Seminar on nuclear techniques in agriculture and environment

Kuala Lumpur, Malaysia

8 - 11 June 1981

UTILISATION OF RADIOISOTOPES AND IRRADIATION IN CROP PROTECTION RESEARCH

By ONG, S.H.
(Crop Protection Branch, MARDI, Serdang, Selangor, Malaysia)

ABSTRACT

There is a growing realization of the benefits which may be derived from the application of radioisotopes and radiation sources in the different disciplines of crop protection research. Many investigations which might only be carried out with extreme difficulty or not all by conventional methods, could be pursued with relative ease. Radioisotopes and irradiation have been utilized in understanding the physiology and behaviour of pests and their biochemical processes and in consequence, have contributed beneficially to the development of better control techniques and more effective pesticides. On the environmental aspects, radioisotopic techniques have provided a useful tool in understanding the behaviour, metabolism and residues of pesticides in the environment.

INTRODUCTION

In Malaysia, greater reliance on pesticides to reduce crop loss has become apparent as the country makes tremendous progress in agricultural development. In particular, the need to overcome shortage of labour and to increase production and quality has prompted farmers to rely more on pesticides. With the strong emphasis on agriculture in the years to come, it is anticipated that agricultural development will proceed at a faster rate in the future; and it is also expected that pesticides will be more widely used.

Despite the great benefits in food production brought about by the use of pesticides, much public concern has been generated to recent years on their possible side-effects on the environment. In Malaysia, some of these undesirable effect are already evident eg. pest resistance, fish kills, pest resurgence and acute poisoning in animals and man. As such, there is an urgent need to examine more closely some of these aspects. Although nuclear technology is not an universal remedy to all these problems, it certainly has an important role to play, especially in the development of better control techniques and more effective pesticides. The ability of radiobiological technology to provide alternative means of pest control primarily lies in their versatility in offering new research techniques which can be utilized to understand better, the physiology and behaviour of pest and their biochemical processes. In the environmental study of pesticides, nuclear techniques offer an extremely useful tool in many areas including the behaviour, metabolism and residues of pesticides.

Entomology Research

Since the pioneering work of the USDA in the application of radiation and radioisotopes in controlling pests of cattle (9) many countries have attempted to exploit the advantages that might be gained in this field. To date, a considerable amount of basic research on the application of nuclear science in entomology and insect pest control has been undertaken by many countries.

Radioisotopes have been used in the study of several aspects of Entomology. These include ecological studies, biological control, population studies and insect physiology.

Radioisotopes have been of value in labelling and studying the life history, food habits, dispersal, mating, behaviour, parasites, predators and other biological aspects of insects (8). A knowledge of the biological and ecological aspects of insect pests enable the capitalization of the weakest link or vulneruble point for economic control using a wide range of measures such as quarantines, environmental control, crop practices, insecticide treatment, irradiation sterillization, baits, traps, and predators or parasites.

The importance of certain predators and parasites in controlling injurious insects is frequently tedious to determine, especially if the pests are nocturnal, underground or inconspicous. Pests can be radioactively

labelled and when eaten leave a radioactive record in the predator. Based on the amount of radioactivity which indicate the relative numbers of pest consumed, predator efficiencies can be calculated. Using the same technique, parasitic and commensal relationship of crop plants can be clarified. In natural insect populations, accurate studies on their abundance and size have been made possible through efficient radioisotope tagging and detection. Using this technique, reliable determination of insect mortality has been simplified and has provided an effective mean of evaluating the efficacy of chemical insecticides or biological methods. Radioisotopes have also contributed to the fast progress in insect physiology. Through radioautography detection, radioisotopically - tagged insecticides are traceable down to the cellular level.

Irradiation of insects have received wide attention from the fundamentals of genetics to the successful application to limited areas or country - wide insect pest eradication programmes. Radiation studies on specific effects have been carried out on male and female germ cells in Diptera, Hymenoptera, Coleoptera and Hemiptera to measure variations in response and sensitivity to radiator at different stages of oogenesis and spermatogenesis. The principles and applications of the irradiated - male technique have been demonstrated on a wide of insects and other anthropods (16).

Insect pests of stored commodities constitute an important problem especially in sub-tropical and tropical countries. Irradiation of stored commodities has been successful in rendering the produce insect-free. However, studies need to be undertaken to ensure that such food are safe for consumption.

WEED RESEARCH

Weed control constitutes a major problem in agriculture. Recognising this, constant effort has been made by researchers to develop and utilize herbicides. For effective use of weedicides, there is a need to understand the absorption, movement, distribution and mode of action of herbicides. Radioisotopes have proven their usefulness in these studies (6). It is probably a general rule that the practical selective herbicidal nature of a chemical compound is usually known some time before the actual metabolic mode of action is traced. Nevertheless, the mode of action is of great importance as its study may lead to the development of other herbicides.

PLANT PATHOLOGY RESEARCH

Diseases of plants are caused by pathogens which include fungi, viruses and bacteria. Fundamental knowledge of each disease cycle is required before any successful control measures can be applied. The use of radioisotope tracers provides a useful tool in elucidating some of the steps involved in each disease situation. When marked with suitable labelled isotopes, very any otherwise invisible pathogenic agents become traceable. Their development cycle in plants, the localization and the modifications induced in host plant tissue may also by thus easily traced.

Radioactive tracers are used extensively in the physiological study of parasitic fungi in the different cycles of their development. These studies have helped elucidate the nutrition of the pathogen within its host (5). By creating unfavourable conditions, the dvelopment of the parasites may thus be impeded.

In epidemiology of fungal diseases, the mechanisms of spore dispersal and spread of mycelia have been studies using radioisotopes, a technique which is very suitable for very small spores and mycelia (2).

In plant virology, radiochemical technique is a powerful tool for a more basic work. It allows for a precise analysis of the effects of viruses in cells. It made possible for the preparation of radioactive viruses for detailed analysis of composition and architecture of the particles. Thus, the application of radioisotopy as a microtechnique method in virology has relieved many scientists of much drudgery in their work.

Isotopes have found many uses in plant virology. Briefly, they are used for virus assay (11) preparation of labelled antibody (10) detection of impurities in virus preparations (Marthew, (12) 1976b), determination of virus - vector relationship (Mathews, (13) 1970c) and studying the mechanism of infection (1) and replication (14).

Much work has been done on the influence of virus on the metabolism of plant. Among the aspects that are studies included phosphorus metabolism, protein and amino acid composition and enzymatic activity of both healthy and virus infected plants (15).

The control of plant virus diseases is one of the greatest problem of our day. Fortunately much damage can be prevented by indirect means of control. More could be achieved however, it we had a better insight into the interrelationships of virus, vector and host plant. Radioisotopes can be of help here. To be able to inhibit virus multiplication without simultaneously blocking plant metabolism, more should be known about the process of virus infection and virus multiplication. Considerable progress in these two areas have been made recently with the use of isotopes.

NEMATOLOGY RESEARCH

Nematodes display a variety of relations with their plant hosts. They may induce growth of galls, destroy host tissues, cause local lesions or be a vector plant virus. Nematodes may also alter the normal development of roots and then disturb the normal host physiology.

The use of radioactive isotopes permits the study of nematodes and their relation to the host. It would be simple to determine the movement of nematodes within roots and leaves using scanning devices or autoradiography. Autoradiography of infected plant provides information as to how nematodes alter the cellular metabolism of the host (4).

The growth and efficiency of infected root have been studies by drenching with the fertilizer incorporating Na^{24}, K^{42}, Ca^{45}, Ca^{49}, P^{32}, S^{35} or N^{15}. Such isotopes have been used in studies on absorption and translocation, and in the determination of the nutritional status of infected plants. (dropkin (4), 1966). There is a possibility that the relationship of macronutrient uptake to nematode population levels may be used to predict crop damage.

Since nematodes may acquire amino acids and organic compounds from their host plant, isotopes are used to elucidate metabolic pathways of these compound (3).

Knowledge of the biology of phytonematodes has advanced to a point where radiation and isotopes offer many possibilities for the study of nematodes and their interactions with plants.

PESTICIDE RESEARCH

The use of pesticides is not without problems. One of these is that not all of the chemicals will remain in the area of treatment. The physico - chemical properties of the substance, together with the enviromental processes result in a portion of the chemical released moving elsewhere in the environment.

The environment comprises of four components, namely, atmosphere, lithosphere (soil), hydrosphere (water) and biosphere (living organisims). The behaviour or pesticides in these systems will depend largely on the transport processes, their physico-chemical properties (such as vapour pressures, solubilities, etc.) and environmental factors (such as photochemical reactions, mircrobiology attack, etc). Acknowledge of these processes will not only assist in understanding the dynamics of pesticides in the various environmental media but also to predict behaviour patterns of pesticides that may get into the environment. This can mean safer, less environmentally contaminating practices and greater effectiveness, both of which should contribute to the production of food and protection of man's health.

In studying the dynamics of pesticides, analytical techniques are essential in tracing their movement, quantities and metabolities in the various environmental media. For these studies, radioisotopy is one of

the techniques that can be beneficially used to identify degradation products and trace the ultimate fate of pesticides. Such studies are of growing importance.

Briefly, the advantages of radioisotopic usage in pesticide research (7) are as follows:-

1. Radioassay provides an immediate and accurate measure of the total initial residue often without destroying the sample.
2. Loss of total residue through harvest, storage, washing, milling, votatility, etc. can be followed quantitatively sometimes with non-desructive techniques and without subjecting sample to solvent extraction and clean-up.
3. Radioassay of extracts and of the extracted fractions provides evidence of extraction or recovery and completeness of possible chemical binding of residues (eg. unextractable residues of malathion in wheat grains).
4. Radioassay of suitably fractionated extracts provides rapid characterization of residues in terms of unchanged parent pesticides, polar metabolities, etc.
5. The fate of a labelled pesticides can be followed specifically in the presence of a background level of other pesticides including the one being studied.
6. Co-chromatographic radioisotope techniques with non-radioactive carriers provide for the identification of labelled metabolities present in quantities below the limits of chemical detection.
7. Evaluation of conventional techniques eg. studying the efficiency of extractions techniques, confirming chemical identity by co-fractionation and co-crystallisation techniques.

INTRODUCTION AND ASSOCIATED TECHNIQUES

Several devices are used for the counting of radioactivity in samples. Among these available, the simplest equipment is the Geiger - Muller tube. Liquid scintillator counters are extremely useful for extracted samples and they are widely used in pesticides study.

Radioisotopic work is often carried out with the combination of paper, thin-layer and cas-chromatography when separation of radioisotopic components are necessary. Scanning for detecting and determining radioactive components or thin-layer chromatography plates has become a popular technique in radioisotopic stdues. Autoradiography, a technique useful for tracing and premilinary detection of labelled compounds or metabolities are often usefully employed in translocation and metabolism studies.

SELECTION OF COMPOUNDS

The use of radioisotopes involves the incorporation of a radioactive atom in an appropriate molecule which an be traced by measuring the radioactivity. To minimise the possibilities of decomposition of the compound by simple chemical reactions of biological breakdown, it should be labelled in a position that is not readily attacked. In general, most functional groups in a molecule can easily be labelled but because of their reactivity, these groups readily undergo changes and the tracer may be lost.

Most pesticides are composed largely of carbon, hydrogen, and oxygen and thus radioisotopes of carbon and hydrogen are widely employed in tracer experiments. The radioisotopes of oxygen are not suitable for tracer experiments because of their short-life. In Entomology, Plant Pathology, Weeds and Nematology, labelling is not only applied to pesticides but also to pest components (such as amino acids, genetic materials, metabolities, etc.) and nutrients (such as Ca, K, Na, P etc). The common radioisotopes used in crop protection are H^3, C^{14}, Cl^{36}, S^{35}, D^{10} P^{32}, I^{125}, Na^{24}, K^{42}, etc.

CONCLUSION

There is a growing of the benefits which may be derived from the application of radioisotopes and radiation sources in the different disciplines of crop protection. Conventional methods used are not only tedious sometimes, but gave unreliable results. With the advent of nuclear science, many investigations which might only be carried out with extreme difficulty or not all by conventional methods, could be pursued with relative ease.

DISCUSSION:

C.G. Lamm : The joint FAO/IAEA/WHO Expert Committee on the wholesomeness of Irradiated Food at its meeting in Oct. 1980 in Geneva recommended that food items irradiated up to 1 MRad do not need any wholesomeness testing (toxicology testing).

Ong Seng Hock : I am pleased to hear of such a report. I am sure this report would act as an important guide to future development in food irradiation. It has been our policy to be cautious of undersirable effects of new technologies. Certainly this report will influence our planning of strategies in the future.

Zaharah A. Rahman : You have given us a very extensive review of the use of radioisotope in crop protection and you also have given a list of insects problem in Malaysian agriculture. Have you or any of your staff ever venture into using radioisotope in your studies?.

Ong Seng Hock : We have not undertaken research using nuclear technology in crop protection. What is given today is the approach we intend to undertake in the future as our personnel are being trained and facilities made available.