Analyses of some samples of Kalahari groundwater did not reveal any significant amounts of tritium and it was concluded that the water from which the samples were taken must be more than 40 years old. One sample was found to contain tritium, which means that the water in the reservoir has an average age of about 30 years or that a small amount of tritium from thermonuclear tests has entered the supply.

Some miscellaneous applications were discussed at the last session of the symposium. These included hydrological investigations with the help of radiostrontium and radiocaesium from nuclear fall-out.

In a closing address, the Agency's Director General, Dr. Eklund, stressed the importance of isotope techniques in groundwater studies. The meeting, he said, had also shown "that the range of applications of radioisotope techniques to hydrological problems is likely to grow considerably in the years ahead". He suggested that governments should consider the application of these techniques while planning projects for the study or use of water resources.

FERTILIZER APPLICATION TO RICE

DIFFERENT METHODS EVALUATED BY ISOTOPE TECHNIQUES

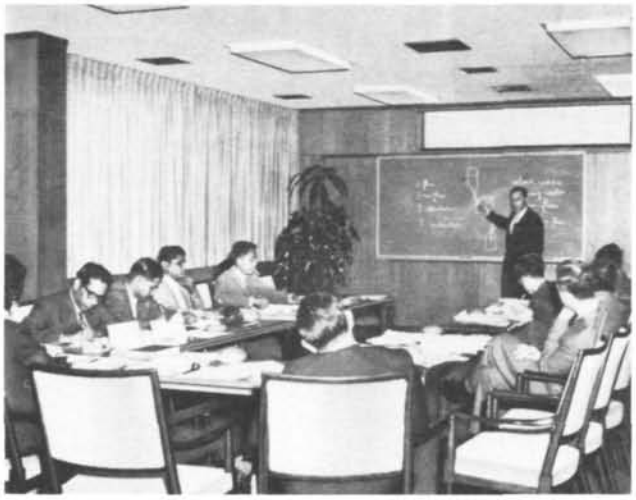
The first results are now available of a research programme on the application of isotope techniques to rice cultivation which was initiated by the International Atomic Energy Agency over a year ago. Work done under a number of research contracts awarded by the Agency as part of the programme has produced important findings on the relative merits of different mthods of applying phosphate as a fertilizer for rice.

The range and depth of agricultural investigations which have been made possible by the use of radioisotopes are now widely known. In general it can be stated that the application of isotope techniques is gradually leading to a detailed understanding of the chemical, biological and other processes to determine the success or failure of an agricultural enterprise, and this understanding in turn provides a certain basis for the adoption of improved cultural practices. Nowhere perhaps is this more evident than in the contribution of isotope techniques to the study of the supply and movement of nutrients and their uptake and metabolism by plants.

While any major change in cultural practices should be based only on a thorough study of all the processes involved, the results of some of the investigations may be of immediate practical interest. To take a specific case, any information on the relative efficiences of the different methods of fertilizer placement - whether, for example, it should be placed on the soil surface or at a certain depth - would be of direct interest and value to farmers.

The need for such information in regard to phosphate application to rice plants is particularly urgent. Several years of classical field experimentation have failed to produce unequivocal results as to the relative efficiences of the different methods of phosphate placement in rice cultivation. This, however, is not surprising. The variations in yield between different plots of a field experiment are not very large. Although the utilization of the phosphate may be quite different, the yields are usually so close to the optimal phosphate response that a comparison of the yields cannot provide an accurate and sensitive measure of efficiency of phosphate utilization for the different placement methods. If, however, superphosphate labelled with radioactive phosphorus (phosphorus-32) is used for such an experiment, it is possible to determine the fraction of phosphate in the plant derived from the fertilizer. In this way the efficiency of phosphate uptake can be determined directly and independently of the vegetative development or grain yield of the crop.

During the eighth meeting of the International Rice Commission, held in New Delhi in December 1961, a number of research workers indicated to the IAEA representative that they would like to use isotope techniques for a comparison of various methods of phosphate placement in rice cultivation. Within three months the Agency's Unit of Agriculture, in co-operation with research workers in several Member States, designed a field experiment and arranged for the supply of labelled phosphate fertilizer. Seven research contracts were concluded with



Meeting held at Los Baños, Philippines, to discuss the results of the experiments to study methods of phosphate placement in rice cultivation

In the experiment in Burma, radioactive fertilizer is being placed at a depth of 10 cm between rows by means of a locally made plunger and piston

workers in Burma, Hungary, east Pakistan, west Pakistan, the Philippines, Thailand and the United Arab Republic. Nine field experiments of exactly the same design and using the same source of labelled fertilizer were carried out simultaneously on widely varying soil types and in different climatic conditions. Leaf samples taken at regular intervals were either sent to the Agency's laboratory at Seibersdorf for analysis or analysed by the research workers themselves.

At the end of last year representatives of the Agency's Agriculture Unit had a meeting with the research contractors and a number of other invited experts at the International Rice Research Institute, Los Baños, Philippines. The results of the experiments were compared and interpreted at this meeting, and the programme of work for this year was drawn up. A report on the results obtained from last year's experiments was presented at the 5th Japan Conference on Radioisotopes held in Tokyo in May. A summary of the results is given below.

Field Experiments and Results

All contractors carried out the same field experiment which consisted of the following treatments:

(1) placement of labelled superphosphate on the surface

(2) placement of the fertilizer hoed into the soil surface (i.e. worked into the top soil);

(3) placement at a depth of 10 cm at the planting point;

(4) placement at a depth of 20 cm at the planting point;

(5) placement at a depth of 10 cm between rows; and

(6) placement at a depth of 20 cm between rows.

In addition to the plots in which these treatments were carried out, there were check plots left without fertilizer. Each treatment was carried out in eight plots selected at random in an experimental block; in other words, there were 56 plots (including eight check plots without fertilizer) in a random block design.

All cultural practices with regard to nursery preparation, such as nitrogen and potassium fertilization and transplanting, were carried out according to a standardized procedure. The labelled superphosphate had an initial specific activity of 0.4 millicurie per gram of phosphorus and was applied at the rate of 40 kg of phosphorus per hectare.

The rice plants were harvested 20, 40, 60 and 80 days after transplanting from the nursery. The effect of placement on fertilizer uptake was determined by an analysis of samples harvested after 60 days. The following table shows the relative rating of the various treatments based on the fraction of phosphorus in the plants derived from the fertilizer applied (as distinguished from the uptake of phosphorus naturally present in the soil).

Treatment	Rating relative to surface placement
Surface	100
Hoed into surface soil	109
10 cm at planting point	54
20 cm at planting point	39
10 cm depth between rows	44
20 cm depth between rows	35

A view of the crop in the experimental field in Hungary; some samples have been taken from the middle of the plot

Final harvesting in the experimental field in East Pakistan

The data show that, on the average, application at the surface or hoeing in was far superior to any other placement. So far as the individual soils were concerned, there was a marked variation in the relative uptake from the different treatments. There was, however, no case in which any of the other four treatments was superior to the two surface treatments. This is remarkable considering the differences in soil (including wide variations in the natural phosphate level), environment and rice varieties, and the fact that one of the treatments was placement at planting point which generally ensures the most efficient utilization with most plant species. It will be clear that in one year a very definitive answer to an important practical problem was obtained by this cooperative effort. (One limitation of this project, however, was that none of the experiments was carried out on a lateritic soil.)

The experiments also showed the changes in the rate of phosphate uptake over the period of plant growth. Samples were taken at 20-day intervals and the percentage of phosphorus in the samples derived from the fertilizer measured. In the following table the results from the various locations are averaged and the uptake at different periods is compared on the basis of a rating of 100 for the uptake from surface placement after 20 days of transplanting.

Treatment	Days after transplanting			
	20	40	60	80
Surface	100	96	89	114
Hoed in	138	124	97	111
10 cm at planting point	146	71	45	58
20 cm at planting point	109	61	34	48
10 cm depth between rows	72	72	45	46
20 cm depth between rows	50	48	37	40

The results highlight both the early efficiency of uptake when fertilizer is placed at planting point and its later insufficiency. At the 10 cm depth in particular, the proportionate uptake from the fertilizer decreases very rapidly as the root system develops, while no changes occur with time in the surface and hoed-in treatments. The decreases with time in the remaining treatments are not nearly as drastic as in the treatment at planting point. Thus the low relative efficiency of the planting point treatment, as shown in the previous table, results from a combination of placement and time effect.

Although from the point of view of fertilizer use the application of phosphate on the surface or its hoeing in into the top soil compare favourably with the other methods of placement, further experiments are necessary to show the effect the phosphate has on the final yield when it is taken up at different stages of development of the crop.

Experiments in IAEA Laboratory

All research contractors sent large soil samples representative of the experimental sites to the Agency's laboratory at Seibersdorf for comparative pot studies with the different soil types under a constant environment. It was thought that local differences in climate, soil type and rice variety might have an effect on the degree of utilization of phosphate from the fertilizer. The factors which seemed most important were oxidation-reduction* status of the soil and the movement of water through the soil.

The pot studies were designed to evaluate the effects of the following factors on phosphate uptake, using nine different types of soil: (1) upland condi-

* *Reduction is removal of oxygen from a chemical compound, the opposite process to oxidation. Submerging of rice fields, resulting in the reduction of soil, is a feature of rice cultivation in many countries.*

tions; (2) submerged condition without flow; (3) intermittent flow and drainage; (4) submerged condition with continuous flow; and (5) placement of fertilizer on the surface and entirely mixed with the soil.

The necessary arrangements for each of these treatments were made in a greenhouse. All pots received labelled superphosphate and a basic application of nitrogen, potassium, magnesium and some minor nutrient elements. Two months after germination, the rice plants were harvested and analysed for phosphorus-31 (stable) and phosphorus-32 (radioactive) content. The average percentage of phosphorus in the plants derived from the fertilizer is given in the following table.

Watering regime	Percentage of phosphorus derived from fertilizer in the total phosphorus content of plant	
	Fertilizer placement	
	Surface	Mixed
Upland	57.6	38.5
Submerged	45.5	34.5
Intermittent	47.6	37.1
Submerged plus flow	45.4	34.5

It will be seen that with surface application of fertilizer the watering regimes had no appreciable effect on phosphate utilization and in the mixed application only upland treatment resulted in a higher uptake of phosphorus from the fertilizer than from the soil. The results of neither flow nor oxidation of the soil combined with flow differed significantly from those of the submerged condition without flow. This would suggest that:

(1) reduction of the soil for this period of time did not result in an appreciable change in the availability of soil phosphate;

(2) flow of water did not increase phosphate uptake from the fertilizer as compared to that from the soil;

(3) under highly oxidixed upland conditions there was an increase in the availability of phosphate from the fertilizer as compared to that from the soil; and

(4) the higher efficiency of surface treatment was consistent with the field observations (it is to be noted, however, that placement experiments in the greenhouse are seldom directly applicable to the field and have to be interpreted with caution).

The consistency of these findings is particularly impressive as they represent an average of results from nine soils that varied not only in their chemistry but also in their original phosphate status. The following table shows the relative amount of soil phosphorus available for uptake by plants (known as the A-value) in the nine types of soil used in the experiment.

Soil No.	A-value (milligram of phosphorus per kilogram of soil)
1	4
2	12
3	13
4	14
5	15
6	35
7	49
8	68
9	210

Further Investigations

Time of fertilizer application is another problem of considerable importance and isotope techniques are particularly suitable for determining the relative merits of applying fertilizer at different times of cultivation. Under the Agency's rice research programme field experiments will be carried out this year to ascertain the best time for the application of superphosphate in rice cultivation. This will be done at a number of sites in Burma, Hungary, Korea, east and west Pakistan, the Philippines, Thailand, the United Arab Republic, and possibly Japan.

The experiments will consist of (a) application of phosphate at three different rates in the nursery, (b) application at three subsequent times, and (c) single and split application of the same amount of phosphate. The results will show the efficiency of phosphate uptake for each of these treatments. Studies will also be made to find out whether the uptake of phosphate at later stages of development can still be efficiently used in plant metabolism.

It is expected that a number of associated experiments using soil samples from the field experiment sites will be carried out in the Agency's laboratory. Techniques will also be worked out in the laboratory for future field experiments.

Another problem to be studied under the research programme is the efficiency of nitrogen fertilization in rice cultivation. Although nitrogen is the most important nutrient for rice, relatively little work has been done on it. One difficulty is that a suitable radioisotope of nitrogen does not exist, and for tracer work nitrogen enriched with nitrogen-15 (which is a stable isotope but distinguishable from the ordinary variety by its heavier mass) has to be used. This implies that the investigator should have a mass spectrometer at his disposal, but this kind of equipment is seldom available in agricultural research institutes in rice growing areas.

The Agency's laboratory at Seibersdorf has a mass spectrometer available for the analysis of samples on a routine scale. In the near future experiments will be organized for the study of nitrogen utilization by rice plants as affected by nitrogen transformation in the soil, interactions with other elements in the soil, and the methods and times of application of various kinds of nitrogenous fertilizers under upland and lowland conditions. Laboratory, pot and field experiments using compounds labelled with nitrogen-15 will be carried out under a co-ordinated research contract programme, and the samples will be analysed at the Seibersdorf laboratory when necessary. The laboratory is already starting preliminary experiments to work out suitable techniques.

As regards the supply and movement of nutrients in rice soils, emphasis will be given to a study of the mechanisms that are responsible for the chemical composition of the soil solution in the vicinity of the roots when nutrients are continuously taken up by the plant.

The Agency envisages a continuing programme of rice research with isotope techniques to deal with problems of direct practical interest to farmers. The uptake and metabolism of nutrients are among the most important problems of this nature. For example, it is well known that Indica rice varieties in South East Asia often fail to respond to nitrogen and that the level of production is low compared with Japonica varieties in subtropical regions. A detailed study of nitrogen uptake and metabolism of nitrogen into amino acids in both Indica and Japonica varieties may reveal the cause and thereby help in improving nitrogen fertilization practices in South East Asia. For investigations of this nature the need for a co-operative research effort, such as the one initiated by the Agency, has already been well demonstrated.

LARGE RADIATION SOURCES IN INDUSTRY

Chemical and physical changes that are caused by intense fields of high-energy radiation are sometimes useful ones. An IAEA conference held at Salzburg, Austria, (27 - 31 May) gave the participants a chance to see what has been happening in this field since the last similar conference held by IAEA in Warsaw in 1959. Most of the papers given at the conference were concerned with research studies in polymerization, chemical synthesis, chemical catalysis and rubber vulcanization. One paper described a method with which a large chemical company in the USA is manufacturing a product on a large scale using radiation as a catalytic agent. Several others described plants that are being used for commercial sterilization. When these new processes are added to others that have already been reported, one finds that large radiation sources are very active in industry.

Polymers, Synthesis, Catalysts

Most of the Salzburg papers were devoted to polymerization (in which molecules like ethylene, called "monomers", are caused to link to one another to form such polymer plastics as polyethylene) and synthesis (in which new chemicals are produced by the action of radiation). Among polymerizations that are being studied are combinations in which monomers, which are usually liquids, are put into woods and textiles by soaking and then polymerized by irradiation. The products have some of the properties of the natural material and some of those of modern plastics. Many other papers reported work on the kinetics of polymerization and various grafting processes for causing monomer molecules to attach themselves to polymers already formed.

Two papers reported some success in efforts to make hydrazine, useful as a rocket fuel, by irradiating ammonia. Two others were devoted to nitrogen fixation. Other syntheses that are being studied include formation of compounds of biological interest.

Chemical catalysts always present problems to the chemist; it is very difficult to find out how they function. With the use of radiation the chemists would like to answer three questions: How do catalysts work? Can one increase their activity by irradiating the system while the reaction is occurring? Can one change the activity by irradiating the catalyst before it is put into a chemical system? Four of the Salzburg papers were devoted to various studies of catalysts.

Radiation Makes Chemicals

A process for making ethyl bromide (widely used in medicine and industry) with radiation as a catalyst has progressed through preliminary experiments and pilot-plant tests and since last March has been in full-scale operation in the US chemical firm mentioned earlier. D.E. Harmer, who described the process at Salzburg, says that it has totally