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PESTICIDES

THEIR IMPLICATIONS FOR AGRICULTURE

Agriculture Canada

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Chapter 1

SOCIETY'S RESPONSIBILITIES IN PESTICIDE USE

Important factors in the use of pesticides in today's environmental-conscious society are discussed in this booklet. The following chapters show that vast amounts of time, money and effort are being expended to ensure that these chemicals are used in a reasonable way for the general betterment of mankind through the production of wholesome food and the protection of health. It becomes clear, also, that there are some very definite hazards and drawbacks involved when these products are used excessively or unwisely.

One fact that comes through very clearly is that pesticides are now, and will be in the forseeable future, an integral and essential part of most existing pest control systems. The amount of pesticide used in any system or systems will evidently vary according to the crop to be protected, the pest to be controlled, the nature of the compound itself and any other factors such as biological and cultural control methods. By the same token, it is safe to say that society's over-all goal should be to reduce the use of pesticides to the lowest possible levels within the socio-economic constraints of our society.

The so-called 'pesticide problem' is one of many complex issues, including housing, transportation and population growth, that face us today. As a society we are obliged to apply our intelligence and integrity to arrive at objective solutions to these problems. There are no simple yes or no answers.

For the sake of this discussion it is probably worthwhile to divide society into several components and look at the role each has to play in coping with the pesticide problem.

Manufacturers' Responsibility

Manufacturers have the primary responsibility of justifying the need for, and the use of, any new product. They must produce data that back up claims for efficacy, toxicity (to humans, animals and plants) and effect on the environment. This usually entails an average of up to 5 years' work and possibly $10 million. In other words, manufacturers must provide evidence that their products are needed, are safe, and will not cause undue harm to the environment.

Governments' Responsibility

Governments, on the other hand, must establish legislation to regulate the manufacture, sale and use of pesticides. Such legislation must be based on regulations that establish a permissible safe use pattern for each chemical. This use pattern must be described on the labeling for each product and the labels need government approval. In addition, safe tolerance levels must be established for residues in food and feed. In Canada all pesticides are registered under the Pest Control Products Act, which is administered by the Canada Department of Agriculture. We have probably a more sophisticated system of pesticide regulation than any other country in the world. There is close cooperation between the several federal departments involved with different phases of pesticide regulation (e.g., Canada Department of Agriculture, National Health and Welfare, Environment Canada), appropriate provincial departments, the industry and universities.

Users' Responsibility

Both farm and urban users have the responsibility of using pesticides only when necessary and in quantities recommended on the label, as it is assumed that these recommendations will preclude any undesirable side-effects. In the final analysis, it is only through misuse or overuse of pesticides that environmental problems may arise. The use of DDT was proper in terms of what was known at the time it was first widely employed. On the whole, it is thought that the farming community does not knowingly overuse pesticides, since to do so would be poor economics. What businessman deliberately uses more materials than necessary? If he did, he would soon go out of business. It may not be as easy to say the same about urban pesticide users. Although urban residents individually use only small amounts, the quantity used by the whole group is considerable. With urban users, there is a tendency to say, "Oh, the little I use won't have any effect". However, we are all aware of cases where the whole lawn was sprayed to kill a dozen dandelions or the house fumigated to kill a couple of flies. The weed digger and fly swatter are still the best means of control in such cases.

Media's Responsibility

The news media in all forms, print, TV and radio, have an awesome responsibility in forming public opinion. In many cases, an excellent job of objective reporting has been done on pesticides. On the other hand, there have been numerous blatant and unfounded stories about them that have received undue publicity. It goes without saying that objectivity should always come first, whenever the well-being and physical health of the nation are concerned.

Consider the Consumer

Last, but not least, is the consumer. If it were not for the consumer of agricultural products, we wouldn't use pesticides. Today the world is faced with the problem of producing more and more high quality, low cost food for an increasing population and of satisfying the preferences of an increasingly selective shopper. Whether or not the latter part of the problem is in the best interests of mankind, it still forms part of the dilemma — the need for high quality, low cost food. As long as the consumer demands this, the latest technology in its various forms — mechanization, animal and plant breeding, chemical fertilizers and pesticides — will be used. Pesticides play an exceptionally important role in the application of this technology and, if wisely used and used with constraint, will continue to do so.

To sum up, pesticides have provided tremendous benefits in the past, through the control of pests that affect man's health, destroy his sources of food, and damage some of his belongings. They are toxic chemical compounds that must be treated with the same care and respect as pharmaceutical products and other results of modern science and technology. There have been problems in the past due to their misuse or overuse but very rarely, if ever, from their proper use. Increasingly precise analytical procedures that can detect minute amounts of residues; the phasing out of undesirable chemicals; more comprehensive regulatory procedures and the lowest possible use of pesticide through the development of integrated pest control systems will ensure a minimum of problems and a maximum of benefits from use of pesticides in the future.

Chapter 2

THE ROLE OF PESTICIDES

Since the turn of the century, Canadian agriculture has been evolving towards the development of monocultures, or single crop enterprises, occupying larger and larger acreages. This increase in the size of farm units, combined with economic vagaries, has created a situation in which one year's crop loss would cause not only a serious financial setback, but shortages and increased prices. For this reason pesticides, along with good seed and fertilizers, have become a form of crop insurance. At the same time, increasing mechanization has contributed to a decrease in manpower on the farm. It is now practical to seed a crop and apply insecticides, herbicides and/or fungicides, as well as fertilizers, all in one operation. Another labor-saving activity is the spraying of crops from aircraft with systemic insecticides and fungicides that have a long residual life in the plant. In brief, technology has gone hand in hand with an ever-expanding and more demanding agriculture.

Man and the Environment

The wisdom of this evolution in methods is now being challenged in certain quarters because of increasing uneasiness about the ecological consequences of pesticide use in agriculture and a lack of understanding of the destruction that pests can cause. Some Canadians believe that in the future agriculture should be pursued without the use of pesticides, and crops grown in a sort of Garden of Eden, to protect man from chemical pollution. Such people can hardly be taken seriously for a number of reasons. Many of our insect pests and plant diseases have been imported accidentally, and having no natural enemies, must be controlled by pesticides if serious losses are to be avoided in certain crops. Examples of such pests that must be controlled, mostly on an annual basis, are the codling moth on apples, the European corn borer on corn, and the carrot rust fly on carrots. Because of modern land, sea and air transport, natural boundaries to insects such as deserts, mountain ranges and oceans are being crossed daily. Although pests are being intercepted regularly at our ports of entry, some eventually go undetected through our quarantine outposts, and thus add to the problems of pest control. In addition, flying insects and spores cannot be intercepted effectively when crossing our southern border, and cause considerable damage each year to many important crops.

Our present dilemma is that we are asked by some environmentalists to eliminate pesticide use in agriculture in order to protect public health and the environment, while at the same time, pesticides are an essential part of that protection. At the other extreme, many farmers ask us to ignore these demands, insisting that the protection of their crops must continue if farms are to survive economically.

Integrated Control

The answer to effective crop protection in the future is integrated control of plant and animal pests; that is, control through the maximum use of biotic agents with chemicals, applied only as needed at defined damage thresholds. Specifically, through integrated control, we allow the biological forces already existing in nature to act in conjunction with properly timed uses of chemical pesticides, sex pheromones, sterile male release programs and other activities to limit damage to crops and threats to public health.

This type of control operates within two constraints. One is the use of specific viruses, bacteria, insect predators and parasites to kill pests. (This depends upon the availability of a certain density of the pest and enough time for effective attack, and applies as well to non-specific bioagents used.) The second constraint is that man made pest control strategies are generally limited by economics, legislation and the paucity of basic research data required to manipulate and predict the situations being treated. In the final analysis, it is the degree of control desired that will largely determine the best type of control system for adequate crop protection, and the level of monitoring necessary to avoid undue side effects of pesticides on nontarget organisms.

Pest Level at Near Zero

There are many crops that must be grown almost 100 percent free of diseases and pests. Apples are one. During the growing season, the apple tree is attacked by pests such as scales feeding on the bark, mites feeding on foliage, codling moth larvae boring into the fruit itself, and by diseases such as apple scab developing on both foliage and fruit. There could be as many as 150 pests and diseases on a single tree. All these must be monitored. In addition, cold storage and fumigation controls are necessary for crops that are eventually destined for export. Importing countries have stringent regulations against foreign pests. For example, a few European red mite eggs or codling moth larvae in a boatload of apples is sufficient for these countries to refuse to buy from us. These special requirements place exacting demands on the pest control systems we use and, with apples in particular, a zero tolerance cannot be met without the use of pesticides. Hence, in the case of apples and other horticultural crops, the pest control systems used will continue to depend mainly on more specific and short-lived pesticides, but using biological control more and more as such control measures are developed.

Pest Level at the Economic Threshold

Of the known large number of pests that attack our crops, a relatively few species of insects and diseases are of major economic importance. For example, with apples the ratio of economic pests to non-economic ones is approximately 1:18. The economic importance of pests is usually stated in terms of economic threshold; that is, the minimum number of pests that will cause significant crop damage. On the prairies the number of grasshopper egg pods per square meter determines the extent and the areas where there might be damage to cereal crops when nymphs emerge, and could also indicate what control measures to use. These precise figures, on which pest control recommendations are based, are obtained through the continuous monitoring of populations as they develop within a season and within a geographical area. To take another example, a corn plant can tolerate thousands of aphids with minor economic loss, although it takes only a few aphids to carry a serious virus from a primary host to a secondary one. Therefore, we must recognize that there is a relationship between pest numbers and the degree of economic crop damage. This information must be known for every crop and every pest in order to achieve effective control and a reasonable prediction of the results.

In control systems for which an economic threshold has been established, chemical pesticides may not be as important as bioagents or resident beneficial predators, parasites and diseases. Interactions between predators and prey, under natural conditions, often prevent pests from reaching their maximum numbers and can cause population fluctuations that may be economically important. In such situations, as emphasized above, monitoring pest numbers over a period of time is a key operation. Nevertheless, it will often be necessary to intervene quickly with pesticides to reduce a sudden epidemic outbreak of a pest. The prudent application of a chemical under these circumstances will reduce the level of the pest and allow the survival of beneficial agents that will continue to contribute to biological control.

Twenty years ago, progressive Canadian entomologists paved the way for the present concept of integrated control by developing 'modified spray programs' for orchard protection. They advocated more precise timing of selective insecticides for effective control of apple pests at the most damaging stage, yet spared the natural predators and parasites from the effects of the chemical. The end results, for most crops, were less fluctuation in pest numbers above the economic threshold, a reduced amount of pesticides applied, and greater profit to the farmers.

Unspecified Pest Level

Apart from professional farmers who must operate large farm units profitably while adhering to domestic and export regulations, there is a Canadian urban public which uses a considerable quantity of pesticides to control insect pests and plant diseases. With the growth of cities and the assignment of municipal land in some areas for vegetable plots, this section of the population has been contributing to the problem. These people are particularly noticeable around plant nurseries on weekends, buying quantities of fertilizers, herbicides, insecticides, fungicides, vitamins and super-mixtures of near-magic power for the control of pests in their gardens and on potted plants. The quantities of pesticides thus used liberally by people conditioned by advertising far exceed the true needs. The pesticides here are applied without any reference to pest levels or economic needs. For such people, one aphid on a rose bush must be actively pursued with an aerosol can, and a single housefly in the kitchen can be a near tragedy. Yet, if we are to reduce effectively the amount of pesticides applied to the environment we shall require cooperation in the future not only from the farmer, who has a great need to use pesticides for crop protection, but also from the rest of the Canadian population. We should try harder to get the urban public to work with us in reducing the use of pesticides, particularly since this public itself is asking the farmer to stop polluting the environment.

We must therefore work towards integrated control in large agricultural units, monitor pest species wherever economic thresholds are known, use pesticides more intelligently, and increase the use of biotic agents. With this approach we can surely adopt pest control systems that will cause minimum pollution.

Chapter 3

METHODS OF REGULATING PESTICIDES

Pest Control Products Act

Pesticides have long been closely regulated in Canada. Laws have been in force since 1927 to regulate the importation and sale of products used for the control of pests.

The sale of pesticides is regulated by the Pest Control Products Act, which is administered by the federal Minister of Agriculture. Consequently a significant portion of his departmental resources is devoted to research into the control of pests generally, including the use of chemicals and non-chemicals. This work is done in regional laboratories and stations across Canada, where special studies are made on the effects on the environment of the use of pesticides.

In addition to research, two regulatory laboratories analyze samples of products taken in the market place to assure compliance with registration, and to conduct investigations of various kinds for the purposes of the Pest Control Products Act and Regulations.

Pest control chemicals make up a commodity group that covers a wide range of products and uses. The administration of the P.C.P. Act takes into account many disciplinary interests such as human health considerations, wildlife, fisheries, forestry, water and environmental quality. A major consideration in this respect is the Food and Drugs Act, the provisions of which are coordinated with the application of the P.C.P. Act.

The P.C.P. Act was promulgated in 1939, and its provisions require that pesticides that are imported, manufactured or offered for sale in Canada must be registered. Registration is granted only when the Minister is satisfied that the information made available to him is sufficient to demonstrate that the product is effective and safe under practical conditions of use. The Act provides for the evaluation of pesticides that are offered for sale, and for the control of labeling and advertising. It also provides the Minister with authority to refuse registration of a control product that is harmful to humans or domestic animals, or is otherwise unsuitable. The Minister can thereby set forth the purposes for which any product may be represented and to whom it may be sold.

The P.C.P. Act has been revised and its new regulations came into force on November 25, 1972. The revised Act broadens the definition of a control product to include a wider variety of products. In addition to importation and sale, it also provides for the regulation of manufacturing premises, storage, distribution, display and use of control products.

Most provincial governments have enacted legislation to control sales outlets, vendors and users of pesticides, and some of them have established licensing schemes for this purpose. The degree of sophistication of these provincial laws varies from province to province, and their regulations are complementary to those of the current federal P.C.P. Act. For instance, the regulatory status of a control product under the P.C.P. Act sets forth the purposes for which the product may be sold and certain provincial statutes determine the qualifications of persons who may sell or use that product. Some provinces, by means of legislation, control the physical conditions of premises for the display of pesticides and still others schedule certain products for which a permit or a purchaser's signature must be obtained prior to sale or use.

Regulations under the revised P.C.P. Act now exert controls in spheres occupied by provincial statutory requirements. Where this occurs the regulatory requirements of both laws will apply and will supplement one another. There is no conflict because the more restrictive regulation applies, whether under federal or provincial statute. For example, a product may be restricted under the P.C.P. Act for sale only to professional pest control operators, and this limitation would apply nationally. For reasons of its own, a province by means of its legislation may additionally require that a permit be obtained prior to the use of that product.

A number of regulatory methods that are variously applicable under laws governing control products have emerged over the years. These regulatory methods directly influence pesticide use. They vary in degree of restriction, and so may be employed to the extent necessary with respect to any given product, or any particular use of that product. These methods apply on a national or a regional scale depending on whether the legislation in which they are embodied is federal or provincial.

Because of the essential nature of pesticides and the benefits derived from their use, application of the various regulatory methods to prevent undue risk to human health or the environment depends upon a benefit-risk judgment that has to be made in determining the regulatory status of a control product. In making such a judgment, care must be exercised neither to underestimate nor overestimate the competence of persons to whom pesticides are made available. Almost any innocuous product can be used in a harmful way, and conversely, almost any toxic product can be used with safety. The public interest would not be served well nor the intent of the law carried out if either overly stringent or markedly permissive judgments were to be made in imposing the regulatory methods available.

The principal procedure or method of establishing the regulatory status of a pesticide (i.e., the manner in which it may be marketed and used) is through the registration requirements of the P.C.P. Act. Registration implies a number of controls, among which *evaluation* is very important. For a control product or pesticide to be adequately assessed for registration purposes, scientific information must be developed and made available to the Minister. In the case of a new active ingredient, virtually all this information must be developed by the manufacturer at a cost that could amount to millions of dollars.

From the evaluation process emerges the regulatory status of the control product that sets forth the uses for which it may be sold and the limitations on such use.

Implicit in the registration of a control product is *label compliance* with the directions for use, limitations and restrictions that have been accepted by the Minister. Certain provincial pesticide legislation, as well as the new P.C.P. Act, makes it an offense to use a control product in a manner inconsistent with the registered label instructions.

In addition to indicating the uses for which a control product is registered, the label directions may impose restrictions concerning the persons to whom a product may be made available. Control products are classified to restrict their sale and use to persons with the competence and facilities to handle them with safety. Those represented for use in and around the home must meet safety criteria in respect to occupational and environmental risk. Package size and label directions are the primary means used to meet the restrictions of the P.C.P. Act.

Sale of control products for which special knowledge or equipment is essential to their safe use is restricted to persons possessing the necessary qualifications.

Use of some pesticides has sparked concern about environmental contamination, but the degree to which they can cause contamination depends on their chemical nature and the manner and extent of their use. The manner of use can be adequately controlled if the label directions are followed by the user. However, the extent of use depends on the occurrence of the pest or pests for which the product is registered. Where concern exists over any pesticide, it may be subjected to a *signing requirement* on the part of the purchaser at the time of sale. In addition to impressing upon the purchaser the need for special care, procedure helps to provide statistics that, with other information, assist in determining whether the use of a control product is reaching unacceptable proportions. Registration status of a control product may require that its sale for certain specified uses be subject to the condition that the purchaser first obtains a permit to use it. A *use permit* may be required where there is concern either for safety for the environment or for human health. The terms of the permit take into account the conditions and need to which the use relates. The requirement for a use permit with respect to some products is currently imposed under both the P.C.P. Act and certain provincial statutes.

Control products, as defined by the P.C.P. Act, include about 450 active ingredients that are formulated in approximately 3,000 products. Regulatory measures such as the use permit or signature requirement are invoked for a relatively small number of these.

Statistics on reported poisonings, compiled by the Poison Control Program of the Health Protection Branch of the Department of National Health and Welfare, reveal that pesticides as a group are not a major cause of poisonings. Nevertheless, reports from this source as well as from provincial health authorities are taken into account in evaluating the regulatory status of any control product.

Environmental contamination resulting from the use or abuse of pesticides is more difficult to assess; however, the regular reevaluation of control products under the P.C.P. Act provides for consideration of this aspect. A number of continuing analytical programs are carried out under both federal and provincial authority, and the results of these are used to full advantage. These programs involve the analysis of human food, animal feed, crops, soil, water, air and wildlife. The information gained from these programs makes it possible to develop criteria for evaluation of new products, and the reevaluation of older compounds.

Committees Involved with Pesticide Regulations

Several committees have vital roles in the regulation of pest control products. The Federal Interdepartmental Committee on Pesticides includes members from federal departments whose interests are affected by pesticide use. These departments embrace regulatory and disciplinary interests with respect to human health, wildlife, fisheries, forestry, soil water quality and trade. The mandate of the FICP provides for assurance of interdepartmental communication in matters relating to pesticides, and also requires that the committee's advice is communicated to the Minister of Agriculture and from him to the ministers of other departments concerned. Established by the FICP and responsible to it, the Registration Committee is charged with reaching agreement on the regulatory status of any pesticide about which all departments may not agree.

Most provinces have established interdepartmental committees similar in structure to the federal committee and with similar aims with respect to the regional implications of pesticide regulation.

Of a more general nature but nevertheless important to the control of pesticides is the Canadian Agricultural Services Co-ordinating Committee, members of which include the federal and provincial deputy ministers of agriculture and the deans of the faculties of agriculture and veterinary medicine at Canadian universities. The CASCC has established a number of 'Canada Committees' which submit reports and recommendations for its consideration. The Canada Weed Committee, the Canada Committee on Pesticide Use in Agriculture and the Canada Committee on Grain Diseases provide important advice to their parent committee, as well as guidelines to officials with respect to research and the regulation of pest control products.

In addition to the domestic aspects of pesticide safety, international implications must be taken into account. These include the standardization of tolerances for pesticide residues on foods being sold abroad, as well as the environmental consequence of international use of pesticides.

Tolerances for pesticide residues on foods for domestic consumption are established under the authority of the Food and Drugs Act, administered by the Department of National Health and Welfare. The Departments of Agriculture and National Health and Welfare participate internationally in the Food and Agriculture Organization, the World Health Organization and the Codex Committee on Pesticide Residues of the Codex Alimentarius Commission, whose responsibilities include the development and adoption of internationally acceptable tolerances for pesticide residues in foods moving in international trade.

International environmental considerations involving pesticides are included in the deliberations of the Organization for Economic Co-operation and Development. Canada participates in this international forum and provides scientific, technical and regulatory information for OECD purposes.

In addition to the formal instruments established for the consideration of matters of international import, there are a number of less formal avenues that serve to assure communications between responsible officials. One of these is provided by the American Association of Pesticide Control Officials.

Reference has been made to a number of regulatory methods, committees and organizations that are involved in the regulation of pest control products. Specific enquiries on regional details should be directed to the responsible agencies in the province concerned. Information on the P.C.P. Act and its regulations is available from the Plant Products Division, Canada Department of Agriculture, Sir John Carling Building, Ottawa, K1A 0C5, or from the division's district offices.

Chapter 4

THE NEED FOR CONTINUED RESEARCH AND DEVELOPMENT

The professional careers of the scientists and administrators involved in establishing guidelines for safety in the use of modern pesticides average less than 25 years. Public attention has been focused lately on the potential environmental hazards of the large-scale use of pesticides by Canadian farmers during the production of food, but few people are aware of the full role of these compounds in modern society.

Pesticides are as important in the storage, processing and transport of food as in its basic production. The use of chemicals to prevent losses between the farmer's gate and the consumer's table will likely increase in the next decade as a means of minimizing increases in food prices. Equally important is the growing scale of non-agricultural uses of pesticides. Control of insects that carry plant and animal diseases, and control of pests in homes, recreational areas and home gardens are causing the use of increasing amounts of a wide variety of chemicals. The use of weed and brush control products for right-of-way maintenance, for industrial sites, railroads, highways and power lines is expanding every year. The application of persistent herbicides to mark the Canada – U.S. boundary has been a recent cause of controversy. Since all these chemicals have to be licensed by the Canada Department of Agriculture, there must be adequate information to support currently approved uses.

Until the late 1950's, the major concern of research scientists, regulatory authorities and our elected decision makers was to make sure that these new chemical tools would be used with minimal hazard to the user and persons involved in their manufacture. In the early 1960's new emphasis was placed on the development of a philosophy, supported by technology, for pesticide use and of an adequate surveillance system to ensure that no hazard to health resulted from food produced in this manner. In Canada, we have evolved a sophisticated interdisciplinary, social and economic philosophy for arriving at agreements between the agencies of the federal government and the other levels of government concerned that is second to none in the world.

This current general agreement on pesticide management in Canada did not come about fortuitously. It is the result of men of goodwill from several scientific disciplines, agricultural production agencies, health, chemical industry and governments, working together to develop and assess the necessary background knowledge.

In the past decade in Canada we have made preliminary moves in a new area of concern. These involve the setting of new goals for environmental quality as a result of concern over unknown identities, and the amounts of pesticides that may be related to air, water and soil pollution. Because some pesticides find their way into food chains of nontarget organisms, we now need to define a new set of guidelines for safety.

Exchanges of information between scientists and governments in the countries with the most advanced pesticide knowledge indicate that at the moment, insofar as fish, wildlife, water, air or soil quality are concerned, we are not yet in a position to recommend limits of acceptability for many pesticides or their degradation products.

Standards for pesticide residues in air, water and soil are an immediate objective. Impetus for establishing preliminary standards has been provided by the signing in 1972 of an agreement between Canada and the U.S.A. regarding water quality objectives for the Great Lakes and international sections of their connecting channels.

Consequences Must Be Outlined

A policy has been evolved by the Canada Department of Agriculture that clearly states that no research project leading to development of recommendations for pesticide use can be considered complete unless the environmental consequences of the potential recommendations are clearly outlined and evaluated.

For these reasons it will be necessary for agricultural scientists to help develop information relevant to the establishment of standards. The term 'scientist' calls for a broad application here, since economists and social scientists must be involved in future analyses developed to prevent crop and animal losses.

The chemical industry must continue to develop more and better information on the pesticide formulations it prepares for sale. We have examples today of insecticides such as toxaphene for which we cannot establish a standard for purity as sold, since all the ingredients and breakdown products have not been characterized. It rests with the chemical industry to produce herbicides with as few potentially toxic dioxins as possible. Similarly, the lack of knowledge about certain components of some fungicides, and the consequent residues in food, have delayed international agreement on residues of these pesticides in food shipped from one country to another. A relatively new pesticide now used in forest protection is unlikely to receive prompt clearance for use in Canada because methods of manufacture as well as product standards vary between suppliers.

Although none of the uses of these chemicals being made in Canada at present cause any suspected health hazards to humans, the lessons we have learned from the situations that led to the restrictions in Canada on the use of DDT, aldrin, dieldrin, heptachlor insecticides, the mercurial fungicides and the dioxin-containing herbicides are guideposts for decisions about environmental acceptability of such products in the future.

Accepted Goals

Other contributors to this publication refer to generally accepted goals for current research: the development of technologies for 'integrated control' and less reliance on pesticides. Except for a few instances we have not yet developed effective procedures that will change the role of pesticides from an 'insurance' against crop losses to one of being selective chemical tools able to correct the inability of natural forces to regulate pest populations of insects, plant diseases and weeds. Biologists are now moving slowly toward establishing numbers of pest species that will be used for defining economic thresholds for treatment. We still need the participation of economists for cost-benefit analysis of the options that will be open to allow us to achieve control, as well as that of other scientists, when environmental hazards are associated with the available options. To supervise the timing of selective remedial control treatments on an annual basis, in a manner that will minimize the use of pesticides, will require a continuous monitoring of pest populations by a new type of technologist. It will also require a technology for monitoring pests and regions specific to the crop.

Governmental Participation

Reference is also made in other contributions to the requirements for chemicals with narrow range specificity, sex pheromones, juvenile hormones, attractants and repellants, and the research required to make their use technologically possible. Industry is often reluctant to invest the huge sums of money required to develop selective pesticides when, because of their narrow range specificity, there would be only a limited market. This raises the question for governmental participation in producing the necessary scientific information and providing subsidies to industry so that these new chemicals can be sold at a reasonable price.

Examples of Canadian problems having environmental quality components that require scientific, social, economic and political decision-making are the requirements for crash technologies for grasshopper control; vegetable and cereal seed-dressings for insect and plant disease control, and that dread disease of nature transmissible to man — western equine encephalitis, as well as other insect-borne diseases.

The population densities of grasshoppers, and the amount of damage they do to crops, are cyclical in nature. The last large outbreak in western Canada began in the late 1950's and ended in the early 1960's. Dieldrin, an effective low-cost chemical control agent, can no longer be employed because its use has created unacceptable environmental hazards. Intensive research during the past few years has sharpened an ability to monitor and forecast population explosions. An effective replacement chemical has been selected from many compounds tested, and its persistence determined on as broad a base as possible or practical without having tried it out during a major outbreak. Experiences with replacement chemicals are similar to those encountered during the clinical evaluation of drugs for human use.

The possibilities for providing a long look ahead have been demonstrated. However, before principles for forecasting a pesticide's behavior can be developed, a vast array of experimental data that are reliable and representative of its behavior under different climatic conditions, soil types and crop management practices must be generated. They must then be tested under field conditions. In Canada we appear to be capable of mounting a comparable effort for water quality studies for the Great Lakes. But as yet the financial and manpower investment required for similar studies or recycling of pesticides in the environment have not been given serious interagency study.

Replacement compounds

A simpler problem involving the cooperation of biologists, biochemists, chemists and wildlife specialists is being studied today to find acceptable replacements for combined mercury-dieldrin (or heptachlor) cereal seed dressings. A major part of this research is defining the environmental hazards, especially the effects on pheasants. The necessary data can be obtained more readily than in the case of the grasshopper control problem, since fewer predetermined guidelines are involved in determining environmental acceptability. But other economic and political problems are involved in regional decision-making. In one province where a system of effective seed-cleaning and treating plants operates, the mercury pollution problem in game birds and their predators was a major factor in leading to the decision to abandon this use of mercury in Canada. Due to the effective seed-treatment system in that province, mercury fungicides were used as 'insurance' against crop losses. It is estimated that if this practice continues, with a replacement chemical for mercury, the added cost for cereal production in that province would be $9,000,000 a year. This, unavoidably, would increase food costs.

An example involving human and animal health arises from the future need for adequate control of mosquito carriers of western equine encephalitis (or other insect borne diseases). This is a tougher decision for policy makers and contains elements for research and development that will involve the physical, social and economic sciences in the production of the required data. Work is under way to provide a predictive capability for forecasting outbreaks. We are not so well prepared in defining alternatives for DDT or nonchemical treatments to terminate transmission of the disease. It is known that if necessary on a one- or two-season basis DDT use can produce mosquito control levels which could end an outbreak of western equine encephalitis, but continued use would hurt the environment. Also, we are aware that mental institutions in Saskatchewan now still harbor the victims of previous outbreaks, and any decision-making for approaches to this problem must consider the social and economic losses caused to their families in particular and society in general through welfare payments.

Research on the environmental consequences of large-scale area control programs involving new chemicals for mosquito or blackfly control, or control of disease transmission by flies following disastrous floods has not been carried out in Canada. There would likely be some recycling of pesticide residues into air, water and soil since these are already being defined in orchard and vegetable pest research programs and in large-scale herbicide applications to cereal crops. Decision makers will have to choose between the potential known hazard to some bird species from the use of DDT on a short-term basis and the human health, social and economic consequences resulting from the employment of less effective chemicals. The scientists concerned must present the decision makers with the data, options for control, environmental hazards and other factors that are associated with establishing environmental quality standards in such a specialized case. Obviously these should be different than the case involving protection of a crop against grasshopper damage.

These examples serve to emphasize the nature of new challenges and needs for research and development in Canada on the proper use of pesticides in the future.

Chapter 5

ANALYTICAL TECHNIQUES AS TOOLS TO PROTECT THE ENVIRONMENT

As noted elsewhere in this publication, understandable anxiety is being expressed by more and more people, and by both governmental and public agencies, about possible risks to the environment from pesticides used in agriculture.

Despite claims to the contrary, pesticides must still be used to ensure adequate supplies of food. However, continued research surveillance and intelligent control of the use of these chemicals are needed to avoid possible danger to public health and/or the quality of the environment.

Ensuring safety-in-use of pesticides is a dynamic challenge, and is by no means a simple matter. It incorporates the considered judgments of many individuals, highly trained in a variety of complex biological, chemical, food technological, medical, pharmacological and toxicological disciplines. Also, analytical tools for identifying and determining pesticide residues in various biological materials play an important role in many of these studies.

Gas Chromatography

In the early years of organic pesticides, analytical methods of determining pesticide residues were neither very sensitive nor very specific. Since then there have been almost unbelievable advances in pesticide residue analysis, particularly after the development of the electroncapture gas chromatograph. This instrument, under ideal conditions, can detect organochlorine pesticides in concentrations as low as a few parts per trillion. One part per trillion is equivalent to the astronomical ratio of 1 inch in 15,780,000 miles. Calculated similarly, one part per million is 1 inch in 15.7 miles. These ratios demonstrate the almost inconceivably low levels of pesticides that can now be detected by gas chromatographs equipped with highly sensitive and specific detectors. These instruments have received almost unparalleled acceptance by pesticide chemists and by scientists in other fields who are concerned with minute amounts of pesticides in the environment. Although gas chromatographs have led to a revolution in pesticide residue determination and have provided a wealth of data that would not otherwise have been obtained, a few comments about the inadequacy of interpretations made from these instruments are worth mentioning.

One renowned pesticide chemist, Prof. F. A. Gunther of the University of California, Riverside, Cal., says: "Gas chromatography has also created more misinformation and misunderstanding than all other analytical procedures combined, primarily because of operators without the training and experience necessary to evaluate their data intelligently and to recognize the pitfalls inherent in this outwardly simple method . . . . And those who are least qualified are, more often than not, the most certain of their results". Although the electroncapture gas chromatograph can detect a few picograms (10^{-12} grams) of organochlorine insecticides, it can also detect any other type of organic compound if it is present in sufficient quantity. When a biological sample is extracted with an organic solvent for the analysis of pesticide residues, the extract contains not only the pesticides but also many natural components of the sample. These unwanted but unavoidable compounds are known as coextractives and the extract taken from a soil or plant sample for testing may contain them in concentrations a million times higher than those of the pesticides. Unless the coextractives are selectively removed by suitable 'clean up' methods some of them can interfere with or overlap in the determination of pesticide levels by this chromatographic method, and the amounts of pesticides reported to be in the samples could be false. The situation is further complicated by the presence of industrial pollutants such as polychlorobiphenyls (PCBs) in some samples, particularly in fish and wildlife. In many instances in the past PCBs have been mistakenly identified as DDT, DDE, DDD and dieldrin even when coextractives were thought to have been removed from the samples. While gas chromatography is a versatile and very useful tool in the analysis of pesticide residues, the data obtained by this method are no more than indicative of the presence of suspected pesticide residues. The presence or absence of the suspected compounds must be confirmed by other methods. Chemical conversion techniques, thin layer chromatography, infrared and mass spectrometry are some of the tools that have been successfully used to identify pesticide residues in environmental samples.

Results Need Confirmation

Although they may have been published, results that were obtained by gas chromatography alone and without adequate cleanup or confirmation by other techniques, are of questionable significance. The unreliability of gas chromatography alone and the need for cleanup and confirmation of gas chromatographic data were well-demonstrated in the work carried out at the University of Wisconsin, Madison, Wisc., U.S.A. Gas chromatographic analyses of soil samples collected between 1909 and 1911 indicated the presence of organochlorine insecticides in the samples. However, organochlorine insecticides had not been discovered at that time, and none of the suspected compounds could be detected when the same samples were subjected to confirmatory tests. The work on DDT residues in Antarctic penguins was done by a research group in the Pennsylvania State University, College Park, Pa., U.S.A. In this study the penguin fat samples were extracted with organic solvents and examined by electroncapture gas chromatography without adequate cleanup of the extract, and the results were not confirmed by any other technique. It is doubtful that any DDT residue was present in these samples.

Although some of the published results may be in doubt, there is no reason to doubt all of them. All the published data were not obtained by gas chromatography alone; many of them were confirmed by other techniques. Modern methods of pesticide analyses are highly complex and sophisticated and in trained hands can provide valuable and reliable information. With the use of these modern analytical tools, we are discovering new problems associated with the use of pesticides. It is now evident that the organochlorine pesticides are persisting in the environment and finding their way to areas far removed from the site of application. It is also evident that, because of biological magnification, it is possible for animals at the top of the food chain to accumulate these persistent pesticides in concentrations that may be harmful to some species of wildlife and fish. As research into the behavior of these chemicals revealed that excessive contamination could occur, action was taken in many countries to reduce their use drastically. The persistent organochlorine pesticides are now being replaced by the generally less persistent and biodegradable organophosphorus and carbamate types of compounds.

With modern analytical and biological tools it is now possible to study the fate of a few ounces of pesticides applied to an acre of land. We can study how much of a pesticide persists in the soil, volatilizes into the atmosphere, and translocates into the crop or leaches through the soil. In most cases the applied parent chemical is converted to other products, some of them less toxic than the original compound and some more toxic. Usually we can trace the applied chemical and its degradation products through soil, water, crops and animals. In short, it is now possible in many cases to evaluate the hazard to man and his environment posed by a new pesticide before it is allowed to be used in agriculture.

The development of sensitive and reliable methods for determining pesticide residues has also increased consumer safety. The older methods of analysis, for example, were not sensitive below one part per million of DDT residues in milk. Modern analytical techniques can detect much lower concentrations.

Without the recent advances in the methods of pesticide analyses it would have been very difficult, if not impossible, to monitor residues in man's food and the environment. Thousands of samples of food and animal feed are quickly and efficiently analyzed by several federal and provincial laboratories. Foodstuffs rarely contain pesticide residues in excess of the permissible levels, and when they do they are placed under quarantine or withdrawn from sale and destroyed. Monitoring of wildlife and fish is carried out by many federal, provincial and university laboratories. Such activities keep a watchful eye on the way agricultural pesticides are affecting the quality of our environment and suggest remedial actions when problems are indicated.

The object of the use of agricultural pesticides is to protect crops from destruction by pests without adverse effects on man and the environment. It is not easy to balance the risks and benefits associated with their use. Scientists in many disciplines continually strive to achieve the best possible balance and modern analytical techniques used in residue determination play a key role in their efforts.

Contents 6

PEST CONTROL SYSTEM FOR AGRICULTURE

A major milestone on man's road to civilization was his domestication of plants to provide food readily and abundantly. However, this led to the development of monocultures, the cultivation of single products, ecologically unstable but essential to high productivity. That is, they are susceptible to destruction by insects, disease and weeds. The Irish famine of the 1840's, when the potato crops were largely destroyed by disease, is an example of a system's getting out of balance due to the lack of stabilizing control measures such as suitable fungicides.

The mid-1940's marked the introduction of modern organic synthetic pesticides, of which the insecticide DDT is the most noteworthy example. Here was a relatively stable material, with broad insecticidal activity and relative low mammalian toxicity. It had very low solubility in water, could be easily formulated for application and was relatively cheap. These qualities were also ideal for controlling certain insect carriers of human disease and many major crop pests, as well as nuisance insects. In agriculture, this means of readily controlling insects greatly assisted growers in producing high quality products that were attractive to the consumer. Consequently sometimes extra or preventive applications were made to assure insect control and marketability.

DDT and many other organochlorine compounds are classed as broad-spectrum pesticides. Although many are not as hazardous to apply as some of the newer replacement materials, they are considered to be more persistent. Their low water and high fat solubility are properties contributing to contamination of the environment, since they are condensed and held in soil particles and dispersed by wind and rain. The net result has been a concentration, particularly of DDT and some of its metabolites, in the food chain so that high levels have been found in some fish and birds of prey. However, the effect varies between species. For example, DDT causes thinning of eggshells in the case of ducks and falcons but does not affect shell thickness of pheasant and quail eggs.

Specific versus Broad Spectrum Insecticides

Aside from the hazards of pesticide concentration in the food chain, posed by some compounds, persistence and broad-spectrum activity are good characteristics in certain instances for efficient control of several undesirable insect pests. The quality of persistence reduces the number of applications and lessens the need for critical timing of those applications. However, these properties may be a disadvantage where beneficial insects such as predators are concerned, since they also may be destroyed, resulting in a disastrous shift in the pest population. The low water solubility of residues allows them to stay in the upper 6 to 10 inches of soil. Furthermore, these residues tend to adhere to soil particles and silt, and so may be dispersed by wind and water erosion of the soil. This provides another step toward concentration of the insecticide in the food chain mentioned above.

Ideally each insect pest should be controlled by a narrow-spectrum insecticide which does not affect nontarget insects. The non-scientific method of insecticide development makes such selections difficult. However, the insurmountable problem involves the economic costs of development, which have gradually risen from about $1,000,000 to near $10,000,000. Thus some potentially useful materials with narrow-spectrum activity have been dropped from further development as the costs could never be recovered. Therefore a major factor in determining potential use is the value of the crop to be protected.

Rapidly Biodegradable Pesticides

The desirability of having rapidly biodegradable pesticides appears attractive as theoretically this would remove any residues. However, two questions arise; first, are the metabolites from degradation 'ecologically safe'? and second, how precise is the time of degradation? The first requires extensive study to identify the metabolites and their ecological effect while in the case of the second, conditions determining rate of degradation are important. With short-lived materials the timing of application for insect control as well as formulation are usually much more critical than with more stable material. New types of formulation that provide 'controlled persistence will assist.

Developments in Spray Methods

Current spray methods present two main problems: first, spray drift from the target area at time of application and second, volatilization of the deposited material from the target area. The results from current research have indicated that dilute sprays from aircrafts are preferable to concentrates because of less drift. Drift can be further reduced by production of homogenous sprays within a critical droplet size. When optimum conditions for minimum drift and maximum toxicity are obtained, the next critical step is the development of an efficient commercial machine from the more elegant experimental sprayer. A modification in formulation that shows promise of improving spray effectiveness with minimum contamination to the environment is the application of the toxicant in foams.

One other factor that will assist in improving spray effectiveness in orchards is the development of denser and smaller trees.

Integrated Control Programs

In crop protection programs, the terms 'chemical control' and 'biological control' unfortunately have often been used and suggest alternative methods. This differentiation may have had some basis when there was less sophistication in the use of chemical pesticides. Current practice is to use an 'integrated control' concept i.e., the optimum combination of chemical, biological and cultural control. The relative contribution of each component will vary with the situation. For example, a parasite from abroad may be introduced as was the case with the introduction of the beetle *Chrysolina quadrigemina* at Fruitvale, B.C. in 1952, which resulted in the elimination of the noxious weed St. John's wort by 1956. In cultural practices, for corn rootworm control in Ontario, crop rotation every 2 years is recommended. Natural parasites are used wherever possible for control of pests such as the alfalfa weevil, and insecticide applications are made only when the parasite fails.

Integrated control programs involving the use of selective pesticides that control some pests but do not seriously reduce predators are employed in orchards in the Maritimes, Ontario and British Columbia and in greenhouses in Ontario. When spray programs have been developed that use the integrated control concept and later a spray is omitted, the whole ecological complex is modified and a revised program has to be developed. For example, with the removal of the spray for codling moth and the introduction of sterile males in the Okanagan, mites and aphids were soon controlled by predators. However, three other insects increased to damaging proportions. Conditions of chemical control had to be developed that would not harm predators nor the sterile male codling moths yet control the three insects that were present in pest numbers. Studies of their behavior disclosed that application of an insecticide prior to bloom would control the three undesirable insects without affecting the predators or sterile moths and so a new integrated control program was developed.

A chemical of biological origin, the bacterial toxin from *Bacillus thuringiensis,* is effective for control of cabbage looper, cabbage worm and tobacco horn worm in Ontario. However, there are instances where, in a biological complex, this toxin is only partially effective, and in the above example with cabbage, aphids are not controlled and crops may be unharvestable. In this case, two chemicals were found effective against the aphid and thus the use of a chemical pest control agent was obvious.

The demonstrated effectiveness of the sterile male technique or the release of natural parasites or predators has provided control in special areas. Sex pheromones, juvenile hormones and synthetic juvenoids have shown potential for use in integrated control but more research is needed. Possible new materials, such as selective toxicants, attractants and repellants, also are being developed and subjected to physiological and biochemical studies on pests and predators.

Chapter 7

SCREENING PROCESS FOR NEW PEST CONTROL PRODUCTS

Every year research scientists throughout the world screen thousands of chemical substances as potential candidates for new pest control products. The principal purpose is to determine whether these basic chemicals, isolated in a laboratory or possibly already in use in a totally different industrial field, can be used to improve agricultural technology. Their problem can be stated simply: will this 'Product X' some day help to save time, money or labor for the agricultural producer?

At this stage 'Product X' is identified simply by a reference number in the research files of some company. If the compound passes trials and is found to have insecticidal, herbicidal, fungicidal or nematocidal qualities, it will be more positively identified. If it is found to be valuable to agriculture and is marketable, the product will be registered and given a common name and a trade name.

The chemical name is usually complicated. For instance, *O.O*-dimethyl phosphorodithioate *S*-ester with 2-mercapto-*N*-methylacetamide, after its insecticidal and acaricidal properties had been discovered, became American Cyanamid Experimental Insecticide 12880 for all research workers involved in testing it throughout the world. As research progressed, the basic product was given the common name dimethoate and is being sold under the trade names 'Cygon' and 'Rogor'. The same procedure has been applied to many other products. A few examples are carbofuran, which was developed under the code NIA 10242 and sold under the trade name 'Furadan'; ronnel, developed as Dow ET-57 and sold under the trade name 'Korlan', and leptophos, developed as VCS 506 and sold under the trade name 'Phosvel'. All products, from insecticides to plant growth regulants, follow the same path, once specialists have discovered that they can make a positive contribution to agricultural technology.

Small Percentage Reaches the Market

In practice, very few of the compounds originally synthetized and presented for screening reach the final stages of commercial development. The odds against any one of them being sold as an agricultural chemical are quite high. Actually the average is only one new product out of 5,000 compounds examined. Questions, unknown elements and unexpected reactions may easily turn a promising product into a mere laboratory curiosity.

'Product X', which is nothing more than a new chemical compound synthesized in the chemical research laboratory, is initially made in very small (gram) quantities. Its potential value for different agricultural uses is then considered in the screening process. If the results are negative, its file will join thousands of others in the manufacturer's research laboratory archives. It may perhaps emerge again, years later, if the evolution of technology puts it in a new or different light.

To reach farmers as a commercial item, 'Product X' must survive a series of increasingly complex investigations. Judgments and decisions will be made along the way by a team of individuals trained in many and varied disciplines, both in and out of the company, interested in the development of the product. Many years may elapse before anyone can be sure that it will live up to its original promise and justify the time and money spent in its development.

The first critical screening for a prospective selective crop herbicide is conducted in a plant-research greenhouse. The technical staff there tries to determine whether the compound controls certain weeds at a reasonable rate of application without causing damage to agricultural crops. Such tests can be carried out quickly and cheaply. Thousands of candidates are screened and studied, but only the promising few selected for initial field trials on one or more field research stations.

This field screening process represents the second important test for prospective herbicides. To carry out tests on this larger scale, several pounds of the product are needed as well as a full growing season. How the compound works on 40 or more different crops, in addition to the way it controls weeds on the ground instead of in a greenhouse pot, is the main problem to be solved.

The purpose is not to find a universal herbicide, but merely to try to determine where the compound may be useful and where it fails to show promising results. The principal question in this field-test year is whether any of the greenhouse successes merit continued effort and attention and, if so, at what level.

Other Judgments Needed

'Product X', of course, is still in the hands of agrochemical research people at this stage, but it is also viewed in a preliminary way by product development officials. They will act as liaison between the grower and the laboratory; their judgment will be particularly important in assessing its practical worth under variable use conditions involving soil types, climate, weed species and crop tolerance.

As the prospective compound passes through the initial field screen on the company's research farm, more of it may have to be synthetized. It may also be slightly modified on the basis of first-year knowledge. Field tests in other countries are then sought to determine how this compound works under different climatic and soil conditions.

Environmental factors are suddenly important, and field evaluations pass into the hands of company product development representatives, a skilled group of agronomists, entomologists, plant physiologists, plant pathologists and biochemists. They work with trained government investigators and experienced farmers who assist in planning the tests and evaluating the results. Their reports and recommendations may prove to be the most critical of any in all the tests already passed or yet to come.

If the initial toxicity tests have demonstrated that the product can be handled safely by farm operators, additional toxicity trials are conducted to obtain biological data necessary for product labeling. The first of these tests involves a 90-day rat feeding program to provide general information on chronic toxicity, which helps to establish limits for toxicity tests of longer duration. It is followed by a full 2-year chronic feeding test for both rats and dogs, a three-generation rat reproduction study, a study to determine toxicity to fish and wildlife, and a feeding study with lactating cows to determine residues in meat and milk, all necessary to provide data for the labeling. Any negative or even uncertain findings on any of these toxicity tests may force the new product back to the laboratory for modification, or may even result in eliminating it from any further consideration.

Crop Residues

For pest control chemicals that are to be used on crops, a necessary part of the development of any new product is to determine the crop residue of the compound or its metabolites in the agricultural crop, soil and water. As soon as a product shows some potential usefulness in a given crop, samples of the crop on which it was used are collected and frozen, and returned to the chemical laboratory for analysis. A different method of analysis needs literally to be invented for each compound to assure accurate measurement of the residue content of that chemical and degradation products in a crop in parts-per-million or even parts-per-billion.

Samples are collected from many geographical areas and from treatments at normal and double use rates, to assure representative measurements. The residue level, if any, is then used in conjunction with the relative toxicity of the compound so that safe tolerances for residues in crops may be established. These levels are determined by feeding trials.

Right from the start, economics play a role in all these stages of development. Rough calculations on the cost of manufacture have already been made concerning a reasonable, worthwhile cost to the user and a profit to the producer and trade. As the compound clears one screening stage after another, these calculations are refined. At every stage of development, cost estimates are reviewed on the basis of rate of application, effectiveness and, naturally, any potential problems that may involve normal growing conditions in the field.

Planning for Sale of Product

In the second growing season, the candidate compound is given broad geographic exposure in field trials, although it is still a long way from commercial reality. The company's manufacturing staff must learn how to make the product on a full-plant scale. Money must be appropriated by top management and careful planning completed so that 'Product X' can have some reasonable expectation of becoming a commercial success.

Process engineers, designers, financial experts and others join the team adding their judgment and experience to those who have been studying the prospects for the new product. Also involved are government research workers, and perhaps a few commercial organizations who have technical staff interested and experienced in the handling of new agricultural compounds, and in evaluations of these compounds under field conditions.

'Product X' is now within range of more practical considerations

The appropriate rates of application according to the various types of soil and additional crops that may offer promise, are determined as objectively as possible. The product, naturally, must also offer some advantages over current field practice.

The final evaluation is made as the product is introduced on a small commercial scale and reaches growers for introductory applications. By this time, it is being manufactured on a production scale for marketing. In a sense it has outgrown the product development stage, but progress of the introduced product is closely followed as new applications may require additional refinement of labeling directions for use.

The process will have taken an average of 4 years from the time of the first screening test to first grower application of the product, and the company involved in the testing will have spent $4,000,000 to $10,000,000.

No one person, in fact, no small group of people, really carries sole responsibility in this screening process before a product is brought to the market. Capable, trained persons are needed in the agricultural laboratory just as in the fields or in the offices. Contributions to the success of a new compound are constantly made by people at varying levels of responsibility and complete agreement among them cannot be expected as a new candidate compound moves through the successive screening processes. However, priorities are set, needs determined, tests initiated and results interpreted. If eventually a product is to be sold commercially, it must demonstrate its superior qualities and command the attention that is needed to pass one screening step after the other.

For advice about the best methods of pest control in your area, telephone your local agricultural representative or write —

BRITISH COLUMBIA
B.C. Department of Agriculture
Douglas Bldg.
Victoria, B.C

ALBERTA
Crop Protection and Pest Control Division
Alberta Department of Agriculture
Edmonton 6, Alta.

SASKATCHEWAN
Pest Control Specialist
Production and Marketing Branch
Saskatchewan Department of Agriculture
Regina, Sask.

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IF UNDELIVERED, RETURN TO SENDER   EN CAS DE NON-LIVRAISON, RETOURNER À L'EXPÉDITEUR