Seminar on nuclear techniques in agriculture and environment

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ISOTOPE AND RADIATION APPLICATIONS TO AGRICULTURAL DEVELOPMENT IN ASIA AND THE PACIFIC REGION

by

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Distinguished Representatives of the Government of Malaysia, Colleagues and Friends:

It is my great honour and pleasure to be present today and to address this distinguished audience on behalf of the Directors General of the FAO and the IAEA, at this Seminar on the Application of Nuclear Techniques in Agriculture and the Environment.

As Deputy Director of the Joint FAO/IAEA Division which holds the technical responsibility for a number of activities related to isotope and radiation application in agriculture, I am particularly pleased for having been given this opportunity to be present at this occasion. I understand this seminar is one in a series of four in an effort to familiarize local researchers and scientists in the utilization and current development of nuclear techniques for peaceful purposes as it will be carried out under this auspices of the Tun Ismail Atomic Research Centre.

The problem of meeting the food requirements of the world's rapidly increasing population is a matter of urgent concern. While the long range solution to this problem must necessarily be through effective control of the population growth rate, increasing the world's agricultural production can do a great deal to alleviate the situation, as has already been shown. For example, during the 13-year period between 1954 and 1967, world food production increased by about 46% (2.9% per annum), but due to the rising population, the per capita increase was only about 13% (or one per cent per annum). This dramatic increase in the world's food production has been largely due to the evolution and cultivation of new, high yielding cereal varieties, particularly wheat and rice, combined with modern fertilizer, irrigation and other cultural practices. This illustrates what man has been able to achieve through the application of scientific methods to agriculture. On the other hand, we are all only too familiar with the wide-spread crop failures and the resultant food shortages experienced in many developing countries owing to floods or long period of drought.

If the world is to provide sufficient food for its increasing population, and minimize the adverse consequences of natural disasters on food supplies, it is imperative that scientific research directed towards increasing agricultural production through the evolution of new, high yielding crop varities, efficient use of fertilizers and water, and improved soil management practices, the control of pests and diseases, and by increasing the shelf-life of stored foods, is given highest priority, particularly in developing countries.

Nuclear techniques have been recognized to be invaluable tools in agricultural research for increasing crop production and reducing food losses in the technologically developed countries.

But, can developing countries afford the luxury of "sophisticated" research techniques? Would not the introduction of radiation and radioactive isotopes in agricultural research lead to radiation hazards, food contamination and environmental pollution. Has the introduction of nuclear methods been more a fad than a real help, and has this made research workers forget the value of conventional methods? These are questions which have sometimes been posed by administrators, policy makers, and even senior scientists in developing countries - questions which are raised against the introduction of nuclear techniques.

I must emphatically state that in the face of rapidly expanding population and the urgent need for more food, the developing countries can ill afford to ignore any means which would help to fulfill this need. Nuclear techniques have often proved to be the best means, and sometimes, the only means, of solving certain practical problems in agriculture. They cannot considered a luxury. We are no longer talking about "sophisticated" research techniques since the original research based on which these methods are now being applied to food and agriculture was done 2 generations ago. If handled by properly trained personnel, the use of radiation and isotopes is no more hazardous than the application of normal chemical methods, and from the point of view of food and environmental pollution, it is indeed no problem at all.

On the countrary, nuclear techniques can help to reduce such problems. For example, in the control of insect pests in crops, the application of the sterile male technique, where feasible, can greatly reduce the use of toxic chemical pesticides. Radiation methods for food preservation and the control of insect pests in graneries can eliminate the hazards of contaminating food with chemicals. The use of isotope methods to study how chemical fertilizers can be utilized by crops with maximum efficiency, can help to avoid the wasteful and excessive application of such fertilizers, thus reducing the pollution of water resources. With regard to the third question referred to above, namely the role of nuclear methods in relation to conventional tecnniques, I must emphasize that nuclear techniques are only being considered as a further tool in the hands of the research worker for integrated use with conventional methods, when and where necessary, as, for example, in the development of high yielding and disease resistant varieties of wheat and rice through radiation induced mutations. Nuclear techniques are already considered conventional in agricultural research in the developed world.

Over the last 15 years, measurable progress has been made by developing countries in recognizing the value of nuclear methods in solving practical problems for increasing agricultural production. It is no exaggeration to attribute this progress largely to the efforts of the International Atomic Energy Agency. Since the Agency's inception twenty-two years ago, the annual technical assistance it has granted to developing countries, including Malaysia, for the application of radiation and isotopes in agriculture has continued to maintain a position of high priority in the Agency's technical assistance programme.

Let me at this point turn to the Joint Division.

In 1964 two international organisations under the UN system, the FAO and the IAEA, decided to establish a joint programme for the specific purpose of assisting Member States in appropriate application of nuclear techniques for the development of their food and agriculture. As a result, the Joint FAO/IAEA Division of Isotope and Radiation Applications of Atomic Energy for Food and Agricultural Development was established at the IAEA Headquarters in Vienna. Connected to this Division is the Agriculture Section of the IAEA Laboratory at Seibersdorf, outside Vienna.

The objectives of this joint FAO/IAEA programme are to exploit the potential of isotopes and radiation applications in research and development for increasing and stabilizing agricultural production, reducing production costs, improving food quality, protecting agricultural products from spoilage and losses and minimizing pollution of food and the agricultural environment. The programme is oriented to priority areas of the FAO and IAEA programmes and is supplementing and supporting them in selected fields in which isotope and radiation methods are particularly promising.

Within the United Nations system the International Atomic Energy Agency has become regognized as the Agency with primary responsibility for the application of atomic energy in food and agriculture. Thus the UNDP utilizes the Agency to execute all such programmes.

The needs for the services of this joint operation to Member States have continously grown as the practical benefits of isotopes and radiation in agricultural research have gradually become realities throughout the world.

The attention has turned increasingly towards the developing countries who require the application of these efficient tools in order to help solve as quickly and as effectively as possible their pressing food production and storage problems.

In some of the developed countries nuclear techniques have more or less been assimilated into standard laboratory techniques with radiation and isotope knowhow resulting from normal university curriculum training. In this respect there is a serious information gap between these two categories of Agency Member States and I quote the Statute to "take positive steps to encourage the exchange among its members of information relating to the nature and Peaceful uses of atomic energy and serve as an intermediary among its members for this purpose."

Unfortunately, unlike most other areas of application the information in agriculture is not transferable due to the absolute difference in the agricultural ecology of developed and developing countries as well as individual differences between developing countries including major differences in soils, climate and crops grown.

The joint Division is organized into six subject matter sections. These are the sections on Soil Fertility, Irrigation and Crop Production; Plant Breeding and Genetics; Animal Production and Health; Insect and Pest Control; Agrochemicals and Residues; and Food Preservation. In addition there are the supporting activities in the IAEA Laboratory.

The activities of the joint FAO/IAEA programme can be grouped under three main items; coordination and support of research, technical assistance including training and dissemination of information. Presently 250-300 research institutions or experimental stations in Member States cooperate in sore 25 coordinated programmes. Each such programme attempts to solve a practical of economic significance to developing countries.

The joint FAO/IAEA programme is technically responsible for some 100 technical assistance projects in over 40 developing countries with the provision of training, expertise and specialized equipment. In addition to fellowship training, 3 - 4 international training courses are arranged annually.

Scientific meetings are important in giving scientists in Member States the opportunity of exchanging views and keeping up-to date in specialized fields, and approximately two symposia and two seminars annually are part of the joint FAO/IAEA programme as is also the publication of scientific results of practical importance obtained through the programme.

Since its inception the Joint Division has helped organize, supervise, 87 training courses and study tours in 33 Member States, of which 19 are developing. Of the training courses, five have held in the Seibersdorf Laboratory.

During the period 1969 - 80 (12 years) there were a total of 762 fellowships in agriculture, of which 42 were in Seibersdorf.

The map shows the countries receiving Agency technical assistance in agriculture. For comparison the countries with research contracts and agreements are shown in another map. Combining the two maps shows the world-wide spread of activities by the Joint Division. The non-coloured countries are mostly non-member states.

Currently there are four large-scale projects in Brazil and Peru (UNDP), India and Bangladesh (SIDA) as well as a number of smaller UNDP funded projects and the multi-lateral large scale tsetse project in Nigeria. A number of TCDC and United Nations Interim Fund for Science and Technology for Development projects have recently been proposed and other large-scale projects in Bangladesh, Sudan and Thailand and being planned.

Malaysia has taken an increasingly active part in the IAEA's affairs since she became a Member State. Malaysia has made effective use of the technical assistance which the Agency makes available to its Member States. Nuclear methodology can play a very useful part in Malaysia's agricultural development plans, and in that context I believe this week's seminar will be an impetus to the application of isotope and radiation methods to Malaysia's agricultural development. Let me assure you that the Agency and the Joint Division will do our best to assist you in this direction.

Most the Agency's Member States in the Asia and Pacific region receiving technical assistance have agriculture-based economies. It is therefore not surprising that over 30% of the Agency's technical assistance provided to the region over the last 20 years should have been directed to increasing agricultural production. Bangladesh, Burma, India, Indonesia, Republic of Korea, Malaysia, Pakistan, Philippines, Sri Lanka, Thailand and Viet Nam have received assistance for developing facilities for the use of isotopes and radiation in practically-oriented research. This research relates to problems in fertilizer use and crop nutrition, soil moisture conservation and irrigation, production of high yielding and disease resistant crop varieties, animal health and nutrition, control of insect pests, food preservation and environmental pollution from agricultural chemicals. Large-scale assistance by UNDP and SIDA have helped to establish agricultural research institutions specially equipped for the use of nuclear techniques in Bangladesh and India: the Institute for Nuclear Agricultural (INA) in Mymensingh, Bangladesh, and the Nuclear Research Laboratory (NRL) of the Indian Agricultural Research Institute (IARI) in New Delhi, India. Technical assistance has also been provided under the Agency's regular programme for the development of three similar institutions in Pakistan (in Tandojam, Faisalabad and Peshawar).

I would now like to give some examples of specific project activities which are of practical and economic significance to your region.

Field experiments on rice grown under flooded conditions using fertilizers labelled with the isotopes nitrogen-15, phosphorus-32 and zinc-65 have been carried out in most of the above-mentioned countries, under the FAO/IAEA Joint Division's co-ordinated research contract programmes. These have helped to develop efficient fertilizer management practices. This work was made possible as a result of technical assistance provided by the Agency for the development of analytical facilities and manpower training.

In Bangladesh, radition-induced mutation breeding research under the large-scale SIDA-assisted project at the Institute of Nuclear Agriculture has helped produce two early maturing and high yielding varieties of rice (IRATOM 24 and IPATOM 38) which have now been released for use by farmers. Two early flowering radiation-induced jute mutants have also been evolved and recommended for release to farmers.

In Pakistan, under a UNDP-supported project at the Nuclear Institute for Agriculture and Biology in Faisalabad, radiation-induced mutants of wheat, rice, mung beng and cotton, having one or more of the desirable characteristics of high yield, short straw, disease resistance and early maturing have been developed and recommended for release to farmers. Especially it is worth mentioning that the growing season of the valuable Basmati rice was shortened by three weeks enabling two crops per year.

Similarly, in Indonesia, a small UNDP-supported project was helped to evolve a radiation-induced mutant of rice resistant to the brown plant hopper - an insect pest causing considerable damage to rice fields in many countries in the region. This mutant has been tested and found to be promising in Malaysia and the Philippines too.

In India, nearly all of the 4 million hectares of hybrid millet resistance to a major disease, downy mildew, is based on radiation induced mutants developed at the Nuclear Research Laboratory of the Indian Agricultural Research Institute. Also, in India, two radiation-induced mutants of ground nut with very large seeds, which are in particular demand for export, and a high oil-content mutant of mustard have been developed at the Bhabha Atomic Research Centre and released to farmers. These resulted from the large scale UNDP-supported project.

Another result of the large scale UNDP-supported project in India was the development and use of a radiation-attenuated vaccine against lungworm in sheep in Kashmir. This has brought about a significant improvement in the health of the animals and in the the quality of their products. The results of the vaccination programme have been so successful that there is now a heavy demand by nomads for the vaccination of their flocks. At present, the limited supply of vaccine produced enables only 50,000 animals to be vaccinated annually - about 15% of the total needing vaccination. It is hoped to increase the vaccine production under the on-going SIDA-supported project "Strengthening of Nuclear Research in Agriculture" which, like the previous UNDP project, is supporting the development of nuclear agriculture research in four institutions - the Indian Agricultural Research Institute, Indian Veterinary Research Institute, National Dairy Research Institute, and Bhabha Atomic Research Centre.

Root distribution studies on sorghum and millet using radioisotope methods at the NRL in India have helped to identify deep rooting varieties which are particularly suited for growing under conditions of limited soil moisture availability.

A particularly striking feature of the application of nuclear techniques in agriculture in India is the machinery established by the Indian Agricultural Research Council for collaboration between various agricultural institutions and universities in the country so that the results of research are tested in various parts of the country and finally carried to the farmers for practical application.

In Sri Lanka, fertilizer placement studies on coconut palms, (a major export crop) using fertilizer labelled with phosphorus-32 has helped to develop a more efficient method of fertilizer application, reducing the costs of production. Other projects of national importance supported under the Agency's regular programme of technical assistance are investigations, using phosphorus-32 of the efficiency of locally available rock phosphate as compared with imported phosphate fertilizers in connection with the economically important crops rice, tea, coconut and rubber, and the development of effective soil moisture conservation practices on tea, rubber and coconut plantations with the aid of the neutron soil moisture meter. These projects have helped to establish close collaboration in the use of nuclear methods between the various agricultural research institutions in the country - the Central Agricultural Research Institute and the Tea, Rubber and Coconut Research Institutes.

An on-going Agency regular programme project in Malaysia, at the National University in Kuala Lumpur is aimed at developing teaching and research cabability in plant breeding, particularly in relation to rice and soyabean. A notable feature of this project is the successful co-operation which has been built up between various agricultural institutions in the use of nuclear techniques - the National University, the University of Malaysia, the Rubber Research Institute, and the Malaysian Agricultural Research Institute.

The Joint Division's assistance was previously geared towards solving practical problems within the context of the Green Revolution. This involved large inputs of pesticides, fertilizers, etc. involving high energy inputs. Although this emphasis on production must be maintained if the population is to be fed, the high cost of energy is leading to a change in emphasis towards agriculture with a minimum of these high cost inputs. The Joint Division's programme is therefore also gradually changing towards these objectives. An example is the recently initiated SIDA-funded co-ordinated research programme aiming at maximizing the biological fixation of atmospheric nitrogen in field crops or the just initiated programme on efficient use of fertilizers in multiple cropping.

The energy crisis will further spur activities to improve the so-called "no tillage" crop production whereby crops are grown without energy demanding soil cultivation and to conserve water. This calls for the use of isotopes to study the fertility status and the cycle of nutrients in the soil under these conditions.

Efforts are also being made to improve the reproductive performance of livestock so that every breeding animal utilizes its full reproductive potential for producing surviving offspring. The feed necessary to sustain and increase this production is being sought in better utilization of cereal straws and other agro-industrial by-products treated and supplemented with non-protein nitrogen compounds.

It is a sad fact that many insects have developed resistance to insecticides, some towards every known insecticide, and this has created enormous problems for food production and human health in the tropics and sub-tropics. In order to protect cotton it is not unusual to spray the crop 15 - 20 times with various insecticides, and this naturally creates severe economical as well as environmental problems. In that connection I have just read that Americans are not suitable for eating because they have more DDT in their bodies than they allow in any consumable feedstuff. We have initiated programmes of plant breeding for disease and pest resistance as well as continuation of emphasis on use of the SIT to meet both the problems of high cost inputs and environmental pollution.

Similarly, drug resistance is a problem in the control of parasitic and other diseases of animals, and programmes to help resolve these problems are being initiated.

I shall not finish this lecture without mentioning the activities under the Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology (RCA) in this region of the world.

Malaysia joined this agreement in 1975, and the agreement now comprises 12 Member States, namely Australia, Bangladesh, India, Indonesia, Japan, Republic of Korea, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka and Thailand.

The RCA Action Plan for 81 comprises 9 on-going projects, of which one is funded by UNDP and deals with industrial application of isotope and radiation techniques. Three of these projects are in agricultute, namely:-

— Use of induced mutations for improvement of grain legume production;

— Food irradiation; and

— Improving domestic buffalo production using nuclear techniques.

In addition, two projects have been approved but their initiation is contingent upon the availability of funds. These projects are:—

— Application of nuclear techniques for improved utilization of agricultural residues with special reference to biogas; and

— Evaluation of mutant stocks for semi-dwarf plant type as cross breeding material in rice.

JOINT FAO/IAEA PROGRAMME OF ISOTOPE AND RADIATION APPLICATIONS OF ATOMIC ENERGY FOR FOOD AND AGRICULTURAL DEVELOPMENT.

The use of isotopes and radiation in food and agriculture has resulted in faster solutions to a number of practical problems, allowed a more direct approach to others and in some cases provided the sole methodology for solving basic and applied problems. This statement is not based on theoretical speculations but on results of profitable applications with benefits to agricultural production in developed and developing countries alike over many years.

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In all this work the Agriculture Section of the IAEA Laboratory plays an active supporting role whenever requested by the Member States. Although basically most of the research and developmental work involving nuclear techniques is carried out in the countries themselves, the Laboratory provides various services such as training, analyses, and carrying out of supplemental investigations as requested.

The joint FAO/IAEA programme includes six subject matter areas:

- Soil fertility, irrigation and crop production
- Plant breeding and genetics
- Animal production and health
- Insect and pest control
- Chemical residues and pollution
- Food preservation.

The following pages highlight each of these areas with selected examples of some practical achievements of economic significance to developing Member States accomplished within the programme of the Joint FAO/IAEA Division.

Soil Fertility, Irrigation and Crop Production

The objective is to advise and assist Member States in connection with the application of isotope and radiation techniques in problem-oriented research on soil fertility, plant nutrition, irrigation and other soil and water management practices with a view to improving the quality of crops and increasing crop production in the most economic way.

Labelling with isotopes provides a unique means of directly determining the amount of a nutrient taken up in a plant from a given source. Hence isotopes are very powerful tools in studies aimed at the choice of the most suitable chemical form of a fertilizer, the appropriate time of application and the best placement method while taking the soil properties, the crops grown and the prevailing weater conditions into consideration. Such studies can be a major contribution to increasing crop production through improving the efficiency of fertilizer use.

Direct quantitative assessments of the amounts of atmospheric nitrogen fixed by leguminous crops are also possible by isotope labelling. This method enables the evaluation of the effect of various cultural practices on the amounts of nitrogen fixed by legume crops. Ways and means of increasing the amounts of dinitrogen fixed through improved in oculation techniques, fertilization with macro-and micronutrients, the incorporation of organic matter and soil amendments among other techniques and field practices can thus be easily and quantitatively evaluated even under field conditions.

The use of portable radiation equipments makes it possible to follow the moisture changes in soil profiles in a reliable non-destructive way while saving time, effort and money. This greatly facilities field studies aiming at improving the efficiency of water use on irrigated land or the development of adequate water management and conservation practices under dry farming conditions. Such studies are essential of making more rational use of limited water resources. Tracer techniques may also be used for a better understanding of the movement of ions and water in soil profiles.

Over the past 15 years, the joint FAO/IAEA programme has coordinated research aimed at developing efficient nitrogen and phosphorus fertilizer management practices for rice, wheat, maize, and legumes, determination of roof activity patterns of some economically important tree crops, understanding soil-water regimes, and improving water-use efficiency for cereal crops. Recent programmes relate to: studies of biological and dinitrogen fixation for the dual purpose of increasing crop production and decreasing nitrogen fertilizer use to conserve the environment; micronutrient studies in rice production with special reference to zinc deficiency; efficient water and fertilizer use in semi-acid regions and fertilizer and water management in multiple cropping systems.

In one Member State that took part in the programme on nitrogen fertilization of maize, the country estimated that its economic benefit amounted to 36 million U.S. dollars per year after its farmers had adopted the findings of the research programme for the most efficient placement of fertilizer. In a similar programme involving coconut palms in another Member State, it was found that the efficient use of fertilizer not only yielded substantial savings in the cost of phosphatic fertilizers but also that over one million U.S. dollars could be saved annually in reduced allied costs. Results of the radiation-techniques-aided programmes aimed at improving the efficiency of water use will, when applied, lead to increasing yields, to reducing losses of nutrients through leaching below the rooting zone, and to conserving soil through avoiding the accumulation of salts close to the soil surface.

Plant Breeding and Genetics

The main objectives is to advise and assist Member States in the use of induced mutations for the genetic improvements of crop plants.

Mutation breeding is particularly useful when an already established crop variety needs improvement in a specific characteristic such as plant architecture, maturity time or disease resistance. During the last 15 years, mutation breeding has become an established part of many plant breeding programmes and has increasingly contributed to the improvement of crop plant varieties. About 200 varieties of crop plants developed by using induced mutations and an equal number of ornamental cultivars have been released and approved by the appropriate national authorities for commercial production. Many of these have become economically important.

Research coordinated and supported under the joint FAO/IAEA programme focusses mainly upon the technology needed to reach timely objectives, such as high yields, grain protein improvement, and disease resistance.

An example of successful mutation plant breeding is the development in Hungary of a new rice variety that is resistant to blast, a very damaging rice disease. A French variety, Cesariot, known to have a good resistance to this and other diseases was tested first. However, this variety was late maturing in Hungary, and in cool summers it would not produce good yields. Sometimes it would fail completely. Therefore, the aim was to induce mutations that would give early maturity, while retaining good blast resistance and other valuable characters. Samples of a thousand seeds of the Cesariot rice variety that were irradiated with different amounts of gamma radiation and with fast neutrons were planted. Selection for early flowering started in the second generation and continued in the third generation. One of the mutants which resulted from fast neutron irradiation "headed" three weeks earlier than the mother variety. This mutant line when propagated not only showed very rapid germination and early growth compared with the mother variety Cesariot but also had good tillering capacity and proved satisfactory in variety trials with high and low levels of nitrogen fertilizer. Thus, with a relatively simple mutation project, the immediate problem was solved. An early maturing, cold resistant, disease resistant mutant line of rice was developed that could be used directly and in further cross-breeding. In 1976 this mutant was recommended officially for cultivation in Hungary under the name Nucleoryza. This rice variety can be grown far north (at 47°3) in Hungary with a yield potential of wheat. As the price of rice is twice that of wheat, this mutant has great economic importance. In 1978 it was grown on 33.2% of the total rice area in Hungary and compared with the average yields of rice Nucleoryza yielded 30.6% more.

Another example is the improved pearl millet hybrid developed in India. Pearl millet production, which had risen to eight million tons during 1970, came down to 3.6 million tons during 1974 due to a severe attack of downy mildew disease, especially in the hybrids. The percentage of disease varied from 30 to 100 per cent in different areas. The main reason for this failure was that the male sterile line of the pearl millet hybrids became so susceptible to disease that it was no longer possible to raise it. Efforts to induce disease resistance in this male line through irradiation were successful and a mutant line, which showed a high degree of resistance to downy mildew was developed. When the line was released, it became the only male sterile line suitable for hybrid seed production in India. The increased yield due to the new resistant hybrids was estimated to eventually be more than three million tons which would have a value of roughly 300 to 400 million US dollars a year.

Animal Production and Health

The objective is to assist and advise Member States on the use of nuclear techniques to solve or assist in solving animal production and disease problems, including those associated with nutrition, reproduction and adaptation to the environment.

In many regions of the world animal production is limited by poor growth, reproductive performance and milk production; this in turn limits the availability of animal products for use by man. Animal production is a consequence of the interaction between the type of animal (species, breed, strain) and its environment. Improvements depend an identifying the most suitable type of animal for a particular environment, altering the environment to make it less challenging, or some combination of these two. The important environmental components which require some modifications are nutrition, climate and parasites and other diseases. Where these factors are suboptimal production will suffer, but different types of animals are affected differentially. Various aspects of these problems are best studied employing nuclear techniques.

The joint FAO/IAEA programme coordinates research in Member States in a number of fields. One relates to study of non-protein nitrogen, low quality roughage and agro-industrial by-product utilization by ruminants which together with studies on mineral imbalances, is helping to devise alternative feeding practices in countries where good grazing lands and/or grain supplements for ruminants are in short supply. In many aspects of this work labelling with stable and radioisotopes is indispensable.

In arid, semi-arid and marginal grazing lands, water is a scarce resource. Some animals can cope better with these conditions than others since they not only survive but are able to rear their young. Studies on water metabolism using tritiated water have characterized differences between breeds and species and identified those features of adaption which are necessary for animals produced in these areas.

Reproductive performance of livestock is influenced by many genetic and environmental factors but important aspects of it are controlled by hormones. A programme in which radioimmunoassay techniques are used to measure hormonal changes during the reproductive cycle of sheep, goats, cattle and buffalo is leading to enhanced reproductive efficiency through better management practices and more efficient use of artificial breeding techniques.

A major limitation to increased production is that caused by parasitic and other diseases. Isotopes techniques are not only providing a well defined picture of the effect that parasites have on hosts but are also illustrating how management and genotypes (breeds and species) can be modified to reduce the effect of the parasite or disease on production. Ionizing radiation has been used to successfully produce an attenuated vaccine against lungworm in cattle and sheep and this technology is being transferred to those areas of the world where control of this parasitic disease is of economic importance.

An example of the practical application of radiation attenuated vaccines is the following. A systematic study of the incidence of parasitic infections in Kashmir, India, revealed that up to 70% of the lambs born éach year became infected with lungworm **Dictyocaulus filaria,** and that although other parasites were also in attendance, this parasite **per se,** plus the pneumonias it precipitated were the major constraints on sheep production in the area.

Large-scale field trials conducted over two years and involving 6000 lambs, based on earlier work in Scotland and Yugoslavia, showed the irradiated vaccine to be highly efficient in India. Now, approximately 50,000 lambs are vaccinated annually, mortality in the area has decreased dramatically, lambing percentages and weight gains have increased and the overall prevelence of **D. filaria** has decreased to under 5%.

Insect and Pest Control

The objective is to advise and assist Member States in the application of isotopes and radiation in the solution of pest management problems and the development of pest control programmes.

Isotopes are very useful and often unique tools in entomological research. They have been employed successfully in studies on insect dispersal, population dynamics, ecology, insect-host plant relationships, predator-prey relationships, disease transmission, insect physiology, and pesticide penetration, *distribution, accumulation and metabolism in the insect* body. Radiation has been used to induce sterility in insects for use in sterile release programmes which are species specific and environmentally safe.

Over the past 15 years coordinated research under this subject matter has aimed at the development of the sterile insect technique (SIT) against fruit flies, lepidopterous insects attacking fruit crops and tsetse flies. Recently a new programme has been initiated on the application of isotopes in insect pest management with emphasis on rice insects. During this period considerable advances and in certain instances breakthroughs have been made in the development of the relevant and economic mass-rearing, irradiation, quality control and field release methodologies. In this regard mass rearing of the Mediterranean fruit fly has now reached the stage of the practical production of several hundred million flies per week in a SIT field campaign; in the case of tsetse flies recent developments in **in vitro** feeding techniques through membranes have eliminated the dependence on animal hosts for rearing these flies thus making the use of the SIT in tsetse fly control campaigns economically practicable.

Currently the joint FAO/IAEA programme is involved in two large scale field programmes concerned with the practical application of the SIT. One aims at the control or eradication of the tsete fly, vector of the animal trypanosomiasis (Nagana), which profoundly affects the socio-economic development of vast parts of Africa (7 million km^2). It is expected that this project which is located in Nigeria will provide information on the economics of the method and determine its role in pest management for tsetse flies. The second project aims at countering the threat of the Mediterranean fruit fly becoming established in Mexico. It is estimated that is such eventuality lossess due to quarantine of agricultural products for export would amount to 500 million US $ per year. Assistance has been given in the design of the rearing facility and equipment which has a capacity of producing and sterilizing 500 million flies per week. This project aims at eradicating the fly from Mexico and part of Guatemala by the use of the SIT in the context of an integrated control programme.

Many examples of successful field applications of SIT can be cited: Following the spetacular results of SIT in eradicating the screw worm fly from the island of Curacao and South-Eastern United States, the technique gained wider acceptance. Using this technique the melon fly was eradicated from Kume Island in Japan and Rota island in the Pacific, the oriental fruit fly was eradicated from Guam and the Mediterranean fruit fly was eradicated temporarily from Procida, Italy. Following initial tests to control the oriental fruit fly in Taiwan by SIT a programme to cover the whole island was initiated in 1978. For years SIT has been used in an integrated pest management campaign as a quarantine measure against the invasion of the Mexican fruit fly into California, USA. A successful eradication test against a reverine tsetse fly species was conducted in Upper Volta. Complete control was obtained for codling moth in British Columbia and commercial control for boll weevil in Mississippi. The method has also demonstrated its effectiveness against stable flies, horn flies and mosquitoes in the Virgin Islands, Hawaii and Florida, respectively.

Chemical Residues and Pollution

The objectives is to assist and advise Member States on the safe and effective use of isotope and irradiation techniques in solving residue and pollution problems of agriculture, forestry, fisheries and food.

Labelling with isotopes offers a unique tool in studies of residue and pollution problems because such isotopes can easily be detected and determined at extremely low concentrations.

Isotope techniques provide the only means for solving certain chemical residue and pollution problems. As an example the "bound" or unextractable residues of environmental and food samples often escape measurement or even detection by conventional chemical analysis but represent nevertheless a significant fraction of the total residue present. By studying such residues prepared experimentally with a radioactive contaminant such as a pesticide, it is possible to account for, and often characterize, the entire residue, including that "bound" to the sample itself. There are some cases where the "bound" residue has provided to be of greater significance than the fraction determined by conventional chemical analysis.

Similarly, the use of the stable isotope nitrogen-15 for studying the behaviour of fertilizer nitrogen in the soil-plant-atmosphere system enables its fate to be quantified in the presence of the large excess of nitrogen already and naturally present in soil and atmosphere. This technique in the framework of the nitrogen residue programme (below) has provided unique data on fertilizer nitrogen losses through leaching and/or volatilization processes. Such data are essential for the development of suitable counter measures without impairing essential agricultural food production.

Isotopically labelled substrates and analytical reagents often provide unique monitoring tools both for the levels and effects of chemical and radio-active trace contaminants. Thus, the radiocarbon dioxide technique is widely used for the rapid and accurate field measurement of the vital processes of photo-synthesis in terrestrial and aquatic ecosystems and the changes caused by pollution.

Coordinated research in Member States involves studies on the effects of atmospheric sulphur pollutants on crops; pesticide residues in cotton, seed, feed, oil and related products of significance to developing countries; and agrochemcial residue-biota interactions in soil and aquatic ecosystems. Of particular and very great economic importance to developing agriculture is the coordinated research on agricultural nitrogen residues. This deals with the growing and vital problem of conserving both added fertilizer and native soil nitrogen and minimizing their pollutant potential as a result of leaching.

A field project dealing with the efficiency and fate of the insecticide Dieldrin can be cited in the context of pesticide use in developing Member States. The Member State involved wished to increase the efficiency and economy of its large spraying operation to control tsetse. A specialized laboratory was established, training initiated and labelled Dieldrin was applied in a field experiment. The results showed that only some 40% of the sprayed amount of Dieldrin was deposited where it was intended on the trees so that 60% was lost as an environmental threat. The experiment also demonstrated that the insecticidal effect of Dieldrin deposited on the trees was reduced by 50% after 4 weeks. As a result of these findings the spraying routine was changes to a more efficient operation.

Food Preservation

The objective is to assist and advise Member States in connection with facilitating the practical application of food irradiation.

Irradiation is an industrial processing technique, presently being applied extensively on a commercial scale for improvement of the quality of plastics, rubber, wood, wiring and for the sterilization of disposable medical supplies. It can also effectively be used for the preservation of food, because it is an environmentally clean process which is low in energy requirement and does no leave any residue in the treated product.

The main technology benefits of food irradiation are:-

1. to prevent sprouting of potatoes, onions, garlic and other root crops;
2. to extend storage life of fish, meat, poultry, fruits and vegetables by destroying spoilage bacteria and moulds;
3. to disinfest (to kill insects, parasites) fruits, vegetables, grain and dried food products;
4. to produce shelf-stable food items (e.g. meats, poultry and fish) which do not require refrigeration for storage;
5. to allow substantial reduction or elimination or certain chemical preservatives in foods some of which are considered precursors of carcinogens.

The joint FAO/IAEA programme actively coordinates work related to public health acceptance and regulatory aspects of food irradiation as well as to technological and economic feasibility of the process. Connected to these efforts are the wholesomeness studies, some performed as part of the International Project in the Field of Food Irradiation (IFIP) located in Karlsruhe, FRG. Practical application of food irradiation including training for developing Member States is being furthered through the International Facility for Food Irradiation Technology (IFFIT) in Wageningen, the Netherlands.

The introduction of the irradiation technique into the food industry is a rather slow process because the use irradiation for the preservation of food requires approval of regulatory agencies (national and international) concerned with public health. In addition to extensive wholesomeness testing it is also necessary to gather data on the economic feasibility of the process before large investments are made. Finally an informed public needed to gain consumer acceptance of the irradiation process.

Irradiation is presently applied to potatoes on a commercial scale in Japan. In other countries irradiation is used on a semi-industrial scale to produce pathogen-free laboratory animal feeds and for the treatment of vegetable substances, spices and onions. In several countries food irradition is studied on a pilot-plant scale from which potential applications would become real. Presently approximately 28 irradiated food items belonging to different classes of food (e.g. spices, fruits, vegetables, poultry, cereals) have been cleared for consumption in 20 countries. The Joint FAO/IAEA/WHO Expert Committee on Wholesomeness of Irradiated Food (JECIF) has already recommended unconditional acceptance of irradiated potatoes, wheat, chicken, strawberries and papaya for human consumption, as well as provisional acceptance of rice, onions and fish at its last meeting in 1976.