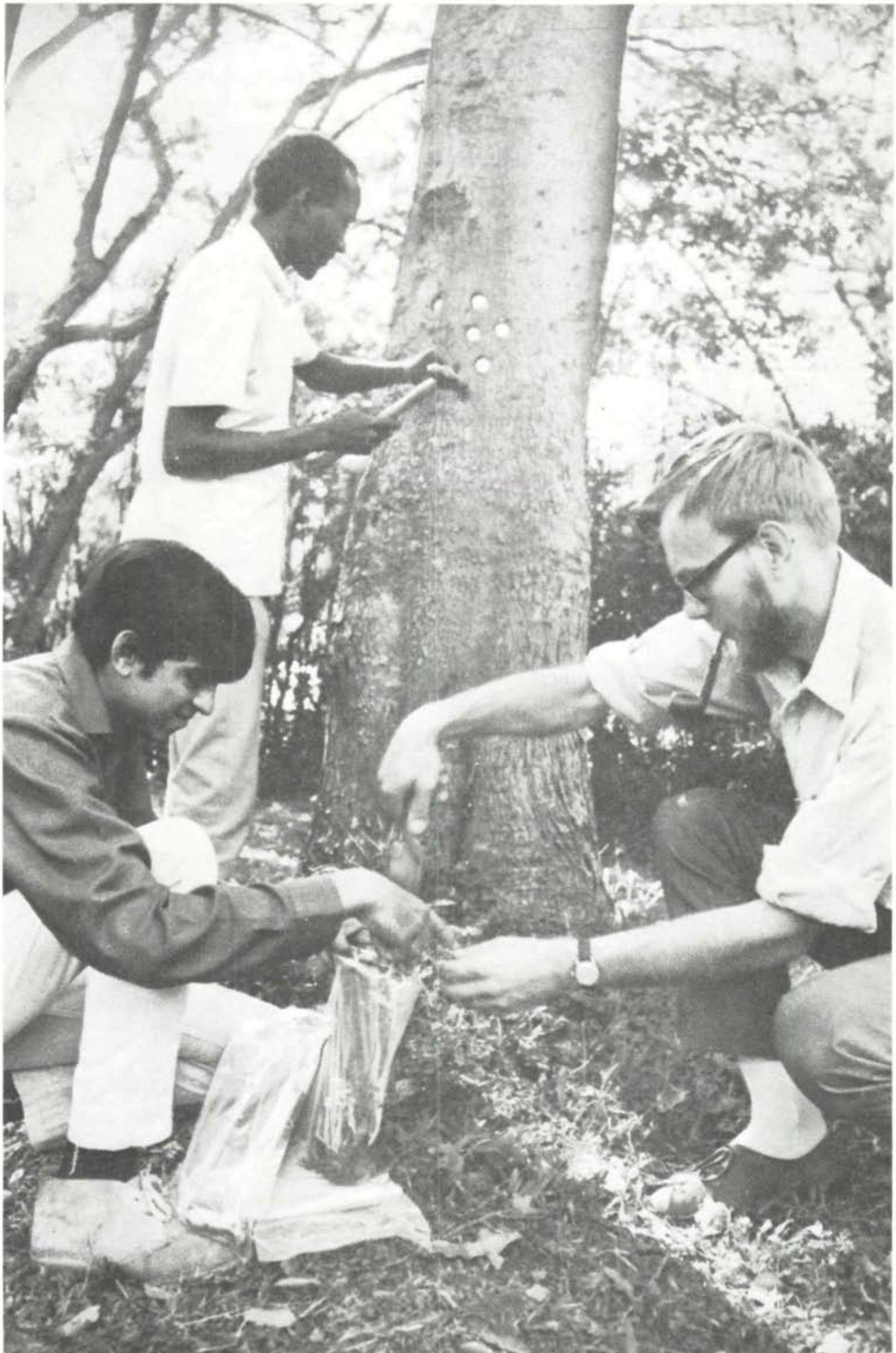
Tracer experiments with nitrogenous fertilizers require labelling with the expensive stable isotope ^{15}N. Recently, however, long-term, field-scale nitrogen tracing experiments for fertilizer nitrogen have been initiated in California and Nebraska with hybrid maize. Here, nitrogen is labelled with ^{14}N, i.e. nitrogen which has been depleted of its normal content of ^{15}N, thereby substantially reducing the cost of the label. This is reflected in the fact that the labelled field plots are approximately 300 m^2, thereby increasing the dependability of the findings.

Much of the next decade's work should be concentrated on the conservation of the soil and scarce water and fertilizer resources without impairment to agricultural production. Limiting the spread of saline soils or their reclamation are important examples. Research designed to improve the efficiency of fertilizer and water use by crops must, however, continue to be of major importance. In this context, studies of the process of symbiotic and non-symbiotic nitrogen fixation and their role in supplying nitrogen to the soil-plant system will be intensified. Recent evidence that certain free-living micro-organisms, when grown in association with tropical grasses, can fix significant quantities of nitrogen, is of obvious practical importance, especially in view of the current shortage of nitrogen fertilizers. Finally, increased research effort into multiple cropping or inter-row cropping is foreseen as well as their inter-relationship with disease and insect control.

Plant Breeding and Genetics

Man's dependence on the green plant for food, fibre and fuel will not diminish but increase as other resources become more scarce and the human population grows. Any improvement in crop plants with respect to yields, quality, disease resistance and other characteristics, is dependent on new genetic combinations.

As part of a tsetse fly control programme in Africa, bark and soil samples are collected in an area sprayed ▶ with an insecticide labelled with the radioactive isotope Carbon-14. Photo: IAEA.



A number of co-ordinated research contract programmes emphasize the production and use of radiation-induced mutations in breeding various important crop plants, including vegetatively propagated crops and tree crops. Compared with conventional breeding, induced mutation breeding is a complementary and not a competitive technique, because induced mutations can compensate for losses of individual genes, and may be able to provide genes which have not been favored during plant evolution but are valuable to man's needs today.

All breeding work necessitates screening of a large number of plants for visual or non-visual characteristics, e.g., protein content or quality. The Agriculture Section of the Seibersdorf Laboratory is now able to undertake this chemical screening at a rate approaching 1000 samples per day as a service for the contractors.

Beside radiation and chemicals for inducing mutations, a variety of new technologies have a great potential for expanding genetic resources. These include the use of cell and tissue cultures of plants, of haploid stocks and of wide genetic crosses to affect the manipulation of genetic materials in a way never before possible. It is foreseen that the new genetic resource products from such work would soon be available to plant breeders and added to those maintained at genetic resource stock centers (gene banks). The potential dividends of such technological developments include higher yielding and better varieties of plants with improved nutritional quality or better adaptability to environments which never before supported crop production. Other possible dividends are the incorporation of the ability to fix nitrogen in plants which did not have the capability before, or the improvement in crop plants of a capability for more efficient fertilizer use, or the promotion of higher photosynthetic efficiency, or the induction of drought, pest and disease resistance, only to mention a few.

Animal Production and Health

Isotopic techniques are used in various fields of animal production and health, and in the application of irradiation to develop vaccines against animal parasites. The objectives of the FAO/IAEA programmes are mainly oriented to the needs of the developing part of the world where productivity improvement and preventive health measures are so urgently required. Isotope-aided studies on maximum productivity emphasize the metabolism of calcium, phosphorus, magnesium and various trace minerals in cattle, sheep, pigs and poultry, as well as non-protein nitrogen compounds (e.g., urea) as a supplement of dietary protein in ruminants. Another programme aims at assessing the suitability of different herbivorous species to produce meat and/or milk under wet and dry tropical environments as influenced by their water metabolism and requirement. Tritiated water is to be used in these studies. Finally, a regional programme is planned to study milk production in buffalo to achieve high levels of productivity based on locally available food-stuffs.

Nuclear techniques continue to be employed in the animal health programmes, i.e., production of radiation-attenuated vaccines from the infective stages of pathogenic parasites, tracer studies of the host-parasite interaction, and radioimmunoassay diagnosis of parasitic diseases. Co-ordinated research programmes have emphasized these techniques in efforts to control major parasitic diseases, and commercially produced vaccines are now available for bovine parasitic bronchitis, sheep lungworm disease and dog hookworm. Other radiation-attenuated vaccines have been produced on a laboratory scale and future activities on major parasitic diseases will include trypanosomiasis, schistosomiasis, fascioliasis, gastro-intestinal helminthiasis, giroplasmosis and cysticercosis.

Insect and Pest Control

Another aspect of increasing food production is the requirement for minimizing crop and domestic animal losses due to insects and other pests. There will, and must be major changes in pest control during the next decade, because of high prices and shortage of pesticides and insecticides, as well as a world-wide concern for environmental pollution due to persistence hazards.

An alternative to insect control with insecticide spraying is biological control, and the Joint Division is concerned with the practical application of the sterile insect technique. Basically, this technique consists of the production, sterilization by gamma irradiation, and release of sterile male insects in such numbers that there is a good chance of a wild female mating with a sterile male of the same species. This work also includes tracer-aided research on insect ecology and physiology as well as the solving of problems related to economical mass-rearing of various insect species on locally available foodstuffs.

This technique has already proved its practical and economically competitive value in controlling the screw worm, the Mexican fruit fly and the pink bollworm, and is ready for use on several species of fruit flies, mosquitos, codling moth, etc. Present co-ordinated research programmes mainly center on various fruit flies and the tsetse fly.

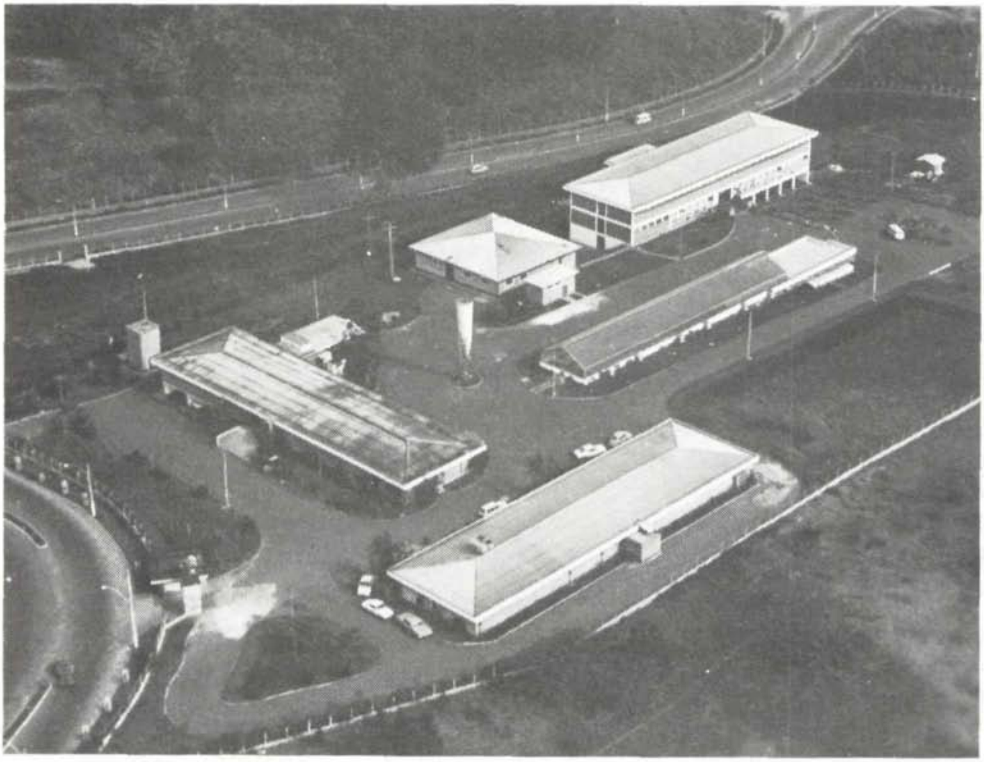
Forthcoming activities will continue along these lines, particularly to overcome present obstacles in mass-rearing of tsetse flies, a most serious insect pest of Africa. A recent major advance is the development in the Seibersdorf Laboratory of membrane feeding, which eventually will permit dispensing with host animals altogether and thus considerably reduce the cost of tsetse production.

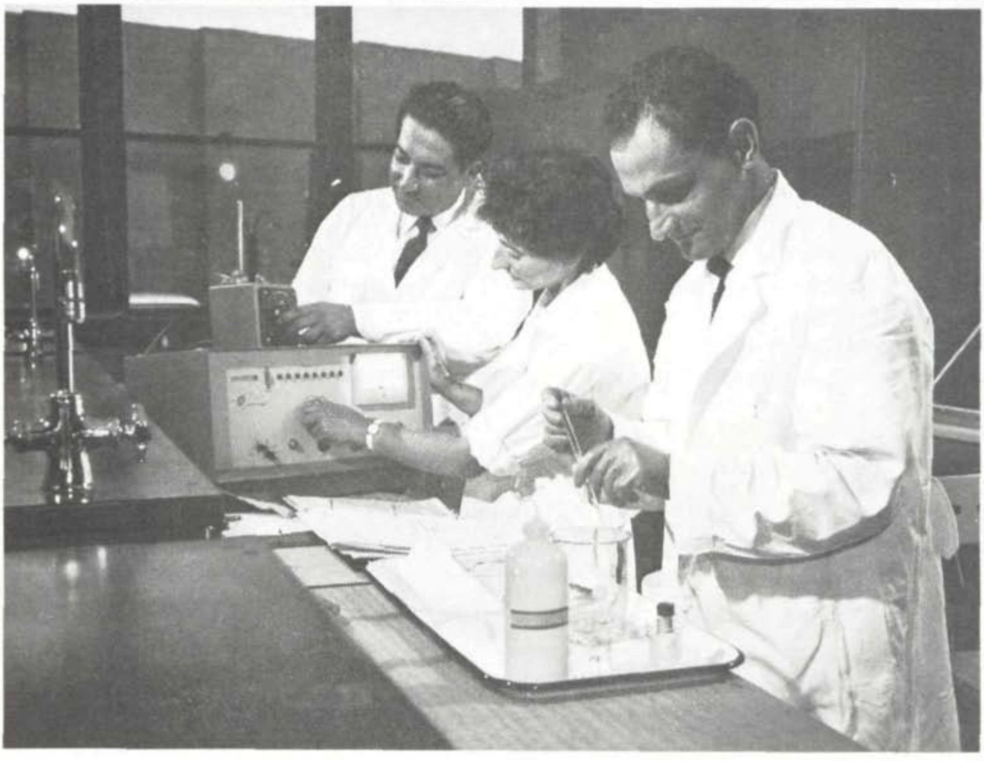
Future legislation must require land owners to control certain insect pests to prevent them from spreading to other hosts in the same area. Pest control pollution will be considered in the same terms as industrial pollution, and for the reasons given above biological control specific for the insect pest appears to be the most viable approach when applicable. One of the objectives in developmental work on the production of population control agents like sterile insects, pathogens, parasites, predators, attractants and hormones, is that they must be made sufficiently economic to be attractive to commercial interests.

Chemical Residues and Pollution

Comparative programmes concerned with the origin, fate and significance of chemical and radioactive residues in food and the environment, are another field in which various nuclear techniques like radio-tracing or activation analysis have proven indispensable.

These general programmes are presently being replaced by more specific ones, such as the agricultural nitrogen residues programme which gives particular attention to their conservation as fertilizers and behaviour as potential pollutants. Another programme deals with isotopic tracer-aided studies of the biological side effects of foreign chemical





residues in food and agriculture, and a programme on tracer-aided studies of chemical residues in the various products of the cotton crop is anticipated. This will deal with the appearence of pesticide and other chemical residues, e.g., solvents from solvent extraction processes, which may appear in cotton seed and other oils that play an important role in the diet of many developing countries. The volume production of the stable isotope ^{13}C for a very reasonable price makes it possible to predict various environmental applications such as studies of the persistence of organic compounds in nature under field conditions. Thus, the isotopically labelled herbicide 2,4,5T has recently been synthesized at the Los Alamos Scientific Laboratory with ^{13}C at ten positions and ^{18}O at three positions. Because the ^{13}C in metabolites or breakdown products can usually be readily identified by NMR spectroscopy without the time-consuming degradation and isolation required in ^{14}C tracer methods.

Food Preservation

Once food is harvested, it is susceptible to deterioration from sprouting and damage from insects and micro-organisms during storage and marketing. This problem is especially severe in many developing countries because of the hot climate and limited storage and preservation facilities. Therefore, preventing food losses by the application of food preservation technology is a major factor in solving world food problems.

Besides traditional methods of food preservation like cooking, canning, cooling, freezing, sun-drying, dehydration, pickling, fermentation, smoking, as well as the addition of various chemical preservatives, the treatment of food with ionizing radiation is a very promising new technique. Since this method emerged some 25 years ago, 17 countries now permit the restricted or unrestricted sale of 19 items of irradiated food.

Nuclear energy for the preservation of food and agricultural products offers the advantages of a saving in conventional energy and the reduction of pollution problems by partial elimination of chemical preservatives. Future work will evaluate the technological and economic feasibility of food irradiation with the objective of increasing the shelf-life of important food items. General public health acceptance of the food irradiation process is being studied in close collaboration with WHO and other international bodies, and special attention will be paid to the elimination of harmful organisms from food.

As can be seen from the above, the prevailing objective of the entire application of nuclear technology in agriculture is based on helping the developing countries to help themselves to agricultural sufficiency through international collaboration in action-oriented research on production problems. To do so, full co-ordination is effected not only between the different sections of the Joint Division, but with other action agencies of the UN and national governments.

An aerial view of the Centre of Nuclear Energy in Agriculture (CENA) in Piracicaba, Brazil, a large-scale UNDP/IAEA project to expand the agricultural application of nuclear technology.

International training courses are regularly organized on radioisotope techniques for research in agriculture, forestry, fisheries and nutrition. Photo: United Nations.