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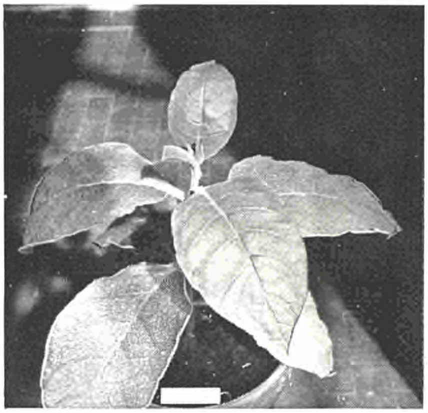

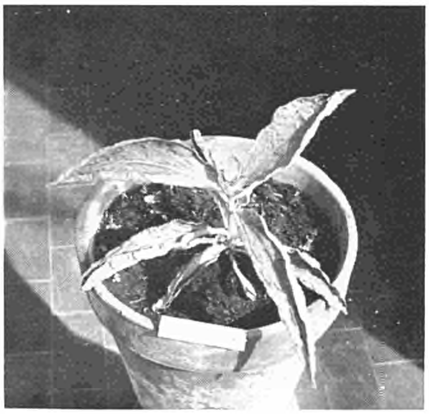

Importance of cell development stage on the radio-sensitivity of plants

Tobacco plants respectively (from top to bottom) not treated, treated with 4000 rads at the gamete stage (before fertilisation) and 4000 rads at the zygote stage (after fertilisation). Tobacco has been chosen purposely as test plant since this species offers the advantage that most of the very numerous eggs, zygotes or pre-embryos present in a fruit are simultaneously in the same stage of development. (Project under sub-contract between the Euratom/ITAL Association *and the* Comitato Nazionale per l'Energia Nucleare; *photographs provided by* G. T. Scarascia Mugnozza, CNEN, Centro di Studi Nucleari della Casaccia.)

Quarterly Information Bulletin of the European Atomic Energy Community (Euratom)

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Cover: A view into the Euratom/ITAL Association's BARN reactor in Wageningen

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Quarterly Information Bulletin of the European Atomic Energy Community (Euratom)

1964 - 3

The Community's mission is to create the conditions necessary for the speedy establishment and growth of nuclear industries in the member States and thereby contribute to the raising of living standards and the development of exchanges with other countries (Article 1 of the Treaty instituting the European Atomic Energy Community).

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In the eyes of the public nuclear technology is so closely associated with the building of nuclear power plants that the two notions tend to coincide. Nevertheless, the day when a substantial part of the electricity supplied to the grids of the European Community will be of nuclear origin is still some distance away. To ensure that it does come, vast, complex and costly research projects have been launched, each one of them a perfectly legitimate step on a long road.

On the other hand there are fields of immediate and vital importance for man in which nuclear technology is already fully fledged; it is not too much to say that radiations and radioisotopes have established themselves as indispensable aids to scientific progress in biology, medicine and agriculture.

In this issue, agriculture has been singled out as an example of one of these vital fields. Such a choice was not arbitrary: it was guided by the fact that the laboratories of the Euratom/ITAL Association, specially dedicated to the use of nuclear techniques in agriculture, are to be officially opened this year.

The evolution of agriculture has sometimes determined and always deeply influenced that of man and of human society. The basic role of agriculture derives from its unique social and economic features.

Throughout man's slow advance from the gathering of roots and wild berries to the refined methods of cultivation used today, agriculture has sought to satisfy the most vital of all needs—the need for food. At the same time it has assumed an economic importance which has always been of the first rank. For comparison we may note that in recent years the annual sale of electrical energy in the six Member States of Euratom has amounted to about 5 thousand million dollars, whereas agricultural production has been around 22 thousand million dollars. Moreover, agriculture in these countries has become a veritable industry, giving direct occupation to a class of the population which has always played an effective and original part in the social, economic, and political development of society.

Laboratories of the Euratom/ITAL Association.

Man formerly devoted the greater part of his time to the search for food. Today seven seconds is the period of direct human work needed to produce a kilogram of maize in the American corn belt. Results of this kind are due neither to nature nor to chance, but to the continuous search for improvement and perfection. This search has gone on at all times—let there be no doubt about it—whether in laboratories and experimental lots as we know them today, or in a frequently confused and empirical, and sometimes even unconscious form.

The demographic explosion which is taking place justifies more than ever the pursuit of this research in the most varied forms, and it has been proved that nuclear techniques may contribute substantially to the acquisition of knowledge in the most diverse branches of agronomy, ranging from the detailed study of cell physiology to the use of fertilisers.

Generally speaking, these nuclear techniques can contribute firstly to the growth of productivity (by improving yields or use of resources) and secondly to the reduction of losses caused by a number of factors coming into play during growth or after the harvest. Whether in countries with intensive agriculture or in under-developed regions, radioactive tracers and radiations are a positive and valuable contribution from the nuclear field to the quest for better living.

By entering into an association with the Dutch Institute ITAL *(Instituut voor Toepassing van Atoomenergie in de Landbouw)*, Euratom has sought to make use of the capacities of the Wageningen centre for training and research in agronomy—one of the foremost in the world. Nowhere else is there such a concentration of institutions and laboratories working in the most varied fields: in all matters relating to the use of nuclear techniques in their activities the Euratom/ITAL Association makes use of their special knowledge and makes it available to the six Member States.

With one exception, the association contract between Euratom and ITAL represents the only direct activity of the Euratom Commission in the agricultural field; it is, however, amplified by a series of sub-contracts in the Netherlands and other countries.

In this way, Euratom's work in connection with the application of nuclear techniques to agronomical research is conceived as a co-ordinated programme; aimed at harnessing the specialities of the various countries, it employs a precious tool for a vital purpose. Every effort will be made to ensure that it succeeds.

RAYMOND K. APPLEYARD,

Director of the Biology Division of the Euratom

Joint Research Centre

EUBU 3-13

Nuclear technology serves European agriculture

In the Dutch province of Gelderland, 55 miles from Amsterdam and 3 miles from Wageningen, stands a large modern construction dedicated to the peaceful use of atomic energy. Its purpose is not the almost traditional one, nowadays, of harnessing the forces of the atom for the production of power, but of investigating the new opportunities which nuclear energy offers to agriculture.

In a 10 acre area covered by beech and oak, its buildings and facilities, worth to-date more than three and a half million dollars, give to a staff of 80 the means of carrying out a research programme geared to this purpose.

This is the "Euratom/ITAL Association".

What is the Euratom/ITAL Association?

Created by the Dutch Government in 1957 as the Institute for the Application of Atomic Energy in Agriculture *(Stichting Instituut voor Toepassing van Atoomenergie in de Landbouw*—ITAL), its construction was started in mid 1960 and is expected to be completed by 1965. By that time its facilities, which include a research reactor, will be in full operation.

The ITAL Institute was given wider scope when Euratom associated with it. A contract putting the seal on the association was signed in 1961, following which the Institute was given its present name. Euratom's contribution is not simply a dry and mechanical one confined to the handing over of funds. It is a living one in the sense that the contract provides for an arrangement whereby scientists from different disciplines and from different European countries are to work side by side in the Institute.

Some modifications had of course to be brought to the planned facilities and to the research programme in view of the fact that the Institute no longer served only national interests but also those of the whole European Community.

The policy of the Association is governed by an international management committee on which sit six members, three representing ITAL and three Euratom.

The study of the biological consequences of radiation has been considered important ever since man learned how to release nuclear energy. Its harmful consequences have, naturally enough, received particular attention: effects of accidental exposure to intense radiation, radioactive contamination in the animals and plants which constitute our food etc. From this point of view the fundamental aim is to neutralise the risks which attend the development of nuclear energy.

On the other hand, some of the biological consequences can be turned to man's advantage, and it is especially in this context that much of the work of the Euratom/ITAL Association has to be placed. In a world where one person in three is undernourished and where lack of co-ordination offers an image of increased production of food on the one hand and its amazing waste on the other, nuclear techniques will be precious if they are capable of helping to provide man with the food necessary to his subsistence.

The Institute's research programme accordingly aims at the production of more and better food and its rational and economic storage. In practice, this means:

— using radiation to induce suitable genetic changes in plants, thus adapting them to modern requirements;

— using new nuclear techniques or new developments of them for learning more about the physiological mechanisms of plants and about the environmental factors which affect their growth and reproduction;

— extending the storage life of fresh or preserved foods by the use of radiation.

The effect of radiation on living matter

Biological material is affected by radiation because a transfer of energy occurs from the radiation to the material. Before expanding on this, let us look at the different types of radiation which are relevant to biological problems, namely α-rays, β-rays, γ-rays and neutrons.

α-*rays* are relatively heavy particles made up of two protons and two neutrons (they are in fact helium nuclei moving at a certain velocity). They are *directly ionising*, but their penetration into living tissue is low, which means that they are of minor importance, except in a few special cases. Figure 1 gives an impression of their penetration as compared to that of β-rays and γ-rays; a mere sheet of paper can stop α-radiation.

β-*rays* are electrons, i.e. negatively charged particles such as those which orbit around the nuclei of atoms, moving at high velocities. They are more penetrating than α-rays and are capable like them of *ionising directly* the atoms which lie close to their path. Ionisation, a phenomenon of fundamental importance in radiobiology, occurs when

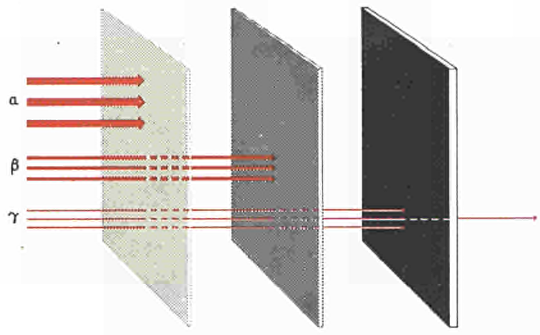


Figure 1: Relative penetration of α-, β- and γ-rays.

Figure 2: Ionising effect of β-rays. – A β-particle is a high-velocity electron. Its electrical charge is negative; it therefore tends to attract the (positively charged) protons in the nuclei of atoms near which it passes and to repel their (negatively charged) electrons. In an atom which is in a normal state, the positive charges are balanced exactly by the negative charges. The effect of the β-particle may be to upset the balance, i.e. to cause ionisation, in the way shown on the drawing. The nuclei of the atoms shown, atoms of lithium, are made up of three protons (white) and four neutrons (black).

the β-ray (or α-ray) is close enough to an atom for its electrical charge to interact with that of the atom; the result is that the atom is divided into positively and negatively charged parts (see figure 2).[1]

γ-rays (and X-rays) are, like light rays, a form of electromagnetic radiation. It is essentially their higher energy which distinguishes them from light rays. They are much more penetrating than β-rays and can also cause ionisation, but, as they have no electrical charge, they do so indirectly (see Figure 3).

Neutrons are the uncharged particles which make up, together with protons, the nuclei of elements. They are usually generated in nuclear reactions as *fast* neutrons, but slow down as they interact with the nuclei of the atoms which lie in their path. Figures 4 and 5 describe the fate of fast neutrons when they interact with the nuclei of either heavy or light elements. Once they have slowed down sufficiently, neutrons are readily absorbed by nuclei and can spark off various nuclear reactions (see Figure 6). In many cases, these reactions produce β-radiation or γ-radiation, or both, which in their turn lead to ionisation.

Thus β-rays, γ-rays and neutrons all cause ionisation to occur, the first directly and the others indirectly. But why is such importance given to ionisation?

Because it is the most striking manifestation of the transfer of energy which occurs when radiation interacts with biological material. If biological material is compared to a complex and highly automated factory, the effect of radiation can be imagined as a series of small explosions occurring at different points in the factory and interfering with its normal operation.

On the other hand, although the ionisations can be thought of as the explosions themselves, it is clear that this is not the whole story: perhaps fires will be started, toxic gases will be released etc. The moral of this analogy (which will be abandoned here and now before it becomes too misleading) is that ionisation is only the initial event and that it is followed by an extremely complex set of chemical, biochemical and physical consequences.

Our knowledge about the nature of these consequences is still imperfect. We may for instance know by experiment, sometimes with a reasonable degree of accuracy, how much radiation is needed to secure the death of a particular type of cell, without fully understanding the mechanisms which bring it about. This does not mean that the knowledge which we do have has no practical value; it can be of immediate interest, for example, to know the radiation dose capable of killing the bacteria which cause rotting in a particular fruit variety. Nevertheless, we are much in the position of someone who could determine the strength of a steel beam of given dimensions only by loading it until it broke; whereas it is evident that a little schooling in mathematics and in the principles of strength of materials would have produced the answer by simple calculation. What is more, this knowledge would enable a similar calculation to be made for a beam of any shape or size.

This point has been somewhat laboured because it is particularly relevant to the kind of research which the Euratom/ITAL Association has undertaken. Its long-term aim is to arrive at the kind of all-embracing fundamental knowledge which can produce solutions to broad groups of problems. On the other hand it would be a pity not to exploit immediately the opportunities offered by nuclear energy; it would be a pity, for instance, not to use radiation in order to develop new useful plant varieties, however empirical the methods may be. In any case, it is difficult to dissociate the long-term and the short-term aims. Most types of experiment yield results which are of both fundamental and practical value.

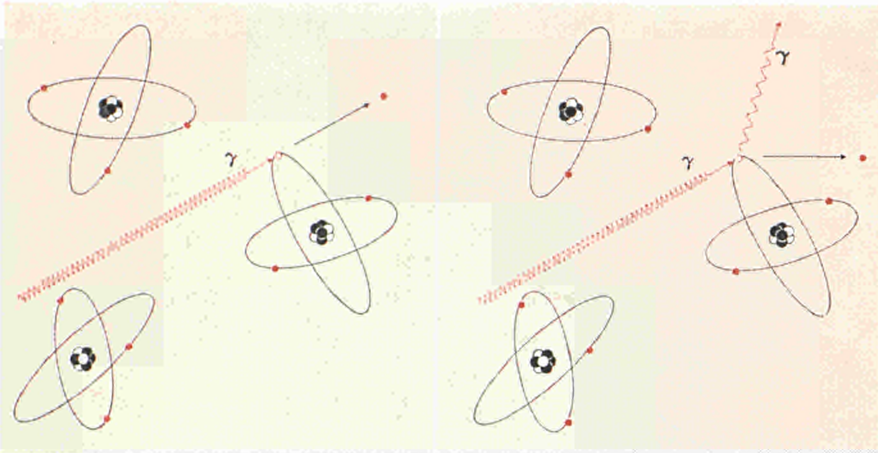
The Euratom/ITAL Association programme and its facilities

Deviations in plants induced by radiation

The aim of the agricultural geneticist is to obtain new varieties of cultivated plants having interesting or useful characteristics. He may, for instance, endeavour to increase the output of a plant type or make it more resistant to disease.

Alongside the conventional methods of

1. It should of course be stressed that the drawings, with all their orbits, black spheres, white spheres etc., do not correspond to reality but are merely convenient representations of it.



Figures 3a and 3b: Effect of γ-rays. – γ-rays have no electrical charge. Therefore, unlike β-rays, they leave the atoms near which they pass undisturbed. On the other hand, when they hit an electron orbiting round a nucleus they may transfer to it either the whole of their energy (photo-effect; Figure 3a) or part of their energy (Compton effect; Figure 3b). The main result of this interaction is that a high energy electron is released. This electron then behaves virtually like a β-particle and can cause ionisation as shown in Figure 2.

hybridisation and crossing, which take advantage of the variations which exist in nature, there is also the technique involving the induction of mutations, i.e. sudden hereditary changes, in living organisms. Irradiation is one of the ways in which the geneticist can bring about these mutations. Whereas the conventional methods make use of existing material, mutation breeding amounts to the creation of totally new material. The method is therefore particularly useful in the case of species where few natural variations occur.

It has been known for some time that inherited characteristics are dictated by the *genes* located in the chromosomes which are part of the living cell. It would seem that it is by interfering with the genes and chromosomes that irradiation is effective in inducing mutations.

From a practical point of view, using irradiation efficiently means inducing the greatest possible number of mutations in a plant in order to have statistically the best chance of finding a useful mutation. It is known that this number, for a given quantity of material, is related to the dose of radiation absorbed or, in other words, to the quantity of energy absorbed.

However, a limit is set by the amount of radiation the plant can stand without being killed by it. This "radio-sensitivity" in turn can be influenced by varying the plant's environment when it is treated, by irradiating one rather than another part of it and by treating it at different stages in its development.

However, far more important is the nature of the mutations induced. Experiments have shown that the mutation "spectrum" depends on what agent is used and on the environmental conditions both before and after treatment. For these reasons the Euratom-ITAL Association aims, in collaboration with a number of research institutes, at examining the exact influence of the environmental conditions on the results of irradiation. Four economically important crops, namely potatoes, beans, peas, and tomatoes are and will be treated with various mutagenic agents (X-, γ- or neutron radiation, as well as chemicals), under controlled conditions, to study their response. In order to make an accurate comparison of the effects of different radiations, a

Figure 4: Interaction of a fast neutron with the nucleus of a heavy element. – When a fast neutron hits the nucleus of a heavy element, it transfers to it only a small part of its energy and then bounces off.

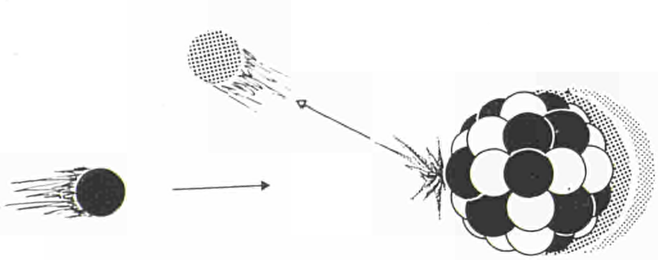


Figure 5: Interaction of a fast neutron with the nucleus of a light element. – When a fast neutron hits the nucleus of a light element, it imparts a considerable amount of its energy to it. The largest energy transfer occurs when a neutron collides with a hydrogen nucleus (as shown in the figure), which consists simply of a proton having the same mass as the neutron.

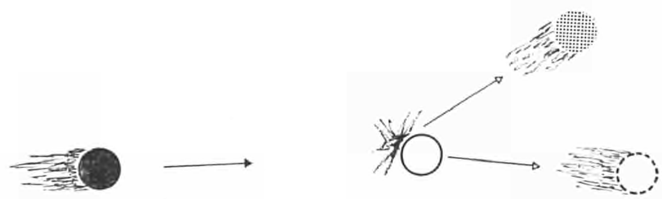


Figure 6: *Interaction of a slow neutron with the nucleus of an element. Two examples are given of the interaction of a slow neutron with a nucleus. In both cases the neutron is absorbed.* Left: *A neutron interacts with a (stable) nitrogen-14 nucleus, which releases a proton to give a(radioactive) carbon-14 nucleus. The carbon-14 nucleus emits a β-particle and disintegrates into a stable nitrogen-14 nucleus.* Right: *A neutron interacts with a proton (hydrogen nucleus) to give a deuteron. γ-radiation is released.*

knowledge of the dose received by the biological material is needed. For this reason a good deal of trouble has been taken over the precision of measurements in order to secure reproducible results.

The facilities which the Euratom/ITAL Association has available for this work include its research reactor, "BARN" (Biological Agricultural Reactor Netherlands), from which both slow and fast neutrons can be obtained (see figure 7).

The reactor is equipped with a chamber, situated below the core, in which luminosity, temperature and humidity can be adjusted at will. In this way it is possible to irradiate entire plants or plant parts in well-defined environmental conditions. The neutrons produced by the core may travel through a heavy water tank, thus becoming slow neutrons, and enter the irradiation chamber after passing through a bismuth filter

which reduces to a minimum the γ-radiation which would otherwise interfere with the study of the effects of neutrons. By emptying the heavy water tank and placing a boron plate to absorb and thus filter out slow neutrons, fast neutrons can be obtained.

The Association also possesses two γ-irradiation facilities. One is a "γ-greenhouse" in which it is possible to adjust the amount of radiation absorbed by the plants in a given length of time. The other is a building divided into four chambers sharing one γ-source (see figure 8) which is ten times more powerful than that of the γ-greenhouse. As the climate in each chamber can be controlled separately it is possible to conduct experiments simultaneously in which plants receive the same dose of radiation under different environmental conditions.

A wide range of dose-rates is thus available: plants of various species can be irradiated either in acute conditions, involving a large dose and a short exposure period, or using relatively low doses and long exposures. The aim is to determine not only the lethal effects but especially the sub-lethal effects caused by exposure under any of these conditions.

In order to understand irradiation better as an instrument for inducing mutations and to be in a position to use it more efficiently, a number of research projects of a basic character have been undertaken. For instance it is known that useful mutations can be obtained by irradiating seeds. A seed is essentially made up of the *embryo*, which is the tiny complex of cells which contains the potential of the fully grown plant, and the *endosperm*, teeming with the reserves necessary to the embryo's growth at the time of germination. While it is interesting to determine the global effects of irradiation on the seed, it is of even greater interest to establish the effects it has on the embryo and the endosperm taken separately, and the particular consequences which irradiation of the one produces for the other. This is why a project has been supported by the Association which involves transplanting irradiated embryos into non-irradiated endosperm and, conversely, non-irradiated embryos into irradiated endosperm.

A further example: experiments have shown that the sensitivity of a cell to radiation is dependent on the stage of development it has reached. Unfortunately for the research scientist, the cells of a growing plant are not all at the same stage of development. Plant tissue cultures or cell suspensions where all cells are in a particular development phase therefore constitute better experimental material. This is why methods of producing appropriate cell cultures are currently being investigated at the Institute.

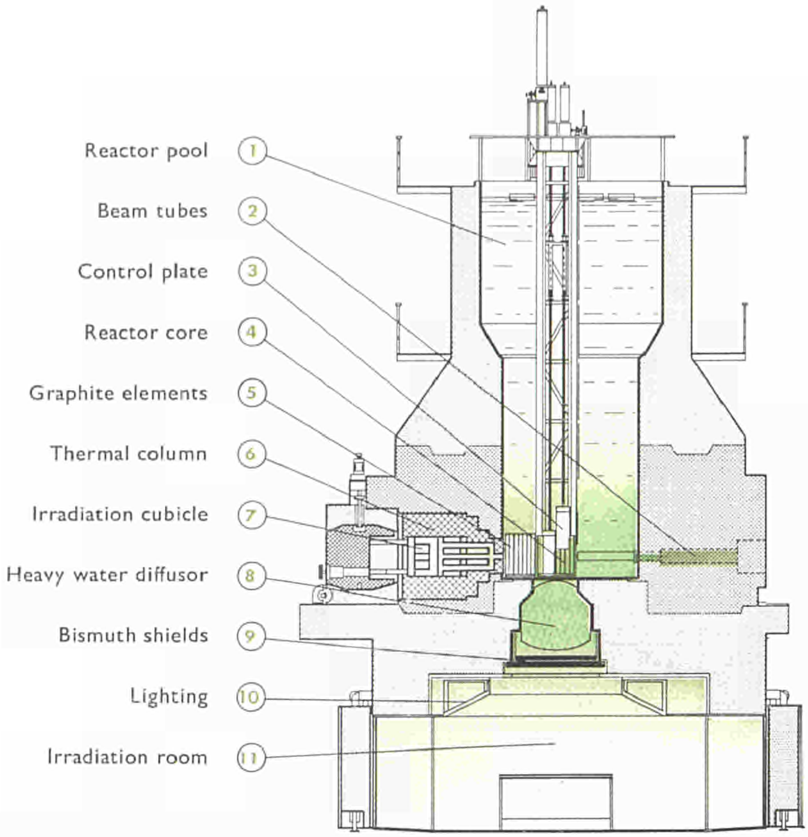


Figure 7: Vertical section of the Euratom/ITAL Association's "BARN" reactor. – The reactor, which is of the swimming-pool type, is fuelled with 90% enriched uranium, and has an output of 100 KW.

Radioisotopes in biological research

Radioisotopes and radioactive "labelled" compounds can be detected, even when they are present in biological material in infinitesimal quantities, thanks to the radiation they emit. They are therefore a precious aid to biological research: it is for instance possible to trace the use made by a plant of a particular nutrient by "labelling" it with a radioactive isotope. The increasing interest in this new tool calls for a constant awareness of instrument development to suit the requirements of the biologist. Indeed improvements in the methods of detection have to be sought continuously, not only to allow detection of smaller and smaller quantitites in smaller and smaller samples, but also to insure the accuracy of the information given.

The scope of the soil-plant research carried out at the Association's Institute aims primarily at ascertaining the mechanism of absorption and accumulation of inorganic chemical substances by plants. It therefore includes studies of root and leaf absorption and studies on movement of these elements in the soil (Figure 9). While contributing accurate information on the fate of nuclear fission- and waste-products in the "food chain" of man, the projects under way concentrate on the uptake and utilisation of chemical elements essential for plant growth. The practical aim of this research is to develop better fertilisers and better methods of applying them, as well as to learn more about the physiology of plants.

The Euratom/ITAL Assocation has, besides standard devices such as Geiger-Müller-counters, liquid scintillation counters or γ-spectrometers, equipment specially designed and constructed in its own workshop-facilities for specific purposes. Efforts have been successfully made to measure very low activity present in plant material, for instance in order to follow the deposition of radioactive nuclides on vegetation after atomic explosions.

The application of semi-conductor radiation absorbers is also currently studied. They offer the possibility of distinguishing γ-rays from β-rays and even of distinguishing between β-rays of different energies. These advantages, coupled with their very small size, make these instruments very attractive to biologists.

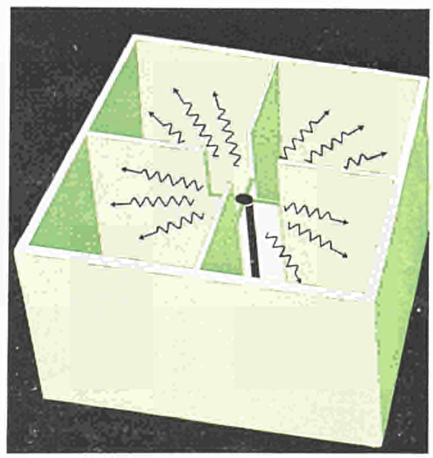
Photographic tracing of isotopes or "autoradiography" is a method often used by biologists of the Euratom/ITAL Association. The method relies on the fact that a photographic emulsion is sensitive not only to light but to all kinds of radiation.

A typical experiment might run on these lines: a plant is given a nutrient labelled with a radioisotope which it absorbs through the roots; after a time, the plant is sacrificed and an autoradiograph of one of its leaves is made; the picture will show whether the labelled substance has reached the leaf and, if so, in what parts of the leaf it is localised.

It is only too easy to obtain fallacious autoradiographs. Therefore improvements are constantly sought in the preparation of the material before exposure and in the method of ensuring contact of the emulsion with the material during exposure. For instance, experience having indicated the necessity of freeze-drying the plant material in order to obtain accurate results, facilities are now available for that purpose at the Institute.

Special facilities for the growth of plants under controlled environmental conditions make it possible to obtain uniform biological material for experimental purposes. When completed, the laboratories will dispose of a total area of 170 m² where temperature,

Figure 8: The gamma irradiation facility of the Euratom/ITAL Association.—The gamma irradiation facility allows for research with bulbs, plants and seeds in differing conditions of humidity, temperature and artificial light. The building is unusual in that it comprises four cells sharing a common radioactive source which moves along a vertical axis. The source comprises 3,000 effective curies of caesium-137.

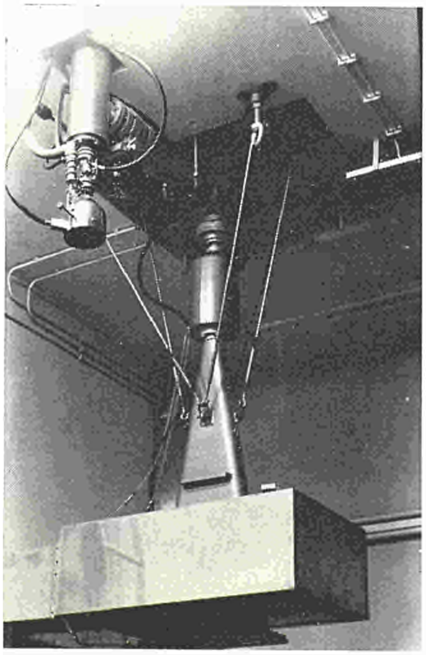


humidity and light intensity can be altered at will to suit the requirements for optimum growth of various plants. The installation will allow the safe use of most isotopes at doses too high to be permitted in a standard laboratory.

Preservation of food

Radiations can be used with success in the fight against spoilage of food products, first of all because they can kill bacteria. However they may also have a direct effect on the food product, by modifying its physiological development, for instance by bringing about delays in ripening and inhibiting cell growth. These facts have led food technologists to seek new possibilities in their field by using irradiation.
The effects of relatively low doses of ionising radiations on perishable food, in particular localised doses such as surface irradiation or so-called "pasteurisation" of only some layers of the product, have been investigated with relative success. The advantages of not treating the entire product are obvious, since possible induced chemical changes are restricted to the surface and cost of treatment is lower. This approach has been considered most promising and is being investigated at the Euratom/ITAL Association.
Besides technological questions and the immediate prospects of extending the shelf life of soft fruit such as strawberries, the fundamental physiological aspects of the problems involved will be examined. The general metabolism of the fruit and vegetable as influenced by radiation will be considered *per se* and in its effect on the micro-organisms responsible for its normal spoilage. Some of the work is being carried out in collaboration with the Institute for Research on Storage and Processing of Horticultural Produce, Wageningen.
Facilities available at the Euratom/ITAL Association in Wageningen have been designed to cope with this initial research programme and the subsequent developments which can be expected. A Van De Graaff electron generator with a wide voltage range[1] is available (Figure 10). Uniform radiation of a large object may be achieved with the equipment available by "scanning the beam" backwards and forwards.
75 m³ of storage facilities are also available in which temperature and relative humidity can be varied as desired for experimental purposes within ranges of —5 to +35°C and 40—95% respectively.

Figure 10: The Van de Graaff electron accelerator of the Euratom/ITAL Association's Institute. The accelerator is used in conjunction with an endless belt system of adjustable height carrying the material to be irradiated. It is used for determining the effects of irradiation on food products at various doses.



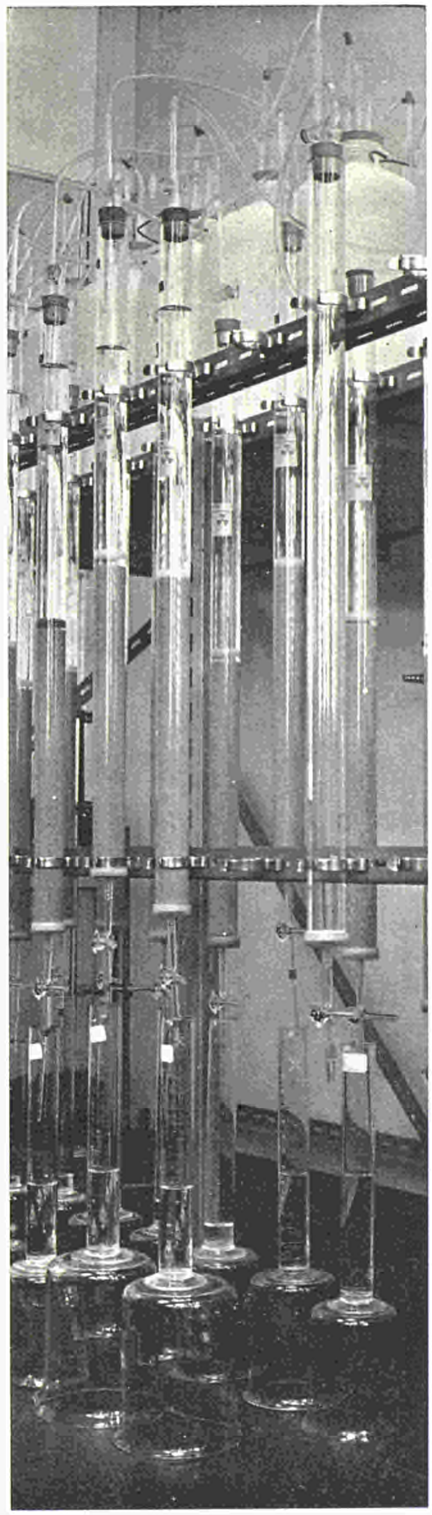


Figure 9: Experimental set-up for the study of movement of inorganic salts in soils. The columns are filled with soil, sand or resins or mixtures of the last two. The top 2 cm layer has been labelled with strontium-85 or strontium-90. A leaching solution can be introduced at the top to simulate rainfall. The flow-rate can be adjusted up to a maximum of 15,000 mm per year.

1. The range is 0,5 — 2 million Volts. The maximum dose rate obtainable is 40.000 rads/second for electrons and 12.000 rads/hour at 1 meter distance from the target for X-rays.

Sub-contracts of the Euratom/ITAL Association

Some sectors of the Euratom/ITAL Association's programme are investigated through sub-contracts let to other institutes in the European Community. This not only completes the programme of the Association but contributes to an efficient use of existing European facilities, thus making for integration on an European scale of research in the Association's field.

In 1963 approximately 250,000 dollars were allocated for work on genetics, on the study of the living cell and on food technology through such sub-contracts.

In 1964, this sum is expected to show a further increase. In June 1964, the following sub-contracts were under way:

Food technology

"The Application of ionising radiation for increasing keeping quality of horticultural produce"

Instituut voor Bewaring en Verwerking van Tuinbouwproducten — Wageningen, the Netherlands.

"The genetical hazards of irradiated food"—

Université de Liège, Centre Interfacultaire des Sciences Nucléaires, Laboratoire de Génétique —Liège, Belgium.

Mutation Breeding

"Effects of radiations and chemicals on different stages of the ontogenetic cycle in higher plants";

"Experimental mutagenesis in *Triticum durum*";

"Studies on the radiosensitivity of plants" -

Comitato Nazionale per l'Energia Nucleare, Centro di Studi Nucleari della Casaccia— Rome, Italy.

"Embryo-endosperm relations in irradiated seeds"

Istituto Botanico della Università di Cagliari (Sardinia), Italy

"Mutagenic changes in the vernalisation pattern (including daylength and temperature reactions)"

Instituut voor de Veredeling van Tuinbouwgewassen—Wageningen, the Netherlands.

"Mutation research on peas, bush beans and potatoes"—

Stichting voor Plantenveredeling—Wageningen, the Netherlands.

"Investigations about pleiotropy and expressivity of mutated genes"—

Institut für landwirtschaftliche Botanik der Universität Bonn—Bonn, Germany.

"Comparison of the mutagenic effect of X-rays, gamma rays, neutrons and ethylene methane sulfonate (EMS) on peas and tomatoes";

"Fundamental radio-cytogenetic investigations";

"The induction of point mutations in potatoes";

Landbouwhogeschool — Wageningen, the Netherlands.

"Utilisation of mutations in plant breeding

a. Significance of micro-mutations in barley and wheat;

b. Significance of macro-mutations in barley;

c. Diploidisation of autotetraploid barley"—

Max-Planck Institut für Züchtungsforschung —Köln-Vogelsang, Germany.

EUBU 3-14

Induction of mutations in barley at various stages of development

A contribution to the induction of artificial mutations in plants

Dozent Dr. HORST GAUL, *Max-Planck-Institut für Züchtungsforschung, Köln-Vogelsang, Germany*

There are no doubt farmers who are unaware that some of the crops they grow are mutants obtained by exposure to ionising radiations. They may be equally unaware of the time and effort which many research workers are spending on developing the new method of breeding these artificial mutants.
The new method has great advantages as compared with conventional breeding techniques. Above all, it can produce new and better varieties in a much shorter time. In future it may prove a revolutionary supplement to conventional methods or perhaps even supersede them to a large extent, thus helping to solve the problem of the future feeding of the human race through larger and better harvests.
On the other hand, the new technique still involves a number of drawbacks, some of which are extremely serious. Work is currently proceeding with particular intensity in many research institutes throughout the world in order to establish a theoretical basis for the improvement of mutation breeding.

There are already many clear indications of the great practical importance of radiation-induced mutants. For example, the short-talked variety of barley "Pallas" can yield more than the mother variety. Thanks to its short culm it is less subject to lodging, in other words it is much less easily bent or beaten down by rain. It can therefore be given larger applications of fertiliser, particularly nitrogen. With other varieties high nitrogen applications have to be avoided in spite of the fact that they mean a larger yield, because otherwise the barley lodges. The Pallas barley was bred in Sweden. Although it only came on the market recently it has speedily ousted other varieties in rainy England for example, last year occupying 20% of the total barley-sown area.
There are yet other radiation-induced barleys which are being widely sown, and similar examples could be given for other cereals and for quite different crops such as peas, beans, rape, mustard and peanuts.
It will be sufficient to mention the new bean-variety "Sanilac", which has attained great importance in the United States. It is an example of the combination of a traditional method of breeding with mutation-induction. An early-ripening mutant produced by ionising radiations was crossed with breeding-nursery lines which were resistant to a dangerous fungus disease (Colletotrichum lindemuthianum). The new variety "Sanilac" obtained from these crossings is both early-ripening and disease-resistant; in addition it yields more than the "Michelite" variety from which the mutant originated.

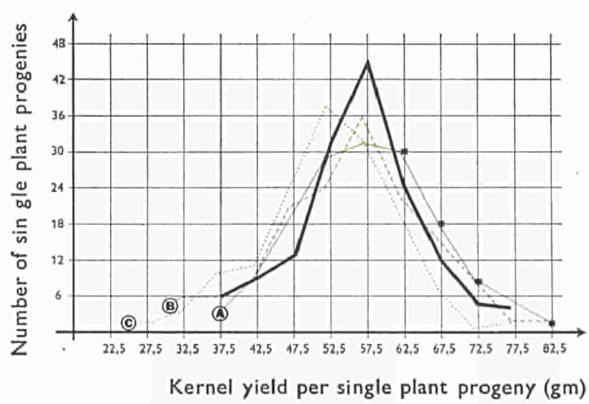


Figure 1: Results of an experiment on grain yield after irradiating barley plants. Each of the four lines represents the yield results of 150 individual plant progenies. The black line corresponds to the variability of the (unirradiated) mother variety. The three coloured lines represent the radiation-induced variability. (A=irradiated before meiosis, B=irradiated at pollen stage, C=irradiated at zygote stage).
It is interesting to note that yield variability appears to be both positively and negatively influenced (as compared to the mother variety) when irradiation is applied before meiosis; in contrast to this, both post-meiotic irradiations gave rise to predominantly negative mutants (with lower yields than the mother variety).

Following the discovery of the mutagenic action of ionising radiations in 1927, it was believed that mutations occurred completely at random. It has since become clear that this is not always true, and that a certain amount of control of the mutation process is possible.
Irradiation produces mutations by affecting the *chromosomes* which are present in the living cell and which contain the *genes* which determine hereditary characteristics. Two fundamentally different types of mutation can be observed: either the chromosomes are broken, after which the fragments are lost or rearranged to form new chromosomes with an altered structure *(chromosome-mutations)*, or the genes themselves are altered *(gene-mutations)*.

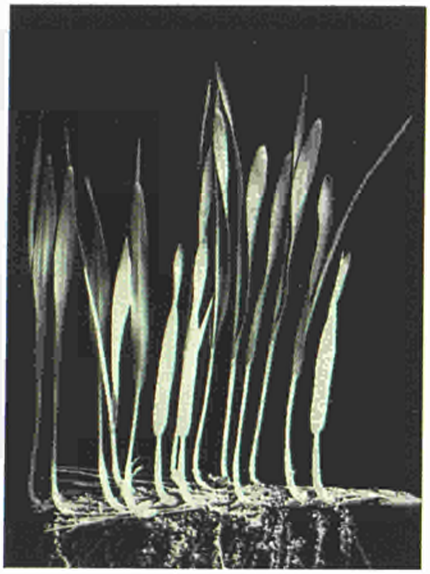


Figure 2: Mutants germinating from a barley spike.
The barley spike is grown from irradiated seeds. The spike was laid for germination in a sand bed and originated, apart from 10 normal green plants, four chlorophyll-deficient pale green mutants.

Experiments carried out on barley have repeatedly shown that treatments given in addition to irradiation can lead to differences in the ratio between each type of mutation (i.e. between chromosome- and gene-mutations). It has also been shown that they could alter the spectrum of gene-mutations and thus favour the emergence of definite groups of mutants showing particular characteristics.

What type of additional treatment can alter the effect of ionizing radiation? There are first of all a number of physical and chemical agents such as heat, colchicine and carbon dioxide, to mention only a few. These "secondary factors" may be applied before, during or after irradiation.

Recent experiments carried out at the Max-Planck-Institut für Züchtungsforschung, under contract to the Euratom/ITAL Association, have shown that purely biological factors, and in particular the stage of development of the irradiated plants may also alter the gene-mutation spectrum.

Barley spikes were irradiated with a cobalt-60 source at three different stages of development, before and after meiosis. Plants were then grown from the seeds which formed in the irradiated spikes. It is well-known that these plants show so-called primary radiation injury, but as yet no specific mutation characteristics. For genetic reasons mutants segregate for the first time in the following generation. In order to recognise and record these mutants, the spikes obtained from the seeds were made to germinate on a sandbed (see fig. 2). In experiments of this type, some spikes segregate seedlings which exhibit chlorophyll deficiencies e.g. these seedlings are white, yellow or light-green. They have partly or completely lost the ability to form chlorophyll. Table 1 summarises the results of the experiments. For purposes of comparison, the results have also been given of many previous seed irradiation experiments.

It can be seen from the Table that many more white mutations (indicating complete loss of the ability to form chlorophyll) occurred when the seed itself was irradiated than when irradiation took place at the stages before and after fertilisation of the egg cell which precede seed-formation.

From a practical angle, plants with chlorophyll deficiencies are of no interest. They are, however, useful to the scientist because they are mutations which can be spotted and classified easily. Chlorophyll mutation frequency serves as a test reaction for the efficiency of the treatment applied.

Most of these chlorophyll mutants die off. Mutants which survive are of course much more important for practical breeding purposes.

It has now been indicated that large mutative changes—even when they lead to fully viable plants—are of minor interest. They may indeed transform a "soft" into a hard or a susceptible into a resistant variety, but the creation of this one valuable characteristic is normally accompanied, with some exceptions, by a general lowering of yield. We believe that small mutations, particularly those affecting yield or quality, are more important than the drastic ones.

Investigations on small mutations, such as are being carried out in our laboratory, are lengthy, since several generations must be grown before definite conclusions can be drawn. Fig. 1 gives some of the results obtained to date. They indicate—as was to be expected—that many harmful mutations have been induced, but that some mutants apparently have a higher yield than the mother variety, as can be observed on the right-hand side of Fig. 1.

The Figure shows that a specially high proportion of poor (lower-yield) mutants was observed when irradiation was carried out *after* meiosis.

Against this it can be seen that irradiation *before* meiosis produced approximately equal numbers of positive and negative mutants—if this finding is considered to be reliable. This favourable result contrasts not only with those obtained for irradiation after meiosis, but also with those which we have obtained in numerous experiments on the irradiation of mature seeds. A point of quite special interest is that—as we have seen—irradiation before meiosis also led to the smallest number of white (i.e. particularly badly-damaged) chlorophyll mutants.

These data require confirmation. Therefore the investigations bearing on yield will be continued through the following generations. One of the practical aims will of course be to isolate those mutants giving the highest yields.

Table I. Spectrum of chlorophyll mutations after irradiation of barley spikes with a cobalt-60 source.
Irradiation took place at three stages of development before and after meiosis (before and after fertilisation of the egg cell, i.e. at stages preceding seed formation). For comparison, a summary of the results of seven experiments involving X-radiation of seeds is also given.

Stage at which irradiated	Proportion of different mutations (%)			Total number of mutations
	white	light green	others	
Directly before meiosis	15.9	59.8	24.3	214
Pollen stage (after meiosis)	22.2	47.9	29.9	528
Zygotes (immediately after fertilisation)	22.6	48.5	29.0	359
Seeds	36.9	44.5	18.6	3.452

EUBU 3-15

Using radioisotopes to study plant growth

EMILIO LEVI, *Euratom/ITAL Association, Wageningen*

Conservative estimates indicate that the world total food production must be doubled by 1980 and trebled by the year 2000. This is not only to cope with increases in world population, but also to feed more adequately the present one. Professor Cépède of the *Institut agronomique* in Paris, Lord Boyd Orr and others have estimated that today approximately two thirds of the world suffers from hunger, ranging from malnutrition to actual starvation.

The role of agriculture in solving this problem is obvious. For thousands of years, man has attempted by trial and error, or more recently through careful experimentation, to increase plant and animal production and reduce spoilage. Besides introducing more method into the trial and error procedure, which is perhaps more spectacular, scientists have also been striving to acquire a deeper understanding of nature in order to exploit its mechanisms more fully. It can be stated quite safely that our knowledge of the laws which govern the growth and development of plants, for instance, is far from complete today; only a firm grasp of them will allow us to plan for our future well-being.

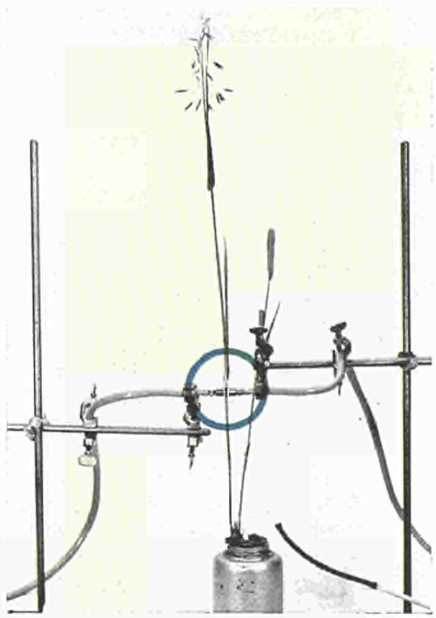
Plant growth is, broadly speaking, influenced by two factors, a genetical one, which is inherited and specific, and an environmental one, which is variable. The environment in turn includes factors such as light, temperature, chemical element supply etc., each of which plays a role, interlocked with all the others, affecting ultimately plant growth and reproduction. Soil scientists, botanists and plant physiologists are still attempting to understand the fundamental links between plants and their environment. It is true that what is perhaps the most important process in plant growth, photosynthesis, by which green plants use the sun's energy to form compounds essential to their life from air and water, has been largely unravelled, in particular by Calvin, using carbon-14, a radioactive isotope of carbon. Yet other processes are either superficially known or are still the subject of controversy.

Radioisotopes have been a great help to agricultural scientists to study, explain and attempt to control various biological, physical or chemical processes going on in soils and in the roots of plants taking up nutritive chemicals. The movement of these chemicals as such or in the form of compounds in tissues within the plant and their role in cell growth are also subjects of active research in which radioisotopes are used constantly with success.

However, the advent of nuclear energy has also placed man in front of a new problem. Atomic accidents, as well as the disposal of radioactive waste, may affect food supply if harmful nuclides are picked up and transported in the soil-plant-animal-man cycle. Although the problems involved are obviously complex from a health physics point of view, from an agricultural point of view they are directly related to the basic studies scientists have been carrying out. The problems involved in assessing amounts of iodine, caesium or strontium found in plants following nuclear accidents are not basically different from those posed by the study of the absorption and movement of elements essential for normal plant growth. For instance, trying to find out how radionuclides penetrate through leaf surfaces involves the same kind of research as trying to improve the utilisation of leaf applied fertilisers, weed killers or insecticides. The movement, availability and uptake of any mineral element from the soil are governed by physico-chemical laws which do not discriminate the origin of that element.

It is clear therefore that any acquisition to our knowledge of plants and their environment will allow us to interpret and suggest remedies for specific cases of artificial contamination.

Since it is practically impossible to alter



the climate in which plants grow, the mechanisms governing the uptake and utilisation of nutritive elements are, besides genetical considerations, the main focus of research.
Root nutrition is the most easily controlled factor and therefore much attention has been paid to the distribution of the root system itself in the ground, and the distribution and transformation of chemical compounds in the soil and their use by plants.
Some of the first experiments using radioisotopes dealt with the absorption of phosphorus by crops. They indicated a hitherto unknown fact. Plants use about 50% of the phosphorus applied as fertiliser and only 10% of that in the soil. When fertilisers are applied, plants take up more phosphorus from the soil itself than if no fertiliser were added.
Similarly, the problem of how to apply fertilisers to growing crops was studied with much more success using radioisotopes than when only conventional chemical methods were available. It was found, for instance, that phosphatic fertiliser present only 3 to 4 centimetres below the seeds will be utilised within a few days, giving a rapid strong growth, whereas placed deeper, or even 5 centimetres aside, they will only be used weeks later, with consequent delays in crop growth. Previously held opinions in both cases had to be modified following these experiments.

Figure 2. Beans growing in an aerated nutrient solution under controlled temperature, humidity and light conditions.
During an experiment the turntables are made to rotate so as to eliminate the effects of slight differences in temperature and light intensity from one point of the chamber to the other. The turntables also make for easy handling of radioisotopes.
Foliar and root uptake experiments are currently carried out at the Euratom/ITAL Association's Institute in connection with studies on the mechanisms involved in plant growth.

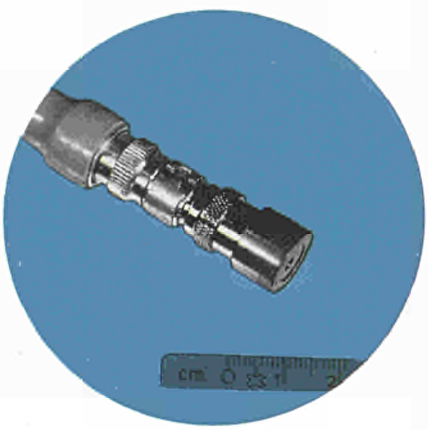


Figure 1. Semi-conductor detectors used to measure in vivo *radioactivity in plants.*

In regions where low temperature of the soil prevents normal penetration of substances through roots, leaf application of fertilisers becomes advisable. In the past ten years this practice has been extended to crops grown in temperate regions, particularly in the United States, because it can be mechanised, or on the assumption that the fertilisers were better utilised in this way since the leaf area is very large and food may be transported directly to the fruit from the leaves. Although this matter is still open to controversy, radioisotopes have allowed it to be studied in details not possible before. We can now see and measure accurately the penetration of labelled chemical elements, their path to the conducting system and their distribution in the rest of the plant. Autoradiographs, made by placing the plant material containing the radioisotope in contact with a photographic emulsion, give a clear picture of the distribution. On the basis of the visual images it is possible to determine more exactly the pathway of penetration and transport from the point of application and the value of theories established as working hypotheses.
It was for instance found, through experiments carried out under controlled conditions at the Institute of the Euratom/ITAL Association in Wageningen, that only a very small fraction of water solutions of phosphorus or caesium salts applied to bean leaves is actually used by the plant. The major part is either removed by washing or rain, or held in the treated leaf without further significant release to non-treated parts of the plant.
While this new information is of an encouraging nature in the study of contamination problems, it is obvious that for better utilisation of chemical fertilisers, insecticides or weed killers supplied to plants through leaf applications, it is necessary to influence the two factors mentioned, for instance by adding various compounds such as wetting agents.
The proper nutrition of various parts of

plants and the accumulation in their tissues of elements that may be reutilised later are directly connected with our knowledge of the movement of simple or complex substances in plants as well as their direction, speed and composition. Again, the use of radioisotopes has greatly helped the study of these problems.

Despite the static nature of plants, physiological processes occur in them at very fast rates. They are able to send to regions of utilisation substances manufactured or stored elsewhere in a matter of minutes. Water has been reported to move at a rate faster than five metres per hour while sugars formed as products of photosynthesis move at 60 centimetres per hour or more.

These values have raised controversies since they may prove or disprove long accepted theories. The use of very sensitive radiation detection equipment, such as semi-conductors, offer possibilities for *in vivo* measurements which, it is hoped, will help to clarify the problem. Encouraging results have been obtained with these detectors in preliminary experiments carried out at the laboratories of the Euratom/ITAL Association.

It will thus be possible, by improving our knowledge in this field and by finding solutions to various complex problems of cell development and plant anatomy, to supply crops, without waste, with the elements they need at a particular moment to increase the yield of their comestible parts. However, crop production cannot be discussed today without considering protection from insects or diseases and competition from weeds for light, water and nutrients. In pest control studies, which have to be based on the same mechanisms as those involved in crop production, labelled compounds are used to a very great extent and have already led to considerable increases in the yields of arable land or pastures.

The accurate detection of infinitesimal quantities of chemical substances in plants and soils through proper handling of radioisotopes or labelled compounds, coupled with the development of experimental facilities for controlling environmental conditions, offer to agricultural scientists today possibilities that could not have been imagined 30 years ago. It is however necessary to state that for botanists, plant physiologists or soil scientists, more than just radioisotopes and refined electronic measuring devices are necessary. Experiments must be carefully designed to prevent errors and to rule out the emergence of secondary phenomena which can mask the truth. Above all there is a need for close collaboration of scientists from different disciplines. Only in this way can we increase our knowledge of plant life on which we depend if we aim at making every day a day with bread for the population of the world.

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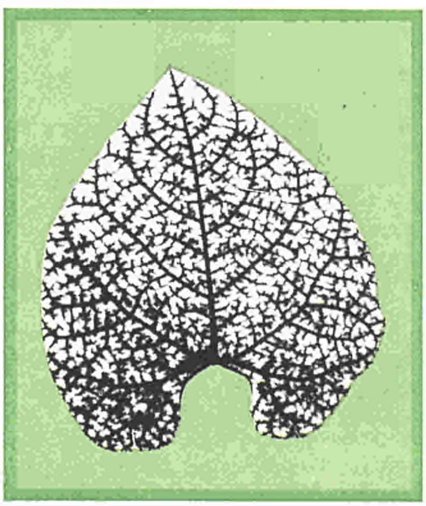

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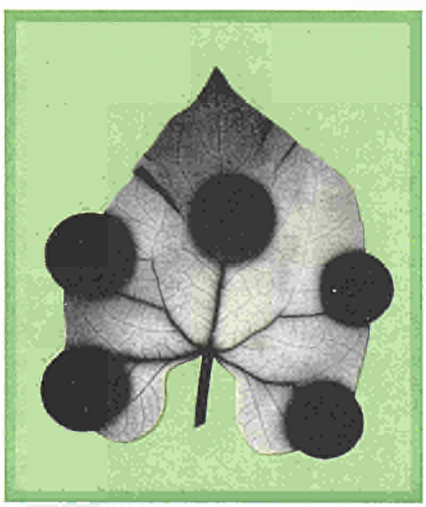


Figure 3. Bean leaf containing calcium-45 absorbed through the roots.

Figure 4. Bean leaf showing downward transport of 5 drops of phosphorus-32 applied to its upper surface. To be noted are the transport of the substance in the vein system and its presence in the tissues, unlike figure 3.

EUBU 3-16

Food irradiation — an improvement to human diet

D. DE ZEEUW, *Euratom/ITAL Association*

In the constant struggle to supply food to man, two clear problems appear, namely food production and food storage and distribution. Both problems are equally important and therefore require equal attention. However, this has not been the case in the past and the result is that while sufficient food is produced to feed most men, the population of the world is generally under- or mal-nourished because of lack of adequate storage and distribution systems and facilities.

All our food begins to deteriorate shortly after it has been harvested, gathered or slaughtered. This breakdown is mainly the result of its decomposition and its subsequent use as an energy source for micro-organisms. There is definitely a competition between man and micro-organisms as to who will consume the food first. The useful storage life of fresh untreated plant and animal tissues at various temperatures is given in table 1. Although some fruit and root crops keep considerably longer than other edible products, it should be borne in mind that these fruit and root crops are normally harvested only once a year; it is clear that for their adequate distribution, in particular to distant places, good methods of preservation are still required.

Among the various methods available to man since he first discovered drying and smoking, are canning, freezing and, more recently, irradiation. Preservation by means of ionising radiations occupies a special place for it meets more or less the ideal goals of the trade, that is retention of the natural or fresh characteristics of the food product. This is due to the fact that radiations can kill bacteria without, as in the canning process, for instance, leading to appreciable temperature increases in the product.

Another advantage of radiations is their physiological action on living tissues, for instance retardation of ripening processes in fruit, inhibition of cell elongation (and thus of sprouting in some vegetables), sterilisation of harmful insects responsible for the infestation of grain, etc . . .

Before evaluating this method of food preservation accurately one should however state that doses of more than 500.000 rads often cause unacceptable changes in the physiology and therefore appearance and quality of the products treated.

Furthermore the possibilities could not be evaluated without a word about their hazard to man. Research to-date shows that irradiation at the doses required for commercial usefulness has no harmful effects. No induction of radioactivity nor formation of toxic or carcinogenic substances was found in irradiated food products. The Canadian and United States Public Health Authorities have in fact, after much research, authorised the marketing of γ-irradiated potatoes and pre-cooked bacon. A favourable decision is expected in the United States for the marketing of irradiated wheat. Similar authorisations are expected in the United Kingdom for irradiated cereals and eggs.

As far as nutritive value is concerned, it has been shown that in general no noticeable reduction occurred following irradiation. When it did occur it was no greater than that produced by more classical methods of food preservation.

Much research has been carried out in the last twenty years to evaluate irradiation as a tool for food preservation. It would be too long to enumerate the products considered throughout the world but some concrete results have been already obtained. They can be summarised as follows:

Sprout inhibition in potatoes and onions:

Commercial application of ionising radiations for sprout inhibition is very advanced in Canada and Russia. Other possible methods give the same results but are not always allowed because of health hazards. Encouraging results have already been obtained with low dose irradiation treat-

Food	Average useful storage life (days) at		
	32°F	72°F	100°F
Animal flesh	6-10	1	Less than 1
Fish	2-7	1	Less than 1
Poultry	5-18	1	Less than 1
Fruit	2-180	1-20	1-7
Leafy vegetables	3-20	1-7	1-3
Root crops	90-300	7-50	2-20

* Desrosier, N.W.; Atompraxis (1960) 8, pp. 293-300.

Table 1 Useful storage life of fresh untreated plant and animal tissues at various temperatures*

ments and the method is attractive economically. An interesting possibility of extending the storage life of pre-fried potatoes, the famous "patates frites" of Belgium and the Netherlands is being investigated. The sprout inhibition obtained in onions is also spectacular, in particular when the need exists for shipping stored onions in late seasons. The hope of controlling neck-rot disease at the same time has not been confirmed sofar.

Extension of shelf life of fresh fruit and vegetables:

The possibilities offered by irradiation in this respect have been investigated extensively in many countries. Much interest is devoted to them in the United States, where a γ pilot plant is at present under construction. In Europe, research in France, Italy, the Netherlands and Sweden has confirmed that the possibilities are real. In fact this appears at present to be the only method, and its high cost is not a drawback since in general the product is highly priced. The two most spectacular results recently obtained in the Netherlands have been with strawberries and mushrooms. In the latter case the panel of tasters, to the surprise of the experimenters, went unknowingly as far as preferring the taste of the irradiated product. Possibilities offered for the storage of other vegetables and hard fruit such as apples and pears are being investigated with varying success sofar.

Insect control in cereals and flour products:

Pilot plant applications of ionising radiations are in an advanced stage in various countries, in particular India, for the control of insects in grain. Indeed, although chemical insecticides exist and have been applied, their use is not totally satisfactory and an alternative method may have very great advantages.

Milk products such as prepacked cheese have shown advantages when irradiated.

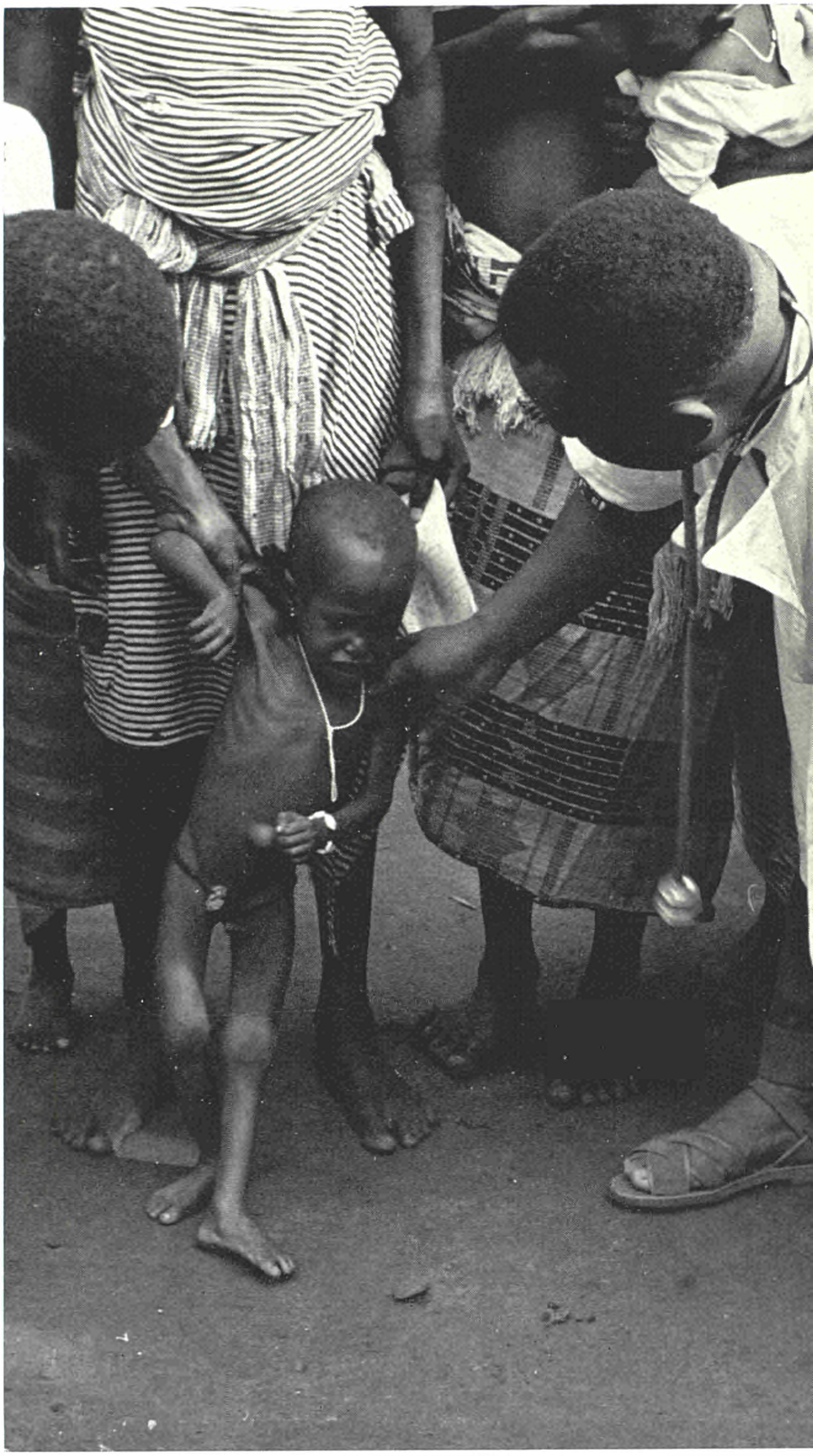
Control of the dangerous *Salmonella* organisms in *eggs, egg product and fish meal* is thoroughly investigated and in particular in the Netherlands and the United Kingdom. Commercial applications of radiations for the preservation of these products are in an advanced stage. It is worth adding that except for liquid egg products this is the only conservation method possible.

As far as *fish and fish products* are concerned, extension of the storage life of the fresh product is most encouraging when combined radiation and cold storage treatments are used. Practically all countries interested in fisheries considered the possibilities offered, and the results are so encouraging that a pilot plant is under construction in the United States. The prospects of extending the shelf life of cooked or smoked fish are also being investigated.

Although commercial applications of radiations for the extension of storage life of bacon have been carried out in the United States, it is true to say that, so far, only a small number of *meat products* have shown good prospects. The improvement of the quality of salted canned ham by means of radiations is an interesting possibility at present actively studied in Denmark.

This broad and necessarily superficial survey of the potentials offered to man by ionising radiations to avoid spoilage of food aimed primarily at stressing that they do in fact exist.

With the industrialisation of agriculture, not only higher yields are obtained but in some cases continuous production throughout the year is economically possible; the most obvious examples are chicken, eggs and mushrooms. The potentialities open to a hungry world are not for chicken with mushrooms being available in one place for 365 days every year, but for their unhampered and continuous distribution as and where required, together with a large list of other commodities necessary to man's diet, diverse as it is for his habits and pleasures.



EUBU 3-17

Irradiated mushrooms taste better

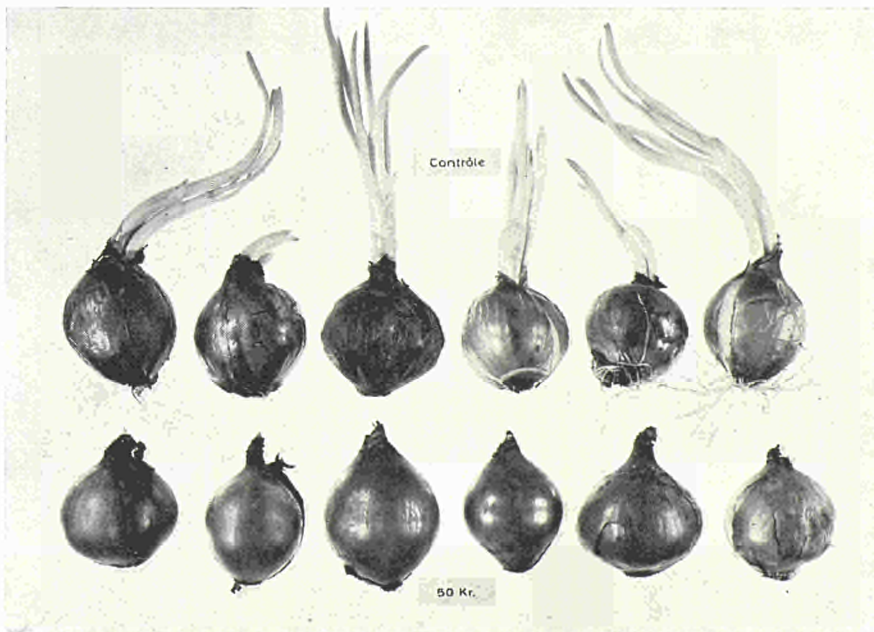
OSCAR L. STADEN

Institute for Research on Storage and Processing of Horticultural Produce, Wageningen

In a combined effort between the Institute for Research on Storage and Processing of Horticultural Produce (IBVT) and the Euratom/ITAL Association, a large screening programme was initiated in 1962 for the investigation of possibilities offered by irradiation for lengthening shelf life of fruit and vegetables.

This programme, while taking into consideration the knowledge already acquired in earlier research in Europe and the United States, concentrates on what is considered to be a more promising possibility for fruit and vegetable conservation: surface treatments. Hard penetrating radiations have been used extensively since early investigations were started in this field, but the use of low penetrating rays such as 1 MeV electrons seemed to offer advantages inasmuch that they could affect only spoiling organisms present on the surface of the material considered without influencing the edible part, the flesh.

Spoilage of soft and hard fruit can be considerable and it has been known to be responsible for the loss of very high percentages of the total produce. The same applies to some vegetables. It was therefore considered of great practical importance to try and improve the keeping characteris-



Effect of irradiation on onions (variety "Rijnsburger") after treatment with 50 krads and 3 MeV. Photo taken 6 months after storage at 10°C.

Effect of irradiation on mushrooms (variety "Darlington") following treatment with 100 krads and 3 MeV.
Photo taken 4 days after storage at 15°C.

tics of such products, even for the relatively small number of days necessary for them to reach the consumer from the producer. The products investigated in this programme varied from fruit such as apples and strawberries to prepacked and pretreated vegetables such as "sauerkraut". A wide range of dose treatments was considered in order to ascertain accurately the effect of irradiation on the vegetable product and the contaminating organisms.

Conditions of treatment had to be adjusted for each product and results of objective measurements and panel tests were compiled.

Differences in the composition of the skin and the flesh of fruit and vegetables would lead to expect differences in response to irradiation. This was confirmed by experimental results and it can broadly be stated that each product has its own peculiar response. The sensitivity of spoiling micro-organisms to irradiations also varies considerably. Some may be killed at doses causing damages to the product, while others may be retarded in their growth or have their germination completely inhibited at doses even lower than necessary for lengthening the shelf life of the fruit or vegetable studied. It is obvious that to be of economic value the irradiation treatment must offer an inhibition of the spoilage without reducing the quality of the product. This is tested by looking out for differences in colour, firmness and flavour between treated fruit or vegetables and identical samples which are not treated and stored in the same conditions.

The study of the effects of irradiation on apples constitutes an interesting example. Physiological diseases, such as scald, spot, flesh breakdown, etc. and parasitic infection, such as decay, badly affect the keeping quality of many varieties of apples. After irradiation, scald is avoided, spot is increased and flesh breakdown can be reduced . . . On the other hand, consumers prefer special varieties, each one because of some characteristic colour and taste. For instance some consumers prefer green apples. These varieties normally turn yellow when stored, but it so happens that one of the responses of the fruit itself to irradiation is that this change of colour is delayed.

Soft fruit has a very short shelf life; strawberries, for example, start decaying within a few hours after harvest. Therefore any increase in shelf life is an advantage both to the consumer and to the producer. Results yielded so far over a four year period by joint experiments carried out by the IBVT and the Euratom/ITAL Association in Wageningen indicate that this rapid decay can be overcome by irradiation of the fruit. Doses of approximately 250,000 rads have allowed a storage period at room temperature of 15°C of four days without influencing colour, firmness or flavour.

Irradiation is however not the cure-all of spoilage problems. Experience has shown that some vegetables, such as cucumbers and melons, were so sensitive that even very low doses caused damages. However, unexpected results sometimes appear. A panel of tasters offered irradiated and non-irradiated mushrooms indicated a definite preference for the flavour of the former! Consumers prefer mushrooms with closed caps and which remain light-coloured even after cooking. It was found that these characteristics were maintained even after storage when mushrooms were irradiated. The improvement of flavour found by the tasters is yet unexplained to the experimenter.

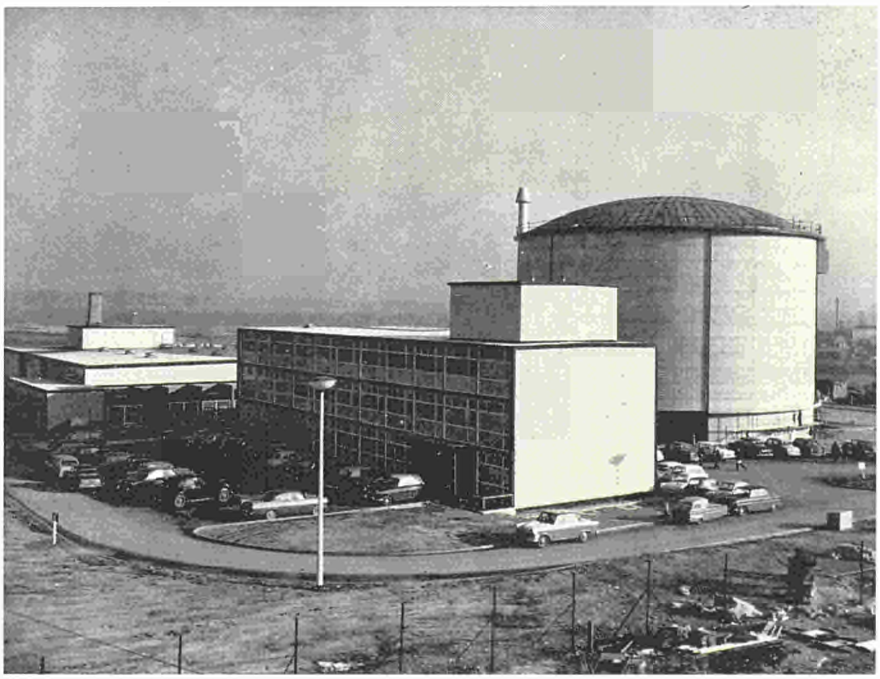
The encouraging results obtained so far on fresh fruit and vegetables suggest that it is well worth while trying to perfect irradiation techniques as weapons in the fight against spoilage of food products.

EUBU 3-18

How does the Dragon Project

The *Dragon* high-temperature gas-cooled reactor project has now been under way for over five years. The most spectacular achievement to date is the completion of the experimental reactor in Winfrith Heath, which went critical for the first time a few days ago.

At the same time patient research and development work has been gradually accumulating solutions to the challenging problems which the sponsors of the project had set themselves.



An additional objective

Two years ago the *Dragon* Project reached a turning-point. Not only were decisions taken to extend the initial five-year agreement setting up the project by an extra three years and to increase its funds, but a new outlook was written into the agreement in the form of an additional objective: thenceforth the Signatories were to be provided with *information leading to the design of an economic land-based, gas-cooled, carbon-moderated, high-temperature reactor.* The situation at the present time suggests that this practical turn was, and still is, justified. Fuel elements have been developed capable of very high burnups (of the order of 100,000 megawatt-days per ton of heavy metal in the fuel; this is to be compared with the 3,000-4,000 megawatt-days per ton of the natural uranium gas-cooled reactors of the current generation, and with the 10,000 megawatt-days per ton of natural-uranium heavy-water reactors.

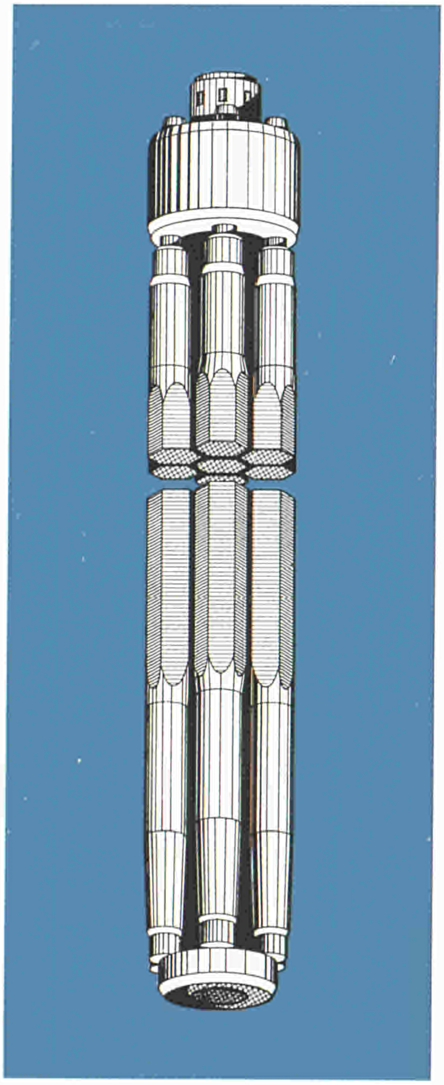
Let it also be said that one of the aims of the fuel element development programme was to devise means of cutting down the release of fission products into the primary cooling circuit to a minimum. This is a real problem: as there is no canning material as such, the graphite itself, which is a fairly porous material, has to hold back the fission products. This has meant coating the fuel particles, which are dispersed in a graphite matrix, in such a way that the fission products will as far as possible be unable to escape. It has also meant providing a purge circuit that could dispose of such fission products as will succeed in escaping from the fuel. During the course of the project, it was recognised that it was possible, and, naturally, interesting from an economic point of view, simply to do without this purge circuit: the pyrolytic carbon and silicon carbide coatings had indeed been improved to such a degree that the contamination of the primary circuit could not prevent direct access to it for maintenance purposes.

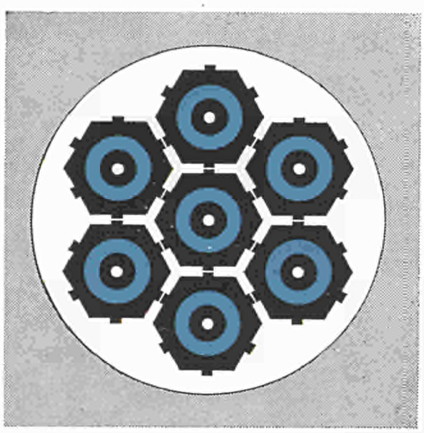
Other problems, such as those connected with the purification of the helium coolant, helium leak-tightness, the lubrication of moving parts in a very dry helium atmos-

stand?

PIETRO CAPRIOGLIO, *Director of the Petten Establishment of Euratom's Joint Research Centre*

MARIO DE BACCI, *Directorate-General for Research and Training, Euratom*





phere, etc. have found solutions which, even if far from completely optimised, are sufficiently satisfactory to make the design of a full-sized power reactor a practical proposition.

Cost of a full-scale reactor

During the year 1963, a preliminary design study was in fact carried out by two firms of the European Community, *AGIP Nucleare* of Italy and *Indatom* of France, under *Dragon* contract.

Calculations were based on a *Dragon*-type power reactor with an output of 1,250 megawatts of heat. In view of the high steam temperature (565°C), the thermal efficiency is high; at 42.5%, it compares favourably with the most modern coal-fired or oil-fired power plants and gives a figure of some 530 MW for the electrical output of the reactor.

Thanks also to other factors, such as the very high power density of the reactor, the excellent neutron economy (due to the almost complete absence inside the core of structural materials other than graphite), the compact character of the heat exchangers (the steam temperature of 565° C is low in comparison with the helium's outlet temperature of 750° C—which makes for efficient heat transfer), the results of the design study could show that the capital cost per kW installed worked out at about 145 dollars, "tender price". This figure compares quite well with those put forward recently for light water reactors of American type.

If a plant of double the quoted capacity were envisaged, using two 530 MWe reactors, this cost would tend towards 125 dollars, in view of the savings which would be introduced by making several of the auxiliary installations common to both reactors.

Figure 1. The Dragon fuel element.—The fuel element consists of a cluster of 7 rods, all consisting basically of graphite. The fuel-bearing part of each rod is shown in colour.

The fuel cycle

A word should also be said about fuel cycle costs. Enriched uranium carbide constitutes the basis of the reactor's fuel. However, it is mixed with thorium carbide with a view to permitting conversion of "fertile" thorium-232 into "fissile" uranium-233. This conversion phenomenon is based on the fact that the fission of one uranium nucleus produces several neutrons (about 2.5 on average) and that only one of these is actually necessary to maintain the chain reaction; the others, if they do not escape out of the system and are not absorbed, can therefore be put to good use for the generation of new fissile material.

A conversion process of a similar type occurs in the natural-uranium-fueled gas-cooled reactors of the current generation; in their case the uranium-238 isotope, which accounts for about 99.3% of the total amount of uranium present, plays the role of "fertile" material and a small portion of the uranium-238 is actually converted into "fissile" plutonium-239. One of the advantages of thorium, however, is that its final product (uranium-233) is a valuable fissile material, better than any other for thermal reactors.

A dilemma

As a matter of fact, it does not seem impossible to design a *Dragon* reactor in which the "conversion ratio" would be 1, in other words in which one fresh fissile nucleus would be produced for every fissile nucleus used up. However, this solution, highly attractive from the point of view of utilisation of natural resources, is less so today on economic grounds. Why? Because of a dilemma which is by no means peculiar to reactors of the *Dragon* type: one must decide, either to aim at high burnups and put up with a certain wastage of neutrons and fissile material, or to aim at optimum utilisation of fuel and put up with low burnups. Let us look at this dilemma as it affects *Dragon* reactors.

The first alternative is to use a core with a high surplus of reactivity. At the beginning of its life its reactivity is kept in check by introducing a considerable amount of neutron-absorbing material in the form of control rods. Thus many of the surplus neutrons produced by fission are simply wasted instead of playing a useful part in bringing about conversion.

On the other hand, thanks to its initial high surplus of reactivity, the core can remain in the reactor for a long time; all that has to be done, as its reactivity decreases, is gradually to withdraw the control rods. Under these conditions, a *Dragon* core should be able to show a burnup of some 100,000 megawatt-days per ton.

From a practical point of view, this solution is not unattractive: there is for example no need to reshuffle or replace fuel-elements constantly in order to maintain reactivity.

The other alternative consists in using a core with a small margin of surplus reactivity. In this case less absorbing material suffices to keep the reactor under control, leaving a greater number of neutrons available for converting thorium into uranium-233. Conversion ratios of the order of 1 are then quite feasible.

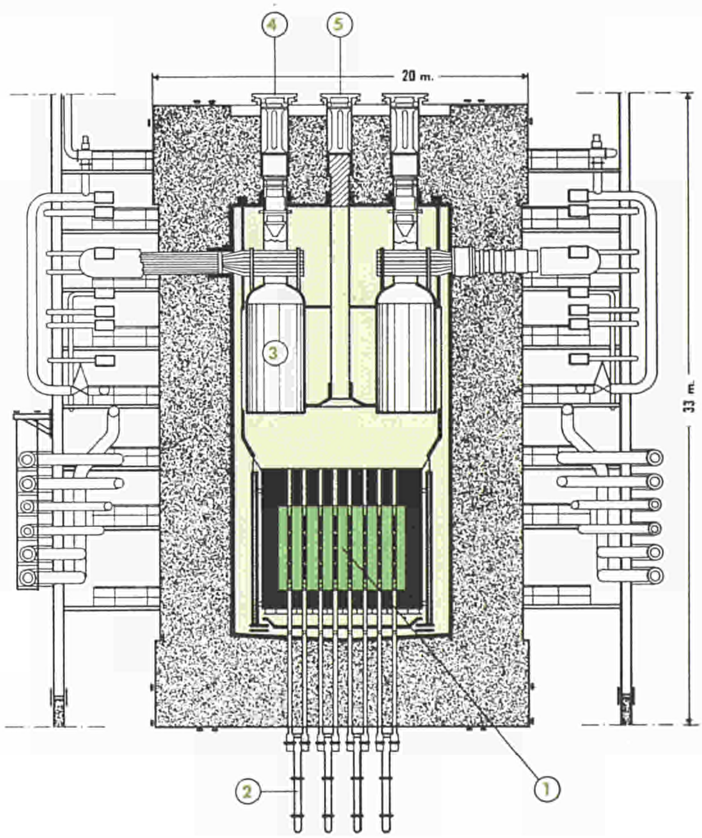
Unfortunately, the fuel-elements cannot be left in the reactor for very long: although the inventory of fissile material may remain constant, the build-up of neutron absorbing fission products will quickly exhaust the small amount of surplus reactivity initially present. At this stage, after a fairly low burnup, the fuel has to be reprocessed—and there is the rub. Reprocessing of radioactive materials is fairly elaborate and therefore costly. A reprocessing plant becomes an economically interesting proposition only if it is built on a large enough scale to serve the reprocessing needs of several reactors.

Nevertheless, this solution remains an ideal one on the long term view. The fuel cycle cost boils down, for all practical purposes, to the cost of reprocessing and refabrication, plus the interest on the initial fuel charge. An added attraction is that dependence on the enriched uranium market is confined to the initial fuel charge.

Fuel cycle costs

To come back to the *Dragon* preliminary design study: as the study assumed that one reactor only would be in existence, reprocessing was not considered. However, calculations of fuel costs were made on the basis of an optimised fuel cycle, allowing for a modest conversion ratio, in the region of 0.8, and for reutilisation *in situ* of as much

Fig. 2. Vertical section of a 530 MWe Dragon reactor.
1 Core. 2 Control rod driving equipment. 3 Heat exchanger. 4 Cooling gas circulator. 5 Shielding plug for charge/discharge machine introduction well.



as possible of the uranium-233 produced, followed by disposal, pure and simple, of the residue ("once through cycle"). This would make the fuel-cycle cost comparable to that of natural uranium reactors, in other words substantially lower than that of light water reactors.
There is no denying that the results of the preliminary design study are encouraging. The epithet "preliminary" protects it against the critics who might challenge its optimism. In any case the research and development work under way, coupled with the vital data which the operation of the experimental reactor in Winfrith will shortly begin to yield, should be decisive.

A few facts and figures about the Dragon Project

Sponsoring organisation: European Nuclear Energy Agency (ENEA) of the Organisation for Economic Co-operation and Development (OECD).

Signatories: Austria, Denmark, Norway, Sweden, Switzerland, Great Britain and Euratom (representing the six Euratom Member States).

Total cost of Project: £ 25 million (for the period 1 April 1959—31 March 1967).

Euratom share: 46%

Aim of the Project: The development of a gas-cooled, graphite-moderated high-temperature reactor.

Fuel: Enriched uranium and thorium carbide particles dispersed in a graphite matrix (see figure 1). Typical enriched uranium (93%)/thorium ratio—1/15.

Moderator and reflector: Nuclear grade graphite. As figure 1 shows, the graphite moderator is incorporated in the fuel elements themselves; it therefore acts as structural material at the same time.

Coolant: Helium. Envisaged outlet temperature is 750° C.

A few advantages of the system:

— *High efficiency*—The high outlet temperature of the coolant means that steam can be generated at temperatures and pressures as high as in the most up-to-date conventional power plants.

— *Conversion*—The absence of neutron absorbing structural materials entails a good neutron economy. Hence the possibility of converting "fertile" elements, such as thorium (a thorium-232 nucleus can capture a spare neutron and lead to the formation of a fissile isotope of uranium, uranium-233).

— *A compact reactor*—Only ceramic materials are present in the reactor core. As they can stand up to high temperatures, and no other materials (such as the metals used for canning in certain other types of reactor) set a lower limit to the temperature which is permissible in the core, it is possible to arrange for large temperature drops from the fuel-elements to the coolant. This gives good heat-transfer and therefore high power-densities (of the order of 10 MW/m^3). A compact reactor can thus be obtained, which is cheap to build because of the relatively small size of the pressure vessel and containment building required for a given power output.

— *Safety*—Another advantage of the omnipresence of ceramic materials: there is no risk of trouble over melt-down.

— *Compact heat exchangers*—The temperature difference between the helium coolant and the steam is almost 200° C. This makes for good heat transfer.

— *Replacement of graphite*—The fuel-elements contain within themselves all the constituents of the core (the fuel and the moderator). Whereas the graphite of the current gas-graphite reactors is put into the reactor at the beginning once and for all, that of a *Dragon* reactor is periodically replaced at the same time as the fuel. This constitutes an insurance against the risk of corrosion in graphite and against its tendency towards dimensional instability under irradiation.

What has been once published is spoken of as known, and it is too often forgotten that rediscovery in the library may be a more difficult and uncertain process than the first discovery in the laboratory.

Lord Rayleigh, 1884.

EUBU 3-19

Research and information

CARLO VERNIMB, Centre for Information and Documentation,

Directorate General for Dissemination of Information, Euratom

The race of scientists who sat brooding in their studies in solitary state has practically died out. Anybody who, wishing to contribute to the march of science, cuts himself off from his fellows and is content to go forward with his gaze fixed on a distant objective, will risk, after years of painstaking effort, arriving long after somebody else. It is not enough, nowadays, for a research worker to have intelligence, spirit of enquiry, patience and the basic knowledge essential to his craft. In addition to this, he must be informed—informed about the ground which has already been covered in his own particular field.

As far back as 250 years ago, at the time of Newton and Leibniz, it came about often enough that a number of scientists arrived independently at the same conclusion, in spite of the fact that there were far less of them then than there are now. Since then, science has boomed, to such an extent that the scientists now living outnumber all those that are dead.

In these circumstances it is not surprising that even large firms, which do generally speaking keep themselves well informed, sometimes carry out expensive, time-consuming and completely futile repetitions of work already carried out elsewhere, like the American electrical engineering company which spent several million dollars and the endeavours of a carefully selected research team over a period of two years on the solution of a problem which had already been solved in Holland. Information may be expensive, but the lack of information even more so.

Up-to-date information

The oldest type of information is the basic knowledge which has been acquired in the course of long periods of time and is conveyed by teachers. Against this, a second type is steadily gaining in importance, which deals with the *present* status of technology and the *latest* research results. We cannot do without the experience gained by our fathers, but that acquired by our contemporaries is equally vital.

Fortunately for the development of science and technology, the research worker is usually keen to convey his results to others. How does he do this?

Leibniz was able to correspond by letter with all the prominent scholars of his time, but with the colossal expansion of the sciences the number of people interested in such correspondence grew, so that it had to be published, i.e. printed, duplicated and distributed. This task was taken over by publishers. In the second place, there was an enormous increase in the number of authors of such scientific publications. In order to cope with the growing number of publications, new and more highly specialised journals and reviews were founded. It has been estimated that there are to-day about 80,000 scientific journals in existence.

The abstract

The reader interested in the latest information published in his field would, strictly speaking, have to glance through literally hundreds of journals to unearth all the papers of concern to him. This is impossible from the standpoint of both time and money, apart from the fact that it would be impracticable in view of the wide range of languages involved. This situation gave rise to the creation of journals of abstracts dealing with special fields (medicine, nuclear technology, etc.). The staff of such reviews go through the original publications and condense the substance of the articles into so-called "abstracts" which enable the reader to pick out fairly rapidly the papers likely to be of interest and to decide which ones he should read. It is still the scientific article or paper which *conveys* the information. The abstract is merely the device which enables the *selection* to be made.

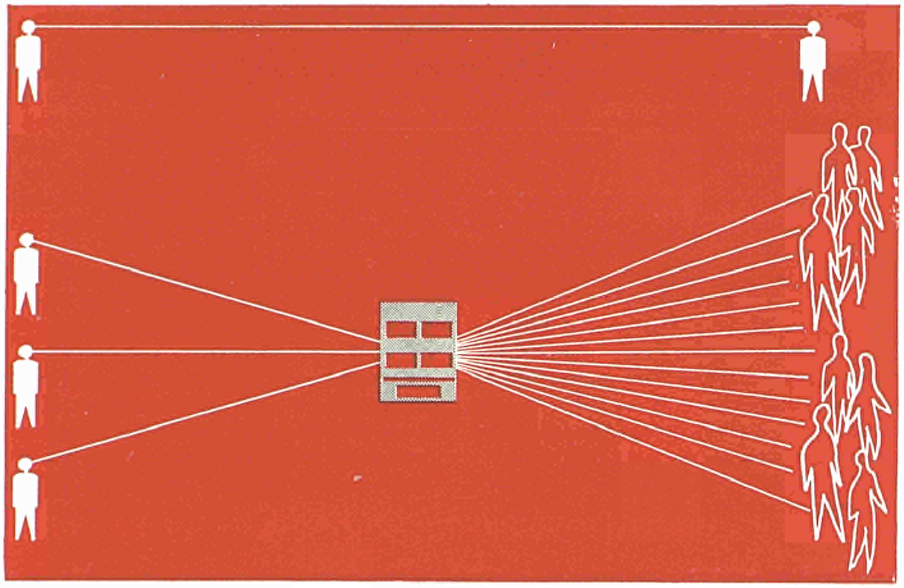
This is how the constant increase in the spate of publications led to the setting up not only of new journals but also of further journals of abstracts. In 1963, several million articles appeared in about 80,000 specialised reviews. In the total number of about 1,500 abstract journals, about 30% of all published articles were not abstracted at all, while 25% were handled more than once, since the journals cover areas in which a great deal of overlapping occurs. In order to reduce to a minimum the amount of material escaping his net, the person seeking information would have to cast it over several of these journals, but even this would be a task beyond his powers.

When it is asserted that the present-day scientist must read a great number of publications in order to keep abreast of his subject, this is true only to a limited extent, since in view of the normally very advanced degree of specialisation involved, he will need on average perhaps only about five articles per month; but merely in order to pin-point these he will have at least to look at a thousand or so titles and check about 50 short-listed abstracts.

An efficient means must therefore be devised to assist in the selection.

Figure 1. Information at the various stages of the history of science.

Figure 1 (a): The earlier stages.
Above: Communication between individual scientists by letter.
Below: A slightly more advanced phase—the "letters" become articles, printed and distributed more widely by publishing houses shown in grey)



Computers

The way out of this impasse is shown by science and technology themselves, with electronic computers. The prerequisite for their use is, however, that the substance at least of the abstracts (the originals, of course, would be better) must be translated into a language which the machine can digest. Only then can it carry out the selection of the literature required, but it will be able to perform this operation much more rapidly than a man.

The European Atomic Energy Community's Centre for Information and Documentation (CID) is already engaged on putting scientific publications into computer language. For this purpose a staff of experts expresses the contents of the publications (or their abstracts) by assigning them sets of keywords that the computer can read. These keywords, together with the relevant bibliographical references such as title, author and source, are fed into an IBM 1401 machine for storage in its memory. When a request for information on a particular subject is received,—i.e. for a list of all the publications dealing with this subject—the procedure for its retrieval consists in the first place in expressing the request in the form of a combination of keywords. The machine can then be made, by checking through all the keyword combinations stored in its memory, to select the publications which are relevant to the request and print them out in the form of a bibliography. A more detailed account of this system was given in Euratom Bulletin n° 2 of 1963 ("Of needles and haystacks", by Rudolf Bree).
The literature dealing with nuclear science and technology since 1947 embraces about 300,000 articles, reports, patents and books, with a yearly increase of roughly 60,000. Euratom has already put in storage the keywords corresponding to about 200,000 of them. The backlog is expected to be caught up by mid-1965.
After investigating the methods practised by Euratom and the preliminary work performed, the United States Atomic Energy Commission (USAEC) has decided to collaborate with Euratom and to analyse the major part of the fresh literature in conjunction with Euratom's experts.
After a running-in time of a few months, Euratom will be able to reply to enquiries from research and industrial organisations by means of the computer by about the end of 1965.

Gaps to be filled

Nuclear Science Abstracts (NSA), a publication put out by the USAEC, covers about 70% of the literature which Euratom intends to handle. The remaining 30% is partly dealt with in other abstract journals such as *Chemical Abstracts*, *Physics Abstracts*, or else not at all.
The following account may serve as a particularly pertinent instance of the need to resort also to other sources than *Nuclear Science Abstracts:* an institute intended to follow the movement of sand dunes by means of radioactive isotopes and requested financial support from Euratom. Before Euratom provided the funds a check had to be made to ascertain whether the same research had not already been carried out elsewhere. A thorough examination of the indexes of *Nuclear Science Abstracts* yielded only four abstracts dealing with the subject. This is not surprising, since NSA covers only *new* methods of applying radioisotopes. A comparison with the documentation in the possession of the institute in question revealed that it had tracked down not merely these four but also a further twenty-five articles on the same subject, some of which had been abstracted in other journals. For this reason, Euratom will check through about 50 selected abstract journals systematically in order to find articles in the field of nuclear science and technology.
But how would it be possible to cover those articles which, albeit of interest from the nuclear technology angle, are not handled by *Nuclear Science Abstracts* and are not dealt with by the other journals analysed

by Euratom? And who is to decide whether an article is important from the standpoint of nuclear science or technology? Such a decision is best left to the editors of the specialised journals. Publishers of scientific periodicals are therefore requested to forward articles of this type to Euratom, who will assign them keywords, store them in the computer's memory and make their existence known to interested parties. The advantage deriving from this system, both for the author and his middle-man, the editor, is that the people directly concerned are made aware of the articles' existence, which therefore have a much more powerful impact. This in turn is of benefit to the publisher who is thereby assured of a wider readership.

Identification code

The CID must of course prevent an article communicated in this manner from being analysed twice—once when it is dispatched and again in the sifting of the abstract journals. Duplication of effort can only be avoided if each individual article can be identified in an absolutely unambiguous manner.

Euratom therefore advises publishers to provide the articles appearing in their periodicals with serial numbers. The journal itself must be given a code which is suitable for storage in a computer. Fortunately such a code already exists. The handbook *CODEN for Periodical Titles* put out by the American Society for Testing and Materials (1916 Race St., Philadelphia 3, Pa.), contains four-letter abbreviations representing 20,000 periodicals. The four-letter periodical code is followed, logically, by the volume number and the serial number of the article in the volume. The journal *Atomkernenergie* (Thiemig Verlag, München) has been using this identification code on Euratom's recommendation since 1 January 1964:

ATKE 9-7

thus means *Atomkernenergie Vol. 9, article 7*. This code can be supplemented by the page numbers (in parentheses) and the year, i.e. ATKE 9-7 (73-77) 1964, but ATKE 9-7 is sufficient for purposes of clear identification. The numbering of the contributions to *Atomkernenergie* found very wide acceptance, but a move of this kind was actually in the air ever since the advent of computers.

Further, Euratom recommends that publishers of abstract journals include the identification code in the reference of the abstracts. The publishers of *Nuclear Science Abstracts* have already agreed to do this.

It should be stressed that identification codes can of course be of service to *all* information centres working with computers; their use is not the privilege of nuclear information centres.

Euratom is thus launching a two-fold appeal. It is on the one hand asking publishers to help fill the information gaps which still exist in the field of nuclear energy by sending spontaneously to Euratom's Information Centre articles which they consider to be relevant to this field. At the same time, the introduction of identification codes is recommended to these same publishers; they indeed promise to be an effective means of making the task of handling all this information much easier.

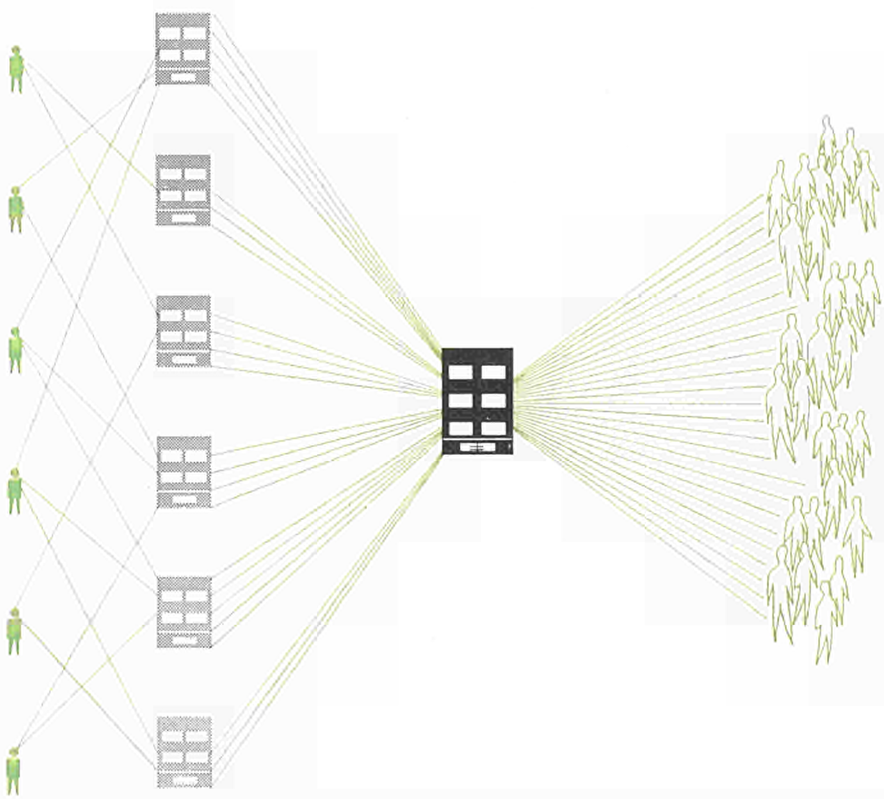


Figure 1 (b): Second stage—appearance of the "abstract journal".
So many articles appear in so many periodicals that the scientist cannot keep track of all the articles which interest him. Hence the emergence of the "abstract journal" (shown in black) covering a particular field of knowledge.

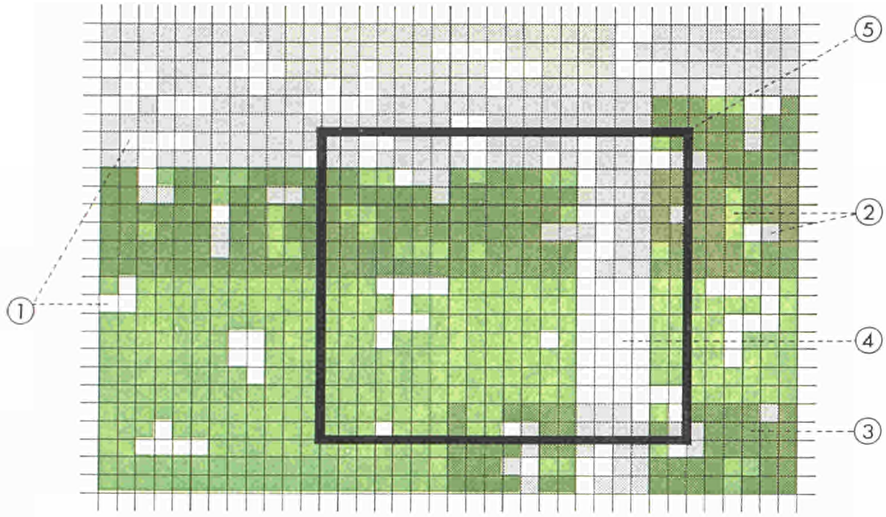


Figure 2: Article coverage by abstract journals. One should imagine all the articles published in one year spread out and arranged according to subject matter, each small square in the diagram representing one article (for simplification, the diagram only covers a small part of all articles appearing in the year).
Abstract journals cover specialised subjects and it is quite normal that one subject should partly overlap with one or several others. For instance, an article dealing with the metabolism of radioactive iodine in the human body could well be abstracted in at least three journals: Chemical Abstracts, Nuclear Science Abstracts and Excerpta Medica.
Four such specialised fields, each handled by one abstract journal, are represented in the diagram.
Four different possible cases are shown:
1. Articles which fall within the scope of at least one abstract journal but are not abstracted (about 30% of the total).
2. Articles abstracted by one journal only
3. Articles covered by two abstract journals
4. Articles the subject of which is not covered by any abstract journal.
The area surrounded by a thick black line (5) represents the range of subjects in which a particular scientist is interested.
The main purpose of this article is to draw attention to the need for making "white" articles available to the scientists concerned.

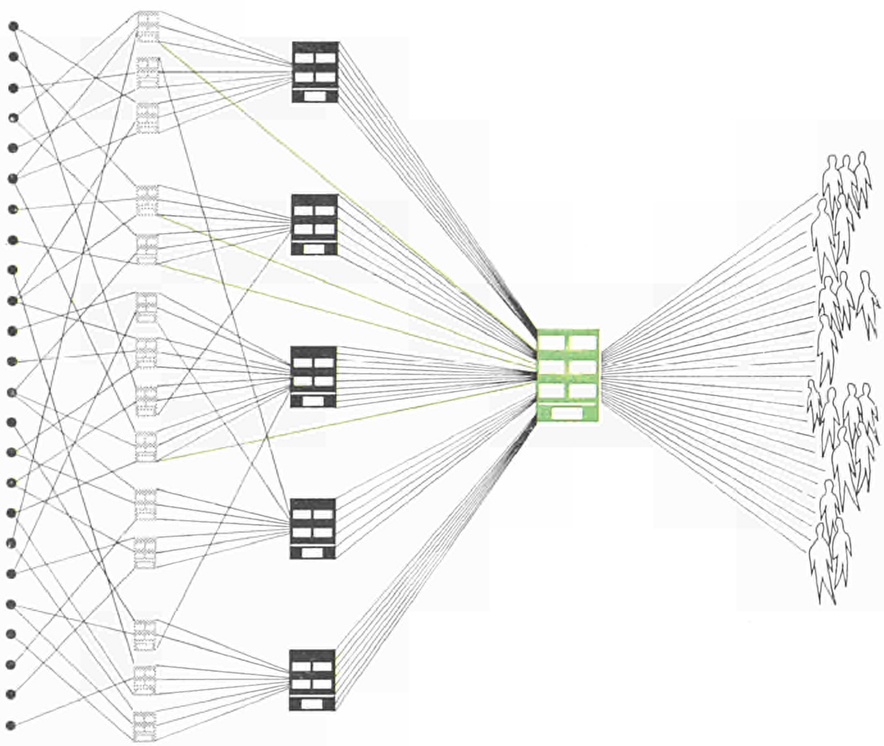


Figure 1 (c): The situation today.
The situation has become even more complex today. On the one hand the increase in the number of new publications is such that it is difficult for the abstract journals to keep up with all of them. In any case there is often overlapping between the subject fields of one abstract journal and another, so that the scientist is faced with the task of scanning several of them to keep up to date. This partly explains the emergence of the information centre (shown in colour) which stores, as far as possible, all the information published within the scope of one broad field of science and technology. The basic aim of the information centre is to be able to answer, quickly, comprehensively and accurately, specific requests put forward by individual scientists, and thus spare them the time-consuming task of hunting for information. Some of the lines (shown also in colour) join the publishing houses and the information centre directly. They represent the contacts which Euratom hopes to create with periodicals which are not covered automatically by the abstracting journals (the "white" publications mentioned in the caption to Figure 2).

EUBU 3-20

The use of "nuclear" patents as an information source

A big step forward was made in the dissemination of nuclear knowledge with the recent signature of an agreement between Euratom and the "*Société française pour la gestion des brevets d'application nucléaire*—"*Brevatome*". This scheme is aimed at promoting the selection and distribution of the information contained in "specifically nuclear" patents or those "connected with nuclear energy and essential to its development".

The value of patents as a source of information is due to various qualities not displayed by other technical publications in exactly the same way. The most notable are the following: the up-to-date character of the information contained in them, their technological interest, the descriptive character of their wording and consequently the possibility afforded of keeping track of the development of a technique, the large number of documents published and their wide dissemination. The value of the patent as a documentation source extends far beyond the technical sphere; it extends to the economic field, for instance, since the literature dealing with industrial property provides information of the various avenues which producers are interested in exploring.

Because patents are such a fruitful source, Euratom has already reserved an important place for them in its plans connected with the dissemination of information.

On its side, *Brevatome* had in 1958 created a documentation service on patents, one of whose activities was the issue of a review "La propriéét industrielle nucléaire" publishing patents covering nuclear and allied subjects from sixteen countries.

The affinity between the aims pursued by Euratom and the Brevatome documentation service led to the idea of an association which, by harmonising aims and methods, and by pooling resources, would make it possible to improve the quality and extend the range of the activities pursued by the two teams.

The association plans to widen the distribution of the information selected by two means:

— firstly, by centralising and mechanising documentation relating to patents;

— secondly, by introducing certain innovations into the review "*La propriété industrielle nucléaire*". The official notices published hitherto will be replaced by abstracts giving a *technical analysis* of the patents. The task of drafting the abstracts will be carried out by way of *international cooperation* within the Community. Moreover, the abstracts of patents filed in Community countries will be published in *English* as well as the original language.

EURATOM NEWS

Euratom signs association contract with German "Pebble-Bed" Reactor Project

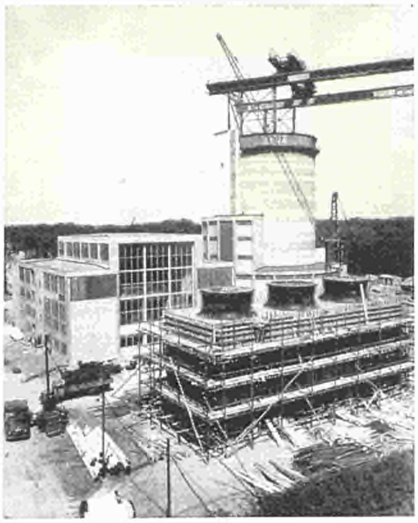
The Euratom Commission announced on 22 May 1964 the signature of an association contract for joint research with the German Brown-Boveri/Krupp group and the Jülich Nuclear Energy Establishment on the thorium-high temperature reactor concept (THTR). The programme of research covers the period to end-1967 and will cost $ 20 million, each side contributing 50 per cent. Through the Association the Euratom Commission will have access to experimental equipment already in operation or under construction, in particular the AVR reactor, which is wholly financed by German funds. This reactor is now under construction at Jülich for the Arbeitsgemeinschaft Versuchsreaktor GmbH (AVR). The joint programme will be concerned with research into the development of a thorium-uranium-fuelled thermal reactor with the fuel arranged in a so-called *pebble-bed* core and using high temperature helium as coolant.

Once it is commissioned the AVR reactor will be operated by the Association for this programme. It will be used in particular as a test-bed for fuel elements.

The programme will also involve the engineering assessment of a large power station operating on this system and the design of a prototype THTR, the construction of which could be the subject of an additional agreement.

The project will be directed by a Steering Committee consisting of three Commission representatives and one of each from the Jülich Centre, the Brown-Boveri/Krupp Group and the Federal Ministry for Scientific Research.

It will be recalled that Euratom is already involved in research in the field of high-temperature gas-cooled reactors, in particular by its participation on behalf of Member States in the ENEA (European Nuclear Energy Agency) *Dragon* project. The necessary co-ordination between the two projects will be carried out by Euratom staff.



The AVR reactor in Jülich

Studies on the economic aspects of nuclear energy

Under the second five-year programme, the Euratom Commission is pursuing its studies on the economic aspects of nuclear energy production. A series of contracts have recently been drawn up in this field with:

— *the Group for the Euratom Economic Handbook*, consisting of three companies, i.e. *Indatom* (France), *Siemens-Schuckertwerke* (Germany) and *SORIN* (Italy), and the *French Atomic Energy Commission* (CEA); this contract is for the development of a method of calculating the cost price per nuclear kWh, aimed at standardising the calculation methods used by the various Member Countries;

— the *Comitato Nazionale per l'Energia Nucleare* (CNEN), for studying the economics of the thorium/uranium cycle;

— the *Bureau d'études nucléaires* (BEN) (Belgium) and the *Société belge d'économie et de mathématiques appliquées* (SOBEMAP), for the study of the economic problems posed by the merging of nuclear power plants with electricity-producing and distributing grids, due regard being paid to the fact that the use of one unit influences that of others throughout their lifetime;

— the *French Atomic Energy Commission* (CEA), for studies on the *economic* value of plutonium, to be determined by comparing the supply of and demand for plutonium for use in long-term nuclear power plant programmes. The value of *using* plutonium in various types of thermal and breeder reactors will also be studied, allowances being made for such factors as the cost of extracting the plutonium and of converting it chemically or metallurgically by various methods;

— the *Technische Hochschule Aachen* (Germany), for the systematic analysis of the components used in a nuclear power plant (boiling-water or pressurised-water), for determining ways and means of reducing investment costs, and also for orientation studies on nuclear energy development programmes in an effort to obtain optimum utilisation of the world's uranium and thorium reserves.

EURATOM NEWS

A common market in nuclear insurance

The problems raised by the creation of a "European common market in nuclear insurance" were discussed by representatives of Euratom and of insurers of the Six Countries when they met in Aix-en-Provence (France) at the end of May. The establishment of such a "common market" —which has become necessary in view of the growing importance which European nuclear industry is assuming beyond the borders of each nation—can contribute to lowering the costs of nuclear energy.

Having previously made a joint study of the problems of bringing into line insurance conditions for the carriage of radioactive substances and the use of radioisotopes, the Euratom Commission and the insurers decided to create uniform insurance conditions for land-based nuclear plants (reactors, reprocessing plants, etc.).

There was a full discussion of the fact that despite the conventions of Paris and of Brussels on third-party liability in the nuclear field, which it is hoped will enter into force as soon as possible, the legislative provisions in this respect vary from state to state.

This situation makes insurance against nuclear hazards difficult, especially in the case of the transport of radioactive substances. The insurers expressed the desire that action should be taken as soon as possible to unify these provisions within the Community.

Radioisotopes in the textile industry

The *Journal Officiel* of the European Communities (no. 80, dated 26 May 1964) publishes a communication from Euratom's *Bureau Eurisotop* in which the specialists of the six Community States in the field of radioisotopes and radiations are invited to participate in a campaign launched by the *Bureau Eurisotop* to promote the application of radioisotopes and radiations in the textile industry.

The specialists concerned are asked to fill in and return to the *Bureau Eurisotop* the questionnaire published in the same number of the *Journal Officiel*. They will be invited by Euratom (which will pay them a fee as well as refund their travelling and subsistence costs) to take part in study visits, lasting one to three months, to textile enterprises in the Community, in order to examine and extend the possibilities for the use of isotope techniques in textiles and act as advisers to the enterprises concerned. Up to the present about 300 textile firms of the Six States have stated their interest in this scheme.

The map shows their distribution over the territory of the Community.

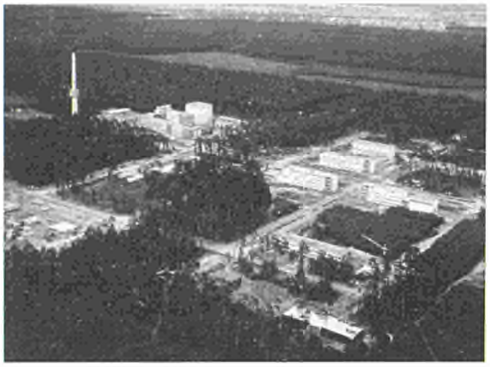
United States and Euratom conclude fast reactor co-operation arrangements

The Euratom Commission announced on 27 May 1964 the conclusion on behalf of the *European Atomic Energy Community*, the French *Commissariat à l'Energie Atomique*, the German *Gesellschaft für Kernforschung* and the Italian *Comitato Nazionale per l'Energia Nucleare*, of an arrangement with the *United States Atomic Energy Commission* under which they will engage in a broad programme of co-operation on the development of fast reactors.

The importance of this particular type of reactor for the future of atomic energy has been recognised on both sides of the Atlantic. All atomic reactors built for civilian or military purposes produce plutonium, but so far this material has been produced and utilised mainly in the framework of military programmes. However, plutonium can also be used as a reactor fuel in the same way as uranium-235 in thermal and fast reactors. Recycling of the plutonium in thermal reactors is one of the main objects under study in the framework of the existing US-Euratom Co-operation Agreement, signed in 1958. The importance of fast reactors stems from their optimum ability to burn the plutonium produced by civilian reactors, and from their ability to breed more plutonium than they actually burn.

The European effort in this field has been organised on the basis of three associations between the Euratom Commission on the one hand, the French Commissariat, the German Gesellschaft and the Italian Comitato on the other hand.

Between the $ 73 million currently provided for by the Euratom second five-year programme and the sum contributed by the three Associates, it is a total of some $ 200 million which will be spent in the Community in the fast reactors field during the period 1963-67. During the same time, the USAEC anticipates spending an approximately equal amount.



Here then lies the prospect of a real partnership since it is in the interest of both sides to exchange information resulting from the implementation of their respective programmes in order to ensure the maximum benefit from their efforts.

An *information exchange arrangement* has been made between the USAEC and Euratom which defines in detail the areas of technology to which it is applicable. It also sets up procedures for this co-operation and contains associated patent arrangements. The term of the co-operation is initially for ten years.

At the same time, an *arrangement* has been concluded which provides for the *supply by the USAEC of plutonium and enriched uranium* for the execution of the Community's fast reactor research programme.

As a result, the Parties have agreed to proceed with negotiation of a contract under which Euratom will purchase approximately 350 kg. of plutonium from the USAEC at the established U.S. domestic base price applicable at the time of delivery. The plutonium will be for use in the SNEAK and MASURCA critical experiment facilities in Karlsruhe, Germany, and Cadarache, France, respectively.

The USAEC will also supply the uranium-235 needs of the Community's fast reactors programme, as now foreseen, under a combination of normal and special short-term lease arrangements at the prevailing U.S. domestic use charge for such material which now is 4.75 per cent.

The Community is also engaged in discussions with the United Kingdom Atomic Energy Authority in the framework of the existing Agreement for Co-operation between the Community and the United Kingdom.

It will be recalled that the Euratom-CEA Association bought the first half (45 kg) of the plutonium for the first core of the RAPSODIE fast reactor project at Cadarache, France, from the UKAEA in May 1963. The second half will be purchased from the UKAEA shortly.

At the same time, active consultations are currently being carried out with British experts in order to organise with the UKAEA an exchange of information as complete as possible in the field of fast reactors.

These co-ordinated efforts will thus provide a concrete example of Atlantic partnership in action in this advanced field of nuclear technology.

New data on the behaviour of organic liquids

Two loops in the *Mélusine* reactor which are being operated under contract with Euratom at the Grenoble Nuclear Studies Centre have provided interesting results on the behaviour of an organic liquid (in this instance the OM 2 terphenyl mixture) in conditions which might be typical of an *ORGEL* reactor.

The *first* loop, which has operated for more than 4,000 hours under irradiation at temperatures of up to 450°C, was intended to give information on the speed at which the liquid decomposes under the influence of heat and radiation, the principal decomposition products being polymers heavier than the terphenyls. These data are important from the economic standpoint, because they make it possible to determine the rate at which make-up organic would have to be supplied to an *ORGEL* reactor in operation.

The problem is somewhat complicated by the fact that the behaviour of the liquid varies according to the tolerable heavy polymer content. It was thought from the outset that the liquid decomposition rate was in inverse proportion to the heavy product concentration. Thanks to tests carried out with the loop, this tendency was found to become much more marked as the concentration increases. The effect is so pronounced that if these results are confirmed and no other factor such as fouling makes it impossible, designers will think in terms of a coolant system with a higher decomposition product content than that originally fixed.

The *second* loop has the original feature of an electric heating core which simulates a fuel element. It has answered an important question which had arisen, namely: if the temperature of the fuel element wall is appreciably higher (about 50°C) than the coolant bulk temperature, must a more rapid decomposition of the liquid be expected? The reply has proved to be in the negative, and the decomposition rate of the organic liquid is therefore only a minor factor in fixing the maximum admissible wall temperature.

EURATOM NEWS

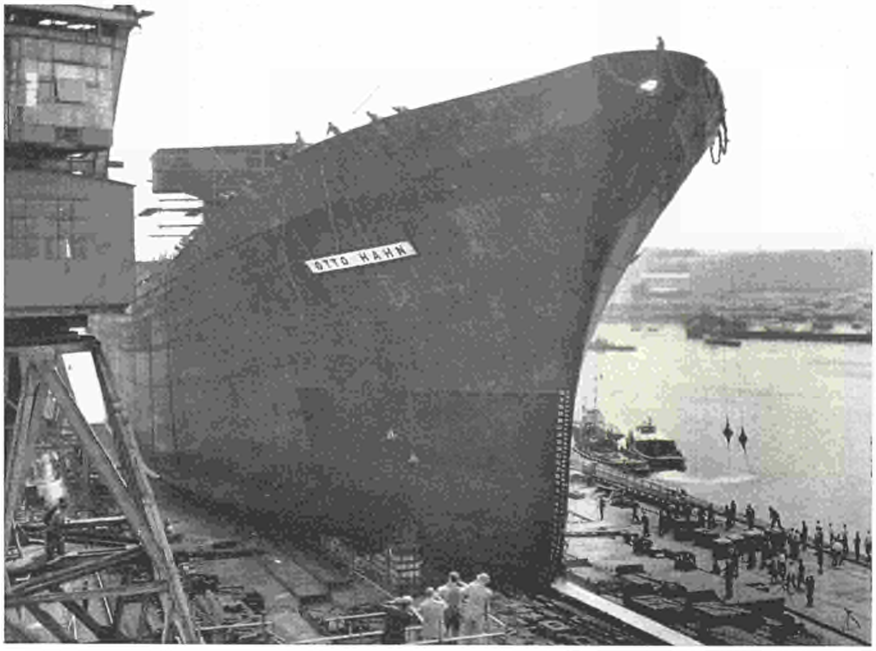
Euratom joins in construction of atomic ship

The Euratom Commission concluded on 30 July 1964 a contract with the German *Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt* (GKSS), under which the European Atomic Energy Community will participate in the construction and sea trials of the "OTTO HAHN" nuclear research vessel.

This contract, concluded for a period of four years, stipulates that the Commission shall contribute $ 4 million towards the cost of the nuclear equipment. In return the Commission will be able to make use of the experience and knowledge gained, which it will receive in the form of reports or through staff seconded to the project. This information will be circulated within the Community in accordance with the regulations drawn up to this effect. In addition, the contract permits industries in any Community country to submit tenders for the supply of nuclear components.

The responsibility for the construction and operation of the propulsion unit as a whole has been entrusted to the Consortium of *Deutsche Babcock & Wilcox-Dampfkessel-Werke AG* and *INTERATOM (Internationale Atomreaktorbau GmbH)*. The reactor is of the light-water type, with a relatively low primary pressure, and a heat exchanger housed entirely within the pressure vessel. This reactor will make it possible to develop about 11,000 shaft horse power. The ship itself is already under construction in the shipyards of the *Howaldtswerke AG, Kiel*. It is designed in the first place for research and experiments in nuclear marine propulsion, but may later be operated as a commercial bulk carrier, with a deadweight of 15,000 tons.

The Euratom programme, of which the contract relating to the OTTO HAHN vessel is a part, is designed to co-ordinate the various efforts being made in the field of nuclear marine propulsion and thus avoid overlapping. The experience and information gained will be shared with the *Reactor Centrum Nederland* and the Italian *Fiat* and *Ansaldo* companies, which are also engaged, under contracts with Euratom, in drafting construction designs for more advanced marine reactors, with the aim of achieving economically viable nuclear propulsion for merchant vessels.



Merger of *Quarterly Digest* and *Euratom Information*

The Euratom Commission announced on 7 July 1964 the merger of two periodicals: *The Joint Research and Development Program Quarterly Digest* and *Euratom Information*. This merger has been decided in agreement with the United States Atomic Energy Commission.

The *Quarterly Digest* has been published since 1961 to meet the mutual information needs of both European and US-contract-holders working under the Agreement for Co-operation (signed in November 1958 and ratified in February 1959) between the Government of the United States of America and the European Atomic Energy Community.

This information is now presented in chapter IV of every third issue of *Euratom Information*, now published monthly by the Commission and reporting on the Commission's publications, contracts and patents. From now on, *Euratom Information* will be the main source of current information on all the scientific and technical activities of the Commission.

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Perhaps the potato of to-morrow

Plants such as the potato, which multiply "vegetatively", do not need to pass through the cycle of "sexual multiplication", which entails the fertilisation of an ovule, the formation of a seed, and the growth from the seed of a new plant. Reproduction is actually effected by cutting, grafting, or simple plant division.

These plants have the advantage that it is easy to fix a mutation characteristic. As soon as a modification appears, the plant or part of the plant can be multiplied directly, without passing through the complicated fertilisation cycle.

With the potato, for example, a single tubercle carrying a given modification may be the starting point for a new plant whose numerous tubercles will in their turn help to establish a modified variety.

The photograph shows a potato plant obtained after irradiation of an eye. The tubercles are of the normal red colour of the irradiated species, with the exception of the four tubercles in the centre, whose skin is yellow.

By planting one of these tubercles, an entire plant with the new characteristic will be obtained (photograph supplied by Dr. F. P. Ferwerda, Foundation for Agricultural Plant Breeding, Wageningen).

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