The Development and Work of the Centro de Energia Nuclear na Agricultura (CENA) in Piracicaba

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If ten years ago anyone had said to me that I should be honoured to address you this afternoon on the development and work of CENA, the Centro de Energia Nuclear na Agricultura in Piracicaba, I would have been frankly surprised. It is true that CENA celebrates its official 10th anniversary during this Conference, because it was in September 1966 that it became a legal entity as an institution of the University of São Paulo, annexed to the Luiz de Queiroz Agricultural College of the University (ESALQ). It was not, however, until 1968 that the first laboratory building was completed and we became an institute in solid fact rather than just a conception in our minds.

The first work with radioisotopes ^{65}Zn and ^{32}P in plant nutrition was started in Piracicaba as far back as 1954, and slowly over the years the work developed so that today CENA is the result of steady growth in studies applying nuclear techniques to agricultural problems. At this point I should say that CENA is jointly supported by the Comissão Nacional de Energia Nuclear (CNEN) and the University of São Paulo, and it is due to their far-sightedness, continuing support, and funding that CENA is what it is today. Without this we should have remained as we started: as informal arrangement between several persons and departments of ESALQ who were interested in the application of nuclear techniques to agricultural research. Now many of the professional staff hold faculty positions in ESALQ, but others are directly employed by CENA.

I occasionally feel that those of us who are trying to apply nuclear techniques to practical problems are in a difficult situation, sometimes leading to misunderstanding. On the one hand those who are engaged in what I might term the pure application of research in nuclear physics or nuclear energy do not see what we have to do with them, on the other hand some workers engaged in agricultural research and practice often tend to feel, or express the opinion even, that nuclear techniques are a "gimmick", which they can quite well do without. I am inclined to think that this latter view is dying fast as the achievements and progress in nuclear techniques have become too great to ignore. Moreover this view was often the product of ignorance and an unwillingness to learn something new, but we now have a new generation coming forward who have learned all about nuclear structure and the possible uses of radioisotopes and radiation even in high school.

However, we have to be on our guard against the opposite extreme: using nuclear techniques for the sake of using them when they may not offer any real advantage over existing methods. It was Cyril Comar who wrote "Radioisotopes, to the naive, may represent the panacea for investigational difficulties – the royal road to successful experimentation;

to the cynic they may appear as gadgetry, a fad that creates more problems than it solves. As always the truth lies somewhere between the extremes". At CENA, I believe, we try to keep this constantly in mind.

I consider it our task to conceive, develop, prove, and try out in practice new ideas and techniques involving nuclear methods, and to make them available to researchers in agriculture both in Brazil and in any other situation where they may be applicable. Nevertheless, if you visit us at any time, as I cordially extend you an invitation to do so, you will find that we have plenty of day-to-day work going on which does not directly involve isotope use. This quite simply is because the isotope or radiation component of much, if not most, of such techniques applied to agricultural research is only a part, though an absolutely essential part, of the whole research. Nuclear techniques are, and inevitably must be, integrated with the classical methods.

By this time you may be wondering how large CENA is, so I will briefly give you some statistics: We now have about 35 professional staff spending a major portion of their time at CENA, our physical facilities include 7300 m^2 of laboratory and office space together with an auditorium and some classroom, now valued at US $ 2 million, plus glasshouses, growth rooms, cold storage, 30 000-Ci cobalt-60 radiation source, etc. Radioisotope counting facilities include liquid scintillation and low background anti-coincidence, and there are three mass spectrometers, an electron microscope, a production facility for ^{15}N enrichment, biochemistry and microbiology facilities with amino-acid analyser and sophisticated gas chromatography instrumentation, and the analytical laboratory has autoanalyser equipment for N and P analyses and an atomic absorption spectrometer. Total input for equipment is US $ 1.5 million.

The annual budget of CENA is about Cr $ 16 million (approx. US $ 1.6 million), 80% coming from CNEN. Since 1972 we have had a United Nations Development Programme Project at CENA, administered by the IAEA and over the 5 years of the Project almost US $ 1.3 million is being provided in the form of expert services, fellowships, and equipment (US $ 426 000).

I have gone into some detail concerning the extent and cost of our facilities because I know that many of you are administrators and you may be wondering if such an institute would be of value to your country. I have to say that there is probably no inexpensive way of doing it, if it is to be done properly. At one time the most expensive item in a research programme was the salary of the research worker involved, nowadays the cost of equipment and its maintenance are ever increasing factors. Moreover, science is no longer neatly compartmented – every branch is interdependent with a number of other disciplines.

For example, consider the bean *(Phaseolus vulgaris)* programme that we have at CENA. This bean represents the major source of protein to the majority of low income families in Brazil, and indeed in Latin America as a whole. Brazil is the world's largest producer of these beans, and for these reasons we attach great importance to the programme. Naturally enough, the programme is centred around the Radiation Genetics Section, which has developed mutant lines and is breeding new varieties from them, but also involved is Biochemistry which carries out amino acid analyses and other protein work; the Analytical

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Research on the bean **Phaseolus vulgaris**, a major source of protein in Brazil, is one of the major programmes at CENA in Piracicaba. ▶

Laboratory that determines nitrogen; the Microbiology Section that is working on factors affecting nitrogen fixation; Soil Fertility which is concerned with optimizing fertilization; and Plant Pathology working with certain virus diseases. All these activities are mutually dependent on each other; it is an integrated programme, as I believe all programmes must be if we are now to achieve significant and worthwhile advances. In other words, you cannot have "half a research station", and the investment cost is high, but equally I believe the return to the national economy can also be great.

I have mentioned the IAEA/UNDP Project that we have had at CENA since 1972. I believe that it has contributed in a very real way to the development of CENA. Although the equipment supplied under the Project has of course been invaluable, I think that in the long term it is the training, interchange of ideas and broadening of horizons afforded by the visits of experts and the fellowship programme that will prove to have been the most significant help. So far we have had 19 international experts at CENA for periods ranging from a few weeks to over a year, and covering most of the subject areas in which we work. During the same time 16 of the CENA staff have gone abroad on fellowships and about another eight are preparing to do so.

The increased interchange of ideas is especially important for us in Brazil because of the distance between Brazil and the main scientific centres in Europe and North America. I may say that we are also involved in a number of areas of the Agency's research contract and agreement programme, and again we appreciate the contacts made at the coordination meetings.

CENA is organized in five major divisions: Plant Sciences (biochemistry, pathology, nutrition, radiogenetics and plant breeding, entomology), Animal Sciences, Soil Sciences (fertility, physics, chemistry, microbiology), Environmental Sciences (hydrology, stable isotopes), and Basic Sciences (analytical chemistry and radioprotection).

The main projects are focussed on some of the greatest problems in Brazilian agriculture: water resources in Amazonia and the North East region; genetic improvement of basic crops such as beans, rice and wheat; methods for potential reduction in losses of stored grain; improved fertilizer practices and the biological fixation of nitrogen; protein quality and photosynthetic efficiency; mineral deficiency in livestock.

In radiation mutation breeding, important successes have been achieved with beans *(Phaseolus).* Varieties are coming forward promising a yield potential substantially higher than existing varieties. Limited multiplication and testing should be possible later this year. Differences in protein content of several per cent have also been found. A mutant tolerant to Golden Mosaic disease has been obtained, and seed supplied to CIAT (Centro Internacional de Agricultura Tropical, Cali, Columbia) and five countries in South Central America. This was the result of screening some 750 M-progenies comprising 15 000 plants in collaboration with the Virology Department of the Institute of Agronomy, Campinas. It should be seen in the perspective of 5000 lines from spontaneous collections having been tested in Central and South America without any tolerance being found. Limited mutation breeding with wheat and rice has produced wheat mutants more resistant to rust and also with shorter straw. Rice mutant lines maturing two weeks earlier and with shortened straw have been obtained.

We are especially proud of our isotope hydrology work in Amazonia which has been attempting to quantify the hydrology cycle of the region. Recent analysis of the results has shown clearly that a large (54%) proportion of the rainfall is recycled within the region. From another viewpoint this means that too great clearance of trees might considerably affect the microclimate of the region. The implications of this for the development of the region cannot be over-stated, as the Brazilian Governement is especially concerned that permanent damage should not be done to existing natural resources. At a more basic level we are looking at the natural variation in $^{15}N/^{14}N$ and $^{13}C/^{12}C$ ratios in an attempt to clarify the nitrogen and carbon cycles in the Amazon forest. In the arid Northeast we are studying the origin and movement of underground water and have shown that in aquifers where the flow speed is higher there is better water quality and less salinity.

The entomology of stored grain insects has been extensively studied, and radiation dose data for disinfestation now exist for all the major Brazilian grain insects. We are therefore prepared for any possible future decision to go ahead with bulk grain storage and irradiation facilities. Ecology and population studies with the sugar cane borer *(Diatraea saccharalis)* have clarified its life cycle in São Paulo State, and have shown that minimal insecticide control at the critical period of the year can result in a 10% yield increase even with as low as 11—12% borer infestation. A radioisotope (^{59}Fe) tracer technique for marking *Diatraea* pupae and adults has also been developed. While searching for cheaper diets for the Med Fly *(Ceratitis capitata)* a diet was found that produces almost 100% sterile males. This may prove to be a means of using physiological sterility for the "sterile male technique".

Work at CENA has demonstrated biological N-fixation by bacteria/root associations in sugar cane. Co-operative work with the stable isotope ^{15}N has provided the first direct evidence of nitrogen fixation in tropical forage grasses beyond possible experimental error. I believe this is an exciting new line of research. The evidence for nitrogen fixation in tropical grass-bacteria associations — what we might call "associative" nitrogen fixation — seems to be hardening to a fair degree of certainty. Can this potential nitrogen fixation be exploited in more economic crop production? We intend to find out. In the more traditional legume nodulation studies we are attempting to produce more effective *Rhizobium* strains through radiation mutation.

Studies in plant biochemistry are investigating quality and quantity of protein in beans and have shown wide variation in both total protein and lysine content. It is apparently possible to obtain bean lines of good productivity with relatively high protein. Bean varieties are also being screened for photosynthetic efficiency by means of a simple apparatus for feeding $^{14}CO_2$ into the plants developed in the laboratory.

Soil fertility and plant nutrition studies were the first activities of CENA, and there are many experiments in progress. Soil physics is concerned with using nuclear techniques to characterize soil water regimes for better irrigation practice. Plant pathology is studying a number of virus diseases through purification and electron microscopy. Animal Sciences have the objective of defining cases of mineral deficiency and toxicity in cattle, with parallel studies of diagnostic methods employing nuclear techniques.

The analytical laboratory is a focal point of many programmes. It is one of only three laboratories in the world using flow injection analysis coupled with ion selective electrodes, and I believe the only one using it on a day-to-day basis for a wide range of routine analyses. This technique was developed by IAEA experts while with the Project and

we have made good use of it. I predict its use will become widespread when its merits are better known: it makes many classical methods look very slow. The Danish International Development Agency (DANIDA) has also helped this laboratory extensively.

We also do a great deal of consulting and collaborative work, both for Government and private concerns , nationally and internationally. There are at least twenty such examples, ranging from water and fish pollution, to gas composition and density of wood utilized in paper production, apart from purely agricultural topics.

The work at CENA is not wholly confined to research and development. As you might expect from an institute that grew out of the interest of university professors, there has been from the start a very strong teaching programme. This programme provides both a 3-year undergraduate introductory course in nuclear energy which is simultaneous with the regular agronomy programme, and also a 2-year post-graduate M.Sc. course. The students who take the undergraduate course have to do a large part of their course work during the normal vacation periods: this means that not only do they have to be highly motivated in the first place, they also have to be of high academic capacity to stand the pace. It has been noteworthy that students who have undertaken the undergraduate course in nuclear science in agriculture always finish high up the final results for the agronomy degree.

For the Master's degree programme we provide course work in extra mathematics and physics and also in subject-related areas, and the students present a thesis on some topic in their chosen area of work. At present we have about 29 students at various stages of the Master's course and about a dozen in each of the years of the undergraduate course.

Probably one of the reasons for the successful growth of CENA has been that there is a large agriculture faculty at ESALQ which not only provides sufficient scientists interested in nuclear techniques to utilize adequately CENA facilities, but also gives continuous contact with teaching and the whole broad spectrum of agricultural problems. There is therefore no danger of us working in a vacuum.

No institute is stronger than the people who work in it and I believe that we set a very high standard for the scientists who work with us. We have had 10 very exciting and stimulating years in developing CENA from an abstraction to a productive institute taking its place in the scientific life of Brazil and making an active contribution to the success of the Government's Basic Plan for the Development of Science and Technology. It is only right that I should acknowledge the hard work, sense of purpose and support that I have received from my colleagues at CENA.

Jean Mayer said in 1975 "This means that we have to find in the next 25 years, food for as many people again as we have been able to develop in the whole history of Man 'til now' ". I hope that in our specialized area of applying nuclear techniques towards the goal of increased agricultural production we shall in some measure contribute to this great endeavour.