PAIR/P.286/1988

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ABSTRACT

APPLICATION OF NUCLEAR TECHNIQUES TO AGRICULTURE : AN EXPERIENCE FROM A MULTIDICIPLINARY PROJECT IN INDONESIA. Experience gained from the UNDP assisted Country Project on the application of isotpes and radiation in agricultural research are described in this paper. The objectives, activities, research out puts and its utilization are included in this paper. Emphasis is placed on the research activities which have generate results of practical importance to the intermediate and ultimate clients of the Project.

ABSTRAK

APLIKASI TEKNIK NUKLIR DI BIDANG PERTANIAN : PENGALAMAN DARI SUATU PROJEK MULTIDISIPLINER DI INDONESIA. Pengalaman-pengalaman yang diperoleh dari Projek Nasional Bantuan UNDP dalam bidang aplikasi isotop dan radiasi di bidang penelitian pertanian dikemukakan dalam makalah ini. Tujuan Projek, kegiatan serta keluaran penelitian dan penggunaan - nya tercakup didalamnya. Penekanan diberikan pada kegiatan-kegiatan penelitian yang telah memberikan hasil yang memiliki potensi untuk dikembangkan pemanfaatannya oleh pengguna hasil keluaran Projek, baik pengguna-antara maupun pengguna akhir.

INTRODUCTION

Nuclear techniques application in agricultural research is based mainly on two different utilization of isotopes : (1) The use of radiation emitted by a particular

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* A paper presented to the RCA Seminar, Jakarta, 13 - 15 June 1988.

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radioctive isotopes as a source of energy to induce specific biological changes : (2) The use of isotopes, either radioactive or stable, as tracers to study the mechanism as well as the efficiency of a certain biological process as influenced by different agricultural production practices. Both types of utilization, when applied properly, may generate results of practical importance or provide needed information for improvements of different areas of agricultural production.

In agricultural research, however, it should always be fully realized that a nuclear technique, is a tool which in many cases, is useful to solve agricultural problems. Its effectivity is much dependent on the nature of problems. In most cases, a particular problem requires a complementary utilization of various techniques, including the nuclear ones. It is very rare that a particular problem can be simply solved by a single technique. On the other hand, however, it must be appreciated that the nuclear techniques offer a better advantage in providing more sensitivity, and specificity as commonly known.

This paper would not describe the technical details of the nuclear techniques as it has been easily found in many literatures. Instead, I would rather desribe our activities and experiences in using nuclear techniques in agricultural research, particularly those which are related to the on-going UNDP Country Project in Indonesia.

DESCRIPTION OF THE PROJECT

As previously stated, the project is a country/national project funded by the goverment and assisted by the United Nation Development Programme (UNDP). The UNDP assistance executed by the IAEA mainly consists of three components : expert services, equipments, and training/fellowships. The first phase of the project started in 1982 and ended in 1987.

The project is multidiciplinary since it covers a wide range of research areas. At the beginning, it included plant breeding, soil & plant nutrition, and insect pest control. In 1984, agrochemicals was included as a new research area in the Project. In 1986. another new area of research, i.e. animal nutrition, was also incorporated. In such a wide range of problem areas covered in the project, the development and immediate objectives have been formulated in such a way based on the existing facilities manpower and operational resources, intitutional framework and rational anticipated achievements attainable within the project period of five years. (1,2)

The development objectives of the Project are : (1) to make more effective use of the potentialities offered by modern research techniques based on isotope and methodology as a contribution to the national efforts for increasing agricultural production in Indonesia (2) to make the results of such research available for improvement of agricultural production.

The immediate objectives have been difined as follow (1) to develop varieties of food crops (particularly rice and grain legumes), technology, and methodology for possible improvement of food crop animal production (2) to improve research facilities of the Centre for the Application of Isotopes and Radiation (CAIR) so that by the end of the Project it will be able to serve the national needs for utilizing isotopes and radiation techniques in agricultural research and training with little external assistance (3) to estabilish effective cooperation between CAIR and the agricultural Institutions of the Ministry of Agriculture at the levels of both research and research outputs utilization.

With such clearly defined objectives, the Project has been consistently executed and implemented to generate outputs of different kind through research programmes, training, and fellowships.

PROJECT ACTIVITIES

Agricultural (plant and animal) production is always exposed to a very wide range of problems and constraints. All efforts devoted to solving/removing problems/constraints invole research on various aspects of crop/animal production. Research approaches from different angles have to be considered along with the available techniques including the nuclear techniques.

Like any other techniques, the isotopes and radiation techniques is simply a tool to induce a useful biological effects and to trace biological processes occuring in plants/animals with considerable sensitivity and specificity pertaining to crop/animal production. Departing from these views, the following research activities have been the major operation of the Project.

Plant Breeding. In carrying out the Plant Breeding program, we realize the principle that a high yield of a corp can be achieved only with the proper combination of variety, environment, agronomic practices, and plant protection measures ; No single combination of these four factors however, is applicable to all situations (3) : Additionaly the development of a new improved variety of crops needs to be based on the improvement of agronomic characteristics such as insect resistance, disease resistance, tolerance to adverse condition of soils, tolerance to drought, cold, etc. The ideal outputs, then, would be disease and insect resistant varieties genetically adapted to adverse factors (4). In such framework, the isotope and radiation technique could provide a complementary contribution towards the achievement of the ultimate outputs.

Through the process of biological interaction, radiation could induce genetic alteration which is known as mutation. When properly detected and screened, this mutation may produce new useful genotypes with better agronomic and/

or other characteristics. After careful screening and selection over generations, and extensive testings over locations, the new selected genotypes can be developed into new improved varieties. In addition to the role of radiation as a mutagenic agent, the radioactive isotopes as tracers also offer a sensitive assessment to identify relative resistant levels of plant genotypes to a particular insect. In some cases, it is of advantage to incorporate the isotope method to the later stages of screening of plant genotypes against a particular insect.

The Plant Breeding component of the Project has been covering three major food crops, i.e. rice (lowland and upland), soybean, and mungbean. The lowland rice breeding activities have contributed two new varieties. In early 1987, a new improved variety of soybean has also been released (5). A considerable number of mutant lines of rice, soybean, and mungbean are at present under field testings at various locations for yield performance assessment under different environmental condition and growing season. From these extensive testings, another new crop varieties are expected to be officially approved for releases.

In addition to the direct utilization of mutant lines as potential new varieties, sometimes the desired improvement needs to be achieved through radiation induced mutations and then followed by hybridization.

With a such combination of techniques an optimal desired varietal improvements could be attained stepwisely. As an example, in our breeding activities we have induced mutations for improving tolerance to a high concentration of Aluminum commonly found in acid soils. A number of mutants have been recovered, one of them (mutant No.23-A1) in addition to having better Al tolerance it has also shown earlier in maturity which is desirable. However to further improve the grain quality (size, shape, and appearance) of this mutant, we cross it with a selected genotype introduced from the Asian Vegetables Research and Development Centre (AVRDC) located in Taiwan. Then after several generations, we have been able to screen genotypes of the offsrings which express the desired combination of characteristics for further testings and evaluation.

Soil and Plant Nutrition. The advantage of using the isotope technique in this research area is quite obvious, particularly in the study of Soil-Plant relationship. The application of fertilizer to provide nutrients to the plants for optimal growth and development always encounter with the problem of efficiency. Under most conditions, Nitrogen is the first limiting nutrient. When fertilizer nitrogen is applied to soil, the crop absorbs it and uses it for grain production. Efficiency of fertilizer nitrogen can, therefore be formulated as (3) :

a. Efficiency of absorption (kg absorbed N/kg applied N).
b. Efficiency of utilization (kg grain/kg absorped N).
Those two kinds of efficiency can only be measured using N-15 isotope technique. With the N-15 labelled fertilizer, nitrogen contained in the plant which derives from fertilizer can be quantitatively differentiated from the nitrogen deriving from other sources (soil and biological fixation).

With the aid of isotope technique and concept of fertilizer efficiency we are able to obtain a curve for relationship between applied fertilizer and crop yield at a particular level of soil fertility as represented by the yield level without any fertilizer. Such curve is important for prediction purposes in an attempt to increase crop yield through increasing fertilizer efficiency.

Proper method of N fertilizer application and suitable timing in relation to plant growth stages are essential to increasing fertilizer efficiency. Studies on such issues have been conducted on irrigated rice culture. Results suggested that considerable increase of fertilizer efficiency could be achieved by a deeper placement of fertilizer and a split fertilizer application to certain growth stages of the crop. Further improvements could also be obtained through modifiying the physical form of urea (briquet versus prill)allowing a slower release of nitrogen from the fertilizer (6).

Under rainfed upland condition, especially in the red yellow podzolic soils, nitrogen is a major limiting factor for crop production. Several pattern of cropping system have been devised to optimally make use of the growing season of about 10 months. In such system, it is of great interest to develop a N management strategy where we could clearly identify the relative importance of different sources of nitrogen (biological fixztion, fertilizer, crop residues, and soil) in providing N to two different patterns of sequential cropping (upland rice-soybean-cowpea; and upland rice-corn-cowpea). The relative roles of each N sources in contributing nitrogen to each crop species grown sequentially in the system can only be determined by the use of isotope technique. A study conducted at Lampung indicated that (7).

a. Food legume crop residues can make a substantial contribution to the supply of N to the subsequent crop, and a significant contribution to the crop after that. In the wet season upland rice, this contribution is comparable to that from fertilizer.
b. Crop uptake from fertilizer N in the wet season is very poor and there is little residual affect on the subsequent crop, suggesting substantial loss of fertilizer N from the system.
c. Cereal residues do not make a substantial contribution of N to the subsequent crop.

Azolla pinnata, the small fresh water fern, in a symbiotic association with the blue green algae *Anabaena azollae* has known to be able to fix molecular nitrogen from the atmosphere. When the *Azolla* biomass is incorporated into the paddy cultivation, it is understandable that the rice crop will take the benefit of nitrogen released from incorporated *Azolla*. The project is interested in assessing the relative contribution of *Azolla* in providing nitrogen to the rice crop using the N-15 isotope technique under a particular local condition. Results of the assessment suggested that when Azolla is applied twice to the soil during the growing period of rice, it could increase the rice yield comparable to the yield increase obtained from application of 90 kg N/ha of urea fertilizer (8). The carry over affect of Azolla application to the succeeding rice crop was also found to be significant. Further studies need to be conducted to assess the technical and ecomomic feasibility of incorporating the biological system of *Azolla and Anabaena* association into lowland rice cultivation to reduce the amount of chemical fertilizer requirement.

Pest Control. The research activities in Entomology have been emphasized on the potential use of isotope to label the insects for the study of insect movement and dispersion in the field. Rice brown planthoppers (BPH) rice stemborers, and bean flies have been subjected to

this study. The labelling techniques for those insect species have been properly defined. Application of this techniques in the actual condition of the field is being carried out at several locations.

The entomological research activities have also successfully developed a laboratory technique using radio isotopes as tracers to screen the rice genotypes for resistance to BPH biotypes through looking at the feeding behaviour of the different biotypes. This technique is currently being incorporated to the rice breeding activities complementary to the conventional techniques.

Agrochemicals. The Agrochemical research was included to the Project in 1984. Its activities are concentrated to develop a new technology to prepare formulations of slow-release pesticides using irradiated latex. The initial products of this technology is being tested on cotton crops this year at East Java, and will be followed by another tests on sugarcane at Pasuruan (East Java) and on soybeans at Kuningan (West Java).

A considerable accumulating information has also been obtained on studies of carbofuran pesticide in rice-fish ecosystem using ^{14}C-labelled carbofuran to define the factors affecting the efficacy of the pesticide against rice pests and to assess the interaction between the insecticide and fish and its persistence or degradation in soil and rice plants. Similar study will also be carried out with

propanil pesticide as the capability to synthesize a labelled pesticide such as ^{14}C-propanil has been successfully strengthened through inputs of expert service and laboratory equipment from the Project. Continuing efforts will be made to develop this capability as the price of imported labelled compounds is generally very high.

Animal Nutrition. The Animal Nutrition research group, whose activity was included to the Project in early 1986, has achieved significant results of partical importance in the national program of increasing animal production. The accumulated laboratory results in ruminant nutrition research obtained during the previous years have been able to be extensively tested at farmers level in many different locations covering the 5 Provinces (West Java, Central Java, Yogyakarta, East Java, and Lampung) in collaboration with the Directorate General of Livestock Services (DGLS) and its subordinates in charge with animal production program (Directorate, Provincial, and Districts) and through active participation of the designated farmers owning the tested animals. Feed supplements in the form of solid blocks made of molasses, minerals, and other ingredients deriving from various agricultural and agro-industrial by-products are formulated at optimal composition based on careful in-vitro and in-vivo laboratory studies on rumen function (9). These multinutrient molasses blocks have been tested on beef cattle, dairy cattle, goat, sheep,and

bufallo. The results obtained from these field trials indicated a prospective and positive affects of the blocks on growth rate (body weight gain) and milk production in dairy cattle. Careful assessment on the results of the trials has been made and concluded at a national level through a Workchop organized by the DGLS in December 1987. The recommendation formulated at the workshop has been submitted to DGLS and Batan. Batan and DGLS have agreed to apply the molasses block technology at Farmer level. On the 17th January 1987, the D.G. of Batan has officially transferred the technology to the D.G. of Livestock Services. The success of this Animal Nutrition component of the Project will offer a promising feeding strategy for ruminants taking into account the purpose for which the animals is being kept (meat and/or milk production, provision of drought power) and to a maximum extent, make use of localy available resources (oftently available as by-produsts of other agricultural production systems or industries). At present, an extension programmes have been initiated in West Java and Central Java to introduce the technology to groups of farmers on how to prepare the blocks. It is of our interest that the farmers would finally to able to produce the blocks theirselves to meet their needs of molasses block supply. Some feed industries have also shown their interest in the molasses block technology.

To ascertain whwther the reproductive performance can

also be improved by this atrategic nutritional manipulations, parallel studies on animal reproductive performance are being prepared on a longer term basis. A proper locations for such studies in West Java and Central Java have been chosen in collaboration with the respective Provincial Livestock Services.

Animal Disease. Activities on Animal Disease is being included to the Project this year (1987). Achievements on this line in association with the Project is not existing yet. However, as the starting point, it might be worth to mention that the research activities at CAIR, Batan, in collaboration with RIAD and Pusvetma, have developed a technology to produçe a vaccine for coccidiosis (a poultry disease) by the use of gamma radiation. The laboratory and limitted field test of this vaccine has led to a currently conducted extensive field tests in 5 different locations (two in West Java and three in East Java) as suggested by the National Evaluation Committee for animal Drugs. These field tests, starting August 1987, are organized through the Directorate of Animal Health, DGLS, Ministry of Agriculture.

With respect to the Animal Disease component, the proposed second phase of the Project will mainly cover the activity on improvements of national capability in rapid diagnosis of several important animal diseases based on immunoassay (ELISA test) and possibly on labelled DNA probe technology.

UTILIZATION OF RESEARCH RESULTS

As anticipated, some results have been ready for direct transfer to end users, some are still at the stage of extensive field testings for obtaining official recommendation, and some others are limiteddly of great importance to scientific communities.Research outputs of these first two categories need to be put forward into the existing national syatems for optimal utilization.

In this respect, we follow the concept of Project/Institute-Clients relationship in which three approaches to increasing utilization of research and development (R&D) are involed : Personnel approaches, procedural approaches,and organizational link. Realizing that the Project has not direct access to the ultimate (end) users, we have to clearly identify the intermediate users which, in most cases, are various institutions within the Ministry of Agriculture. With the concerned institutions and existing systems the Project has been establishing effective relations through applying, whenever possible, those above mentioned approaches. Good examples of the successful relations have been demonstrated in transferring results in animal nutrision, animal disese, and plant breeding through the existing systems.

CONCLUSIONS

The isotopes and radiation techniques have been successfully applied to agricultural research under a multidiciplinary Country Project in Indonesia assisted by the UNDP.

A number of outputs have been produced on the way to achieving immediate and development objectives. Some of them have been in the process of utilization by the end users (farmers).

The experiences gained from this Country Project would be very useful in anticipating any Regional Project which may come up in the future. If common problem areas and common interest among the countries in the region could be identified and formulated, it would no impossibilities of having a solid regional project in the agricultural application of isotopes and radiation in the furute.

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