atomic energy and food

International activities aimed at improving, increasing and conserving food supplies are fostered in special ways by the Joint Division of Atomic Energy in Food and Agriculture established by the Agency and the Food and Agriculture Organization of the United Nations. An examination of the processes by which food is produced and of the skills arising from nuclear techniques which are being applied is made here by Maurice Fried and Björn Sigurbjörnsson. They are the Director and Deputy Director of the Joint Division, which is an integral part of both the Agriculture Department of FAO and of the Agency's Department of Research and Isotopes.

A normal holiday scene on the island of Procida, Italy. The ferry, however, is carrying a consignment of irradiated Mediterranean fruit flies to be used in a continuing demonstration of the use of sterilized fruit flies to control the pest, which damages citrus fruit. The project is a continuation of a joint effort with the Food and Agriculture Organization, the Italian Ministry of Agriculture and the Italian Atomic Energy Agency.

From a technical standpoint food and agriculture means controlled transformation of inorganic matter into organic matter, which in turn is transformed into food products that must be preserved until they reach the consumer.

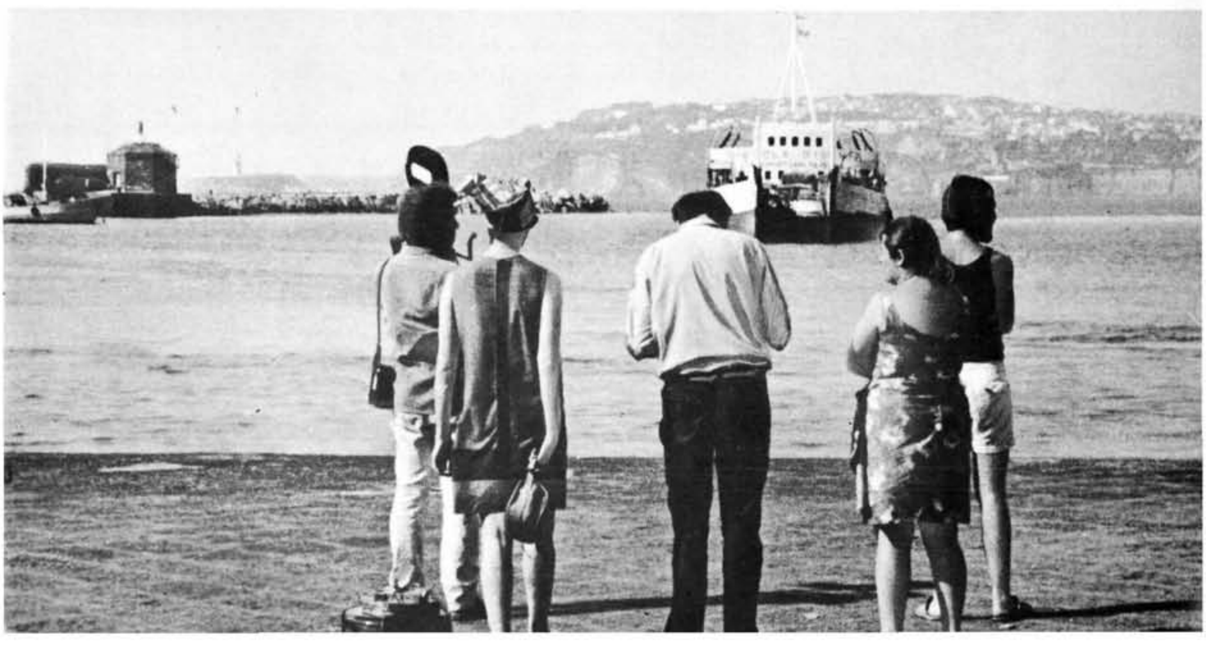
The basis for food production and, indeed, for all life on earth, is the utilization of sunlight by green plants to combine water and carbon dioxide to form organic molecules of sugar, a process known as photosynthesis. All other forms of organic matter are derived from the photosynthetic product. In addition to sunlight, water, and carbon dioxide, the green plant needs a variety of inorganic nutrients to grow and to manufacture the various amino acids, proteins, fats and other sugars. The plants, like all other organisms, also need energy to sustain their various chemical reactions and derive this energy from the oxidation of organic compounds through a normal process of respiration.

Put in terms of energy the green plants capture the energy of the sun, thus raising their energy level and enabling them to create food products which man then uses as a source of energy to maintain life.

Plant products can, of course, provide foodstuffs directly in the form of grain, fruits and vegetables, or they can be converted into livestock products of fish. Food, whether plant or animal, is seldom consumed immediately but must be preserved and transported until available to a consumer. It is thus clear that food and agriculture really implies a long series of complex physical and chemical steps and commercial transactions, all of which are important.

The efficiency of food production depends chiefly on three factors: plants and animals must be provided with enough of the proper nutrients; they must have the appropriate genetic make-up to make efficient use of the nutrients; and lastly, they must be protected against damage and deterioration both while growing and while stored as food products. In short: efficient agriculture must ensure proper feeding, proper breeding and adequate protection.

In order to achieve efficient provision of food, one must apply a varied technology at all steps along the way from the inorganic molecules to the finished product on the consumer's table. It requires a thorough



understanding of all the physical, chemical and biological factors involved and the application of science and technology to the production processes themselves.

One may ask how nuclear techniques enter into this picture. The fact is that for this work one needs to apply all known technological skills. Nuclear techniques form a part of man's skills, and in the short period since the dawn of the Nuclear Age it has become clear that isotopes and radiation represent unique and often indispensable means of studying and promoting food production and preservation at every level of the process. Examples of applications of nuclear techniques, and the work of the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture including its promotion of international co-ordination of these applications are described in this article.

Soil and Water

The problem of feeding plants primarily deals with making adequate nutrients available and providing enough water.

The three nutrients most commonly lacking in adequate supply are nitrogen, phosphorus and potassium, though calcium, sulphur, magnesium and a number of nutrients required in lesser amounts may also be lacking under a given set of circumstances. Soils provide these constituents naturally in variable quantities and therefore differ in fertility. However, in order to achieve peak performance of a plant, one must usually add nutrients to the soil in the form of fertilizers.

Fertilizers must be bought by the farmer and in the developing countries may represent the only cash outlay of the farmer in addition to a hard currency import for the country. It is therefore imperative that fertilizer is not wasted. It must be applied at the correct time, placed correctly in the soil and be in the most usable chemical form to ensure the most efficient uptake by plant roots. By using isotopic forms of the elements concerned, it becomes possible to make use of two qualities. One is the ability to detect them in minute quantities and the other the ability to distinguish the added fertilizer nutrient from that present in the soil. Thus a unique method is available of studying the fate of applied fertilizers in the soil and their movement from the soil into the plant. Isotopes provide the only direct method of measuring the uptake from the fertilizer.

An example of this application is the determination of the most efficient place to put a fertilizer to ensure maximum uptake by the plant. By labelling a phosphorus fertilizer with the radioactive isotope (phosphorus-32) a quantitative determination can be made from which place in the soil the plant is best able to take up this added nutrient element. This is only possible because the radioactive phosphorus can be distinguished from the phosphorus native to the soil.

Applying this technique to studies of efficient placement, timing and chemical composition of fertilizers, the Joint Division has organized several internationally co-ordinated programmes in rice, maize, wheat and tree crops. The results of these programmes have provided answers to many questions of fertilizer management and have in some cases already been extended to farmers.

In soil moisture studies, nuclear techniques also provide a quick and efficient way of soil moisture determination, based on the principle of neutron scatter measurements. The Joint Division has assisted a number of countries which have limited water resources in this application.

The Division has organized a number of scientific meetings dealing with soil and water studies and had responsibility for various technical assistance projects which will be dealt with later.

How Plants can be Changed

In order to achieve peak production, crop plants must be bred to make efficient use of high levels of fertilizers, plus the ability to withstand diseases and pests. They must also be of high nutritional quality and possess numerous other qualities influenced by preferences of the consumer or the practical requirements of handling commodities.

Plant breeding involves the combination of a set of desirable characteristics in a single crop variety. Its success depends largely on the variability in plant characters available for recombination and selection. All variability in plants as well as in animals and man derives from mutations, which are sudden changes in the genetic make-up, taking place during evolution as a result of cosmic radiation and other factors. Present forms of life represent the result of natural and artificial selection of the limitless mutations which have occurred throughout aeons of evolution and recombination.

During natural evolution of plants, only those mutations are selected which contribute to the plant's ability to survive and reproduce. Primitive agriculture supplied the selection pressure which resulted in the so-called crop plants, e.g. the cereals.

Modern agriculture, using huge amounts of fertilizers, mechanized field management and demanding specific requirements as to the chemical composition of the products, e.g. balanced amino acid composition, represents a totally new selection environment. Not many mutations which could have met these requirements, and occurring during evolution, have been preserved in present-day plants.

If plant breeding were solely based on existing variability, there would be little hope for sustained progress in plant improvement. Fortunately we now have the tools, primarily in ionizing radiations and some selected radiomimetic chemicals, to increase vastly the rate of natural mutations. The science of applying this tool effectively in plant breeding has taken a long time, but now, thirty years after the discovery of artificial mutagenesis, this technique has become an important means of breeding plants.

One of the chief advantages of mutation breeding is the ability to imporve a single feature in a variety without significantly altering the otherwise desirable make-up of agronomic characters in the variety. For example, a well adapted and accepted local variety lacking in straw strength can be shortened and strengthened in this way, resulting in much higher yields. Many crop varieties have resulted from this kind of breeding, e.g. the highest yielding rice variety in Japan, Reimei, three varieties of durum wheat in Italy, barley varieties in Sweden and USA. Examples of early-maturing mutations can be found in a Japanese soybean variety, a Swedish barley and Japanese rice.

Mutation has also been used to imporve certain defects of high-yielding introduced varieties. Thus in India one of the high-yielding Mexican varieties of wheat, Sonora 64, a red-kerneled type, was adapted to

Indian consumers, who preferred an amber-coloured grain, by radiation treatment. The variety Sharbati Sonora was the result.

Anather advantage of mutation breeding is the ability to increase variability thus widening the base of selection. Of great significance is the relatively short time required to breed a new variety by this technique. Thus the variety Sharbati Sonora was on the market three and a half years after the gamma ray treatment, about half the time required by other methods. Finally in vegetatively propagated crops mutation breeding represents the most efficient methods, and in asexual crops is the only method available since no hybridization can be carried out.

As a result of recent progress in mutation breeding we now find, as an example, that most of the winter barley grown in the USA results from an induced mutant, as well as most of the navy beans grown there. Induced mutants are now a part of nearly all barley breeding programmes in Northern Europe and mutant varieties are becoming the most widely grown rice in Japan and wheat in India and Italy.

The Agency/FAO Division has organized international programmes dealing with research to improve the mutation breeding technique including more efficient use of neutrons for seed irradiation. One programme deals with use of induced mutations in rice breeding, another with testing in over 20 countries of mutant varieties of durum wheat. A programme now being developed deals with the use of radiation and radioisotopes in breeding and selecting for improved protein quality and quantity in crop plants. Other activities include scientific meetings and technical assistance.

Animals

Both radiation and isotopes play an important role in various aspects of animal production and health, although, unlike plants, radiation cannot be used, at least yet, for breeding livestock. One of the important problems connected with livestock production, particularly in subtropical areas, is posed by a variety of parasites which significantly reduce production potentials and in some instances nearly prevent the economic raising of livestock.

Parasite control is exceedingly difficult. Vaccines such as are used against bacterial and viral diseases cannot be produced. In fact, the only known method of producing helminthic vaccines is their attenuation by radiation. Radiation-produced vaccines are already available commercially and the Division is promoting internationally co-ordinated studies to extend these applications to further parasite pests.

Another problem in which radioisotopes play an important role is animal nutrition, and in particular, mineral nutrition. Isotopic tracers are used to follow the metabolic pathways of a particular nutrient from the feed through the animal and its deposition in the various tissues and products.

Phosphorus metabolism and deposition in bones, iron metabolism and blood investigations, iodine and the function of the thyroid; the pathways of nitrogen and sulphur in connection with protein synthesis, are among studies which are supported and co-ordinated. A number of scientific meetings have been organized and technical assistance projects supervised - mentioned later.

Examining apricots on the island of Procida, Italy, for signs of damage by the Mediterranean fruit fly. Experiments to test the efficiency of control by releasing large number of flies sterilized by irradiation have been extended to this island.

Fighting Against Destructive Pests

Food must be protected both during production in the field and in storage. The application of radiation to animal parasites has been referred to before, but there are many other areas where nuclear techniques make important contributions. The biggest cause for food losses are insects and related animals. Insects attack livestock as well as crop plants at all stages of growth. The tsetse fly is not only a dangerous disease carrier in man but prevents vast acreages in Africa from being used for raising of livestock. Another serious animal pest is the screw worm.

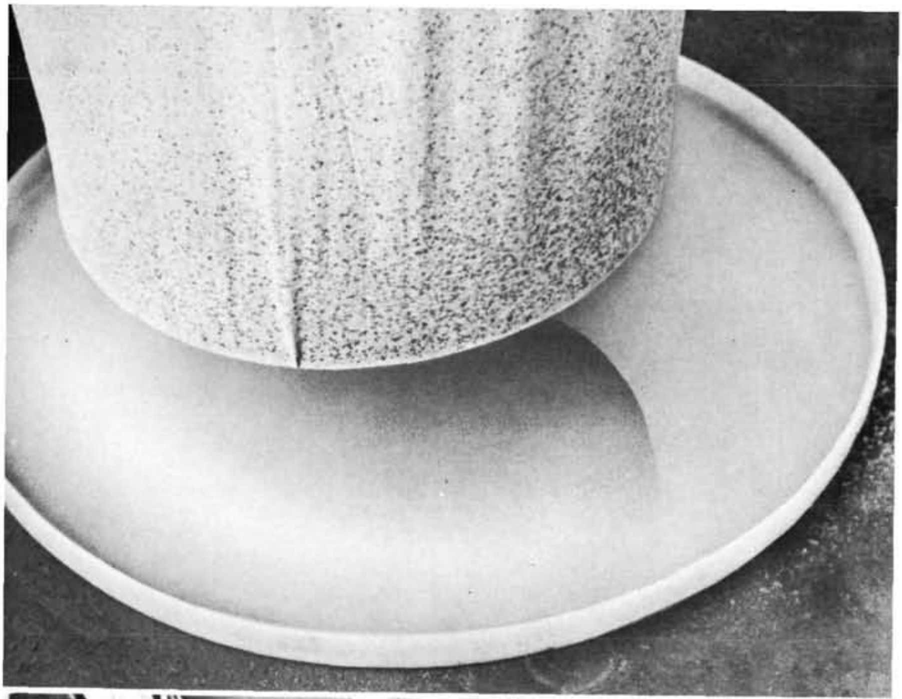
Of insects attacking crops one can mention the rice stem borer, the Mediterranean fruit fly, the olive fly and the codling moth attacking apples. These pests are all examples of insects species for which the use of nuclear techniques may provide an efficient means of control or eradication. The screw worm has already been essentially eradicated from the United States. Attempts at controlling the other species using nuclear techniques are in various stages of progress.

In order to achieve control, radiation is used to sterilize vast numbers of insects. Actually the insects are technically not sterile but transmit dominant lethals within germ plasm. These insects are released in infested areas where they compete with the natural population during the mating season. Since matings involving sterile insects do not result in offspring, the native population is reduced in the following generation. Subsequent releases of overwhelming numbers of sterile insects can, within a few generations and in a well-conducted programme, completely eradicate the species from the release area as was done with the screw worm. The chief advantages of this method of control are:

1. Only one insect species is affected, i.e. other beneficial insects and other wildlife are not affected;
2. No harmful chemical residues are left since no chemical was applied;
3. It is possible to expect total eradication from a given area.

Map showing Research Contracts and Research Agreements in Food and Agriculture, 1969. Countries in North America are Canada and USA; in Central and Latin America, Argentina, Brazil, Colombia, El Salvador, Mexico, Peru, Puerto Rico and Venezuela. In Europe the countries are Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, Finland, Federal Republic of Germany, Hungary,

Iceland, the Netherlands, Portugal, Spain, Romania, Sweden, USSR, United Kingdom and Yugoslavia. Africa has contracts in Ghana, the Ivory Coast, Kenya, Madagascar, Morocco and the United Arab Republic; the Middle East in Iran, Iraq, Israel, Lebanon and Turkey; and Asia in Burma, Ceylon, China, Korea, India, Indonesia, Japan, Malaysia and Pakistan (East and West). There are also contracts in Australia.



Eggs laid by fruit flies in a muslin cage fall on to a tray for collection. This is part of the research programme to establish the best ways of raising large numbers of the insects for subsequent sterilization by irradiation and release in infected areas.

Part of the laboratory established at San Jose, Costa Rica, for mass production of the Mediterranean fruit fly in the large-scale demonstration being executed by the Agency for the United Nations Development Programme in co-operation with seven Central American countries and the International Regional Organization for Plant and Animal Protection.

The chief problems encountered are:

1. The need for and difficulty in mass rearing of enormous populations of the insect;
2. The high overhead cost of mounting a large programme;
3. The difficulty of getting funds for pilot trials;
4. The efficient organization required to carry out a successful programme.

This so-called sterile male technique is the chief entomological concern of the Joint Division. It is involved in demonstration projects with Medfly in Central America and Italy. The Division co-ordinates studies on various insects including the use of isotopic tracers to study insect ecology, dispersal, and habits. A number of scientific meetings have been held to discuss radiation entomology.

There are other aspects of food protection which receive the attention of the Joint Division. One is the serious problem presented by residues of harmful chemicals which can be found on food items following treatment with various pesticides. Although potentially a serious threat to human health, these residues and their metabolic products are often present in such minute quantities as to defy detection and investigation by conventional analytical techniques. Neutron activation analysis is unique for their detection and the application of radioactive tracers is indispensable in studies of the fate of pesticide residues. The Joint Division is now preparing to establish international programmes in this field.

Another aspect of food protection is concerned with contamination caused by atomic energy itself. This includes contamination from the products of fallout from nuclear explosions and such contamination which can occur following reactor accidents or as a result of atomic waste materials. The Division, in co-operation with other responsible bodies, keeps a watch over such environmental contaminations and reports to the UN.

Helping to Preserve Food

The ability of ionizing radiations to penetrate matter and to kill cells and tissues in the process has long fascinated food technologists. For many perishable food products such as certain fruits which can neither be cooked nor treated with other conventional methods of preservation, radiation treatment seems to be the only way of increasing storage life. For other products such as grains, radiation treatment will disinfest without leaving residues; for still other products such as fish and certain meats, it will significantly increase shelf life enough to permit marketing of a nearly fresh product.

Radiation can effectively suppress sprouting in potatoes — or using the technique differently — cause immediate sprouting. Onions, too, can be preserved in this matter and ripening of fruits, such as bananas and pears, can be delayed.

The problems encountered with radiation preservation are similar to those encountered with any other method of food treatment. The effect on the colour, taste, and quality of the products must be reduced to a minimum and one must be sure that the product is no more adversely affected than by other comparable treatments such as smoking, salting, deep-freezing or cooking.

Until recently, the Division has been chiefly concerned with the technology of food irradiation, the operation of pilot plants, various studies concerned with the effects of radiation on food, and questions concerning legislation for irradiated food products. The emphasis is now being shifted somewhat towards wholesomeness testing of irradiated foods and to establish a clearing house for information relating to petitions for clearance of irradiated food.

Other Activities

The work of the Joint Division is related to the various subjects described. Most of the scientific programmes are carried out in co-ordinated programmes in a number of countries on the basis of research contracts and research agreements. In connection with these programmes, the Division has arranged a number of co-ordinated meetings in various places. The IAEA Laboratory at Seibersdorf, Austria, carries out a large agricultural programme for which the Division has technical responsibility. The laboratory activities form an integral part of the co-ordinated research programmes and render services of various kinds to Member States and provides training in nuclear applications. The Division also technically supervises a number of activities funded by the Agency's regular programme of technical assistance and the United Nations Development Programme. The Joint Division has supervised a number of training courses and has technical responsibility for three Special

Fund projects. One of them, in Yugoslavia, resulted in a well-equipped nuclear laboratory and a core of well-trained staff which is now carrying out a vigorous programme of scientific research. A similar but much larger project is being implemented in India. In Central America a demonstration is in progress of the application of the sterile-male technique on the Mediterranean fruit fly.

The basic philosophy is that the best way to ensure sustained economic and social progress in the developing countries is to develop the capability of the countries themselves by thorough training, by supporting local research to solve local problems, but at the same to foster co-operation and co-ordination among scientists in different developing and developed countries facing similar problems, in order to bring them in contact with the scientific community.

Nuclear tools are of great significance in agricultural research and production, as a valuable addition to those already in use. The Division would strongly advise against their use if inappropriate. It will strongly promote their use where they are likely to solve problems better or quicker than is possible with other means; or if, as is sometimes the case, they provide the only means of solving a problem.

The article is based on information presented by the authors at a July symposium in Kinshasa, Democratic Republic of the Congo, organized by the Organization of African Unity and supported by the Agency, on the peaceful uses of atomic energy in Africa.

Adeke H. Boerma, Director-General of the Food and Agriculture Organization of the United Nations (FAO), took the opportunity while visiting Vienna in July to discuss current work with members of the FAO/IAEA Joint Division of Atomic Energy in Food and Agriculture. Seated at the table in the centre is Maurice Fried, Director of the Joint Division.