AGRobinson

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	1952	1953
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Proceedings of the

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INTRODUCTION

This year the two regular meetings of our Society were held. The spring meeting consisted of informal panel discussions presented by members of the Society. The fall meeting featured papers on aspects of the chemical control of insects, by visiting entomologists. For these contributions we are very much indebted to: Dr. H. Hurtig and Dr. J.J. Fettes, Defense Research Board; Messrs. L. Peterson and C.Y. Hovey, Division of Forest Biology, Indian Head, Sask.; and Mr. O.B. Hitchcock, U. S. Industrial Chemicals, Portland, Oregon. The papers prepared appear in the text of the proceedings.

It is gratifying to hote that the new make-up adopted for the Proceedings in 1952 has been received with favourable comment. We wish to commend the Editor-Librarian and his committee for the fine improvements instituted.

On the national scene our representations to the Entomological Society of Canada stimulated the formation of a national committee on the common names of insects. This committee, working through the regional societies, will integrate the views of Canadian workers on official names and present them to the committee of the American Association of Economic Entomologists.

We wish to acknowledge with thanks the co-operation of the various individuals and institutions whose assistance has made the publication of these Proceedings possible.

W. R. ALLEN,
President.

THE MARCH MEETING

The Business Session

A business meeting was convened in the Department of Entomology, University of Manitoba, at 9:00 a.m., March 14, 1952.

Minutes of the last general meeting on November 20, 1951, were read and approved on a motion by W. Stephen, seconded by T. Cole.

The proposed revision of the Constitution and By-laws was discussed point by point. Several amendments were proposed and accepted. The proposed Constitution and By-laws as amended were approved unanimously on a motion by A.V. Mitchener, seconded by A.J. Thorsteinson.

Because the annual meeting was changed from spring to fall it was moved by W.J. Turnock, seconded by R.D. Bird that the present executive remain in office until the 1952 annual meeting.

CARRIED.

Two interim auditors were elected. Nominations were G.L. Warren by W.J. Turnock, W. Romanow by W. Stephen. It was moved by A.V. Mitchener, seconded by W. Stephen that nominations cease.

CARRIED.

Mr. R.J. Heron reported on plans for improving the quality of the Proceedings. Mr. Heron moved adoption of his report and recommendations for financing the 1951 Proceedings. Seconded by B. Berck.

CARRIED.

The treasurer, F.L. Watters, reported a bank balance of $59.11.

Prof. A.V. Mitchener reporting for the Committee on Approved Common Names advised that after the fall meeting, 1951, 8 names were submitted to Dr. Hauser of the American Association of Economic Entomologists. These names cannot be considered by the A.A.E.E. for some time.

A lively discussion considered the editorial policy of the Canadian Entomologist. A resolution for submission to the Entomological Society of Canada was drafted by a special committee comprised of A.V. Mitchener, W. Stephen and G.L. Warren. The adoption of the resolution was moved by A.V. Mitchener, seconded by W. Stephen, and carried unanimously.

The business meeting adjourned at 12:00 p.m.

Scientific Business

The scientific session of the regular spring meeting of 1952 was held in the Department of Entomology, University of Manitoba, on March 13.

Under the chairmanship of P.H. Westdal, a panel discussed life history studies of four economic species: The sunflower maggot (Strauzia longipennis (Wied.), a spruce root weevil (Hypomolyx piceus (DeG.), the caragana seed chalcid (Eurytoma n. sp.) and the imported cabbage worm (Pieris rapae (L.). A second panel conducted by W.B. Fox discussed various phases of the chemical control of insects. In addition to these two discussions a series of demonstrations of apparatus and techniques of entomological interest was arranged by W.J. Turnock.

Abbreviated accounts of the discussions and demonstrations are presented here.

LIFE HISTORY STUDIES: Panel Chairman - P.H. Westdal.

The discussion was opened by P.H. Westdal with general remarks on the purpose and importance of life history studies. It was pointed out that a complete knowledge of the life history of an insect was essential to an intelligent application of remedial or preventative measures. The preliminary steps necessary before the initiation of the study, such as, the importance of obtaining accurate determinations of the insect followed by a thorough search of the literature to obtain information on the insect or related species, were stressed.

Some of the difficulties most frequently encountered in a study of this type were pointed out and illustrated with examples from studies of the life histories of insects attacking sunflowers. Such problems as the location of the various life stages of the insect in its natural habitat and particularly the rearing of insects in the laboratory, together with interpretation of laboratory results, were considered. One example cited was the problem of following the development of the larva of the sunflower maggot, Strauzia longipennis (Wied.), which develops entirely within the sunflower stalk. Little success was encountered in rearing larvae on artificial media in the laboratory. This markedly curtailed observation on this stage of the life history of the insect.

Mr. Warren discussed his study of the life history of Hypomolyx piceus (DeG.). It was pointed out that the larval stage of this weevil bores in the bark and along the cambium on the root collars of most of our native conifers. This subterranean and subcortical habit coupled with a low current population complicated the study. However, the inability to observe larvae "in situ" posed the greatest problem and created the necessity of devising a method for rearing larvae in some medium which would facilitate periodic observation. Three methods using artificial nutrient media were tried, but in no case was it possible to rear larvae through all stadia. It was pointed out that diseases, both physiological and infectious, were prominent in all methods but that at least two of the techniques had possibilities if controlled laboratory conditions could be utilized.

The study of the life history of the caragana seed chalcid, Eurytoma n. sp., was outlined by Mr. Hedlin, as follows:

The female caragana seed chalcid oviposits in newly formed seeds of caragana during June and early July. The egg, which is usually deposited singly in the seed, hatches in about one week. The larva feeds on the cotyledons of the seed during the summer. When the caragana pod dehisces, the larva is thrown out and remains within the seed coat on the ground until the following spring. In the spring the larva pupates and after a period of two weeks the adult emerges.

Mr. Furgala discussed a study of the life history of the imported cabbageworm, Pieris rapae (L.).

An examination of the Canadian Insect Pest Review for the years 1922-51 suggests that the populations of the imported cabbageworm fluctuate in what appears to be a ten year cycle. This insect occurred in considerable numbers in 1951 when its life history was studied at The University of Manitoba. The following table gives the development data based on rearings made in cages in the laboratory.

Period of observations:	July 5 to Aug. 1	July 6 to Aug. 2	July 11 to Aug. 2	Aug. 15 to Sept. 5
No. of eggs:	99	38	29	50
No. of eggs hatched:	87	32	25	43
Incubation period (days):	2-3	2-3	5-8	3-5
No. of larvae:	86	31	25	37
Larval period (days):	16-19	16-19	13-15	15-18
No. of pupae	82	27	25	36
Pupal period (days):	5-8	8-9	5-8	diapause pupae

A few insects were reared in the field but all the pupae were parasitized by chalcids.

From the discussions it was evident that investigators must show considerable ingenuity and imagination in developing techniques and methods of study.

THE CHEMICAL CONTROL OF INSECTS: Panel Chairman - W.B. Fox.

The Case Against Insecticides: - R.R. Lejeune. (Abstract).

Insecticides have saved untold millions of dollars worth of crops and property and they have been and probably will continue to be one of the chief weapons of the entomologist to prevent insect damage. Nevertheless, we would do well to realize the limitations of insecticides. These are listed briefly below:

1. They are expensive to use.
2. They do not produce permanent control.
3. They upset the balance of nature to such an extent that frequently they aggravate the insect problem and complicate control measures.
4. Insects develop resistance to many insecticides.
5. Chemical control of forest insects may affect fish and wildlife adversely.

6. Many insecticides are dangerous to humans and livestock.
7. The use of insecticides has caused many entomologists to neglect fundamental ecological investigations that could lead to permanent control by cultural practices.

The Evaluation of Insecticides: - F.L. Watters. (Abstract).

The main requirement of most insecticides is that they should kill insects. Before insecticides are used generally in a particular region for the control of a specific pest, considerable testing is necessary to determine suitable methods of application, formulations and dosage. In stored products entomology insecticides are usually, so far as possible, tested in the laboratory and again in the field under conditions found in practice. Although these tests are carried out separately they are designed to find out the effectiveness of the insecticide under a variety of conditions. Either the field test or the laboratory test may come first and the one complements the other.

Laboratory tests of an insecticide are usually undertaken to obtain more precise information or to elucidate a particular finding from the field experiment. In the laboratory it is possible to control many of the variables which beset and perplex the entomologist in the field. But control of these variables brings other problems chief of which is the pitfall of generalizing on the results of a laboratory experiment that has been carried out under a standard set of conditions. However, even though we are not on too solid ground when we generalize on the results of a controlled experiment it is sometimes imperative that we do so if the results of the laboratory are to be translated into practical usage.

The most variable of the variables is the test insect itself. Homogeneity of a test insect culture can be improved by starting it from a single pair of insects reared on a standard diet kept free of parasites and other organisms detrimental to their health. Adults of the confused flour beetle, *Tribolium confusum* Duval, respond to insecticides more uniformly if they are of the same age and sex.

Other variables include: dosage; formulation; physical state in which the insecticide is exposed to the insect; age of deposit (with contact insecticides); temperature of surroundings during and after exposure; duration of exposure.

Effectiveness of insecticides may be assessed by classifying insects, that have been exposed, as knocked out, moribund or dead. This gives a more complete picture of biological effectiveness than a record of dead insects only. Results of tests can be more readily interpreted if they are subjected to statistical analysis.

The Mode of Action of Insecticides: - W.R. Allen (Abstract).

The mode of action of insecticides would be reasonably well understood if the following information was available and indicated a single overall pattern that explained the observed biological properties.

Firstly, the absorption into the insect and its distribution within it should be quantitatively known.

Secondly, the chemical fate of the insecticide should be known. We should know if toxic action results from the chemical, a breakdown product or a metabolite that may be identified. The existence and nature of defense mechanisms animals may use to degrade the toxin or synthesize an innocuous derivative also should be known.

Finally, the nature of disturbances to the normal physiology and metabolism of the living animal, that give rise to the fatal symptoms and death, should be understood.

Registration of Insecticides:- R.W. Coleman.

The Pest Control Products Act is an act to regulate the sale of products used in controlling agricultural pests. Administration of the Act is carried out by officials, technical staff and inspectors of the Production Service, Plant Products Division, who are responsible to the Minister of Agriculture.

The text of the Act is outlined in two publications. These are the Act and the Regulations under the Act. In the Regulations the various sections of the Act are outlined in more complete detail.

A "Pest Control Product" is defined as: "Any product used or represented as a means for preventing, destroying, repelling, mitigating, or controlling directly or indirectly any insect, fungus, bacterial organism, virus, weed, rodent or other plant or animal pest."

Through the provisions of the Pest Control Products Act it is obligatory that any product manufactured, imported, advertised or in any manner whatsoever offered for sale in Canada shall first be registered with the Department of Agriculture.

Certain specific information is required to be submitted in detail when application is made for registration; the name and address of the applicant, the chemical and physical nature of the product, and the percentage by weight of each ingredient, the brand name to be used and the guarantee of the applicant for the product.

Accompanying the application for registration must be submitted transcripts of the intended label to be used on the containers in which the product will be sold. Details on the label include some of those found on the application and in addition, complete claims and representations as to the purposes of the product in pest control, the practical directions of the use of the product, the word "poison" and the poison symbol if considered harmful to human or animal life and the antidote for the poison, and the net quantity by weight or volume. Applications and labels are received and reviewed by officials of the Department at Ottawa. If the details submitted are complete and satisfactory, and the product is considered to be effective for the purposes claimed, then a certificate of registration is forwarded to the applicant.

A number of sections in the Act are devoted to the powers given to the Minister of Agriculture and his advisors to make regulations, such as those:

- prescribing what pest control products may be sold for any purpose, for example, B.H.C. and Lindane wettable powders (but not emulsions) are not permitted for use in livestock dips for control of lice, ticks, horn flies, etc.

- prescribing the percentage of ingredients which may be present in pesticides, for example, the standards of strength for DDT products as set up in 1945 were:

Surface spray - 5%
Liquid concentrate for dilution - 25%
Dust concentrate for dilution - 50%
Air Spray - 1/2 of 1%

- prescribing the strength or purity or both under which they may be sold, for example:

Up to 1951 Parathion formulations accepted for registration were - 15% wettable powder and Parathion aerosols.

For 1952 - 25% emulsions of Parathion will be accepted for registration.

The responsibility of accepting or refusing an application for registration of a new insecticide rests with department heads at Ottawa. Two prime questions to be considered are:

(1) Is it effective as an insecticide?
(2) Can it be used with reasonable safety?

The first question is determined by our consultants in the Division of Entomology. These entomologists have their particular specialties, that is, garden and field crop insects, animal insect pests, storage pests and household insects.

The application and text of label submitted is reviewed. The formula may be approved as submitted, approved with modification or rejected. Most of the labels as originally submitted require some modification to a greater or less degree respecting the rates of application, manner of application, the kind of insects controlled, and the kind of crops, etc., to which they may be applied. With the many new insecticides introduced during the past ten years there is a legion of detail to be observed. For example, the chlorinated hydrocarbons represented by DDT, Chlordane, BHC and Lindane, Toxaphene, and Aldrin, though similar in chemical structure vary considerably in their particular application.

While the product, especially one of the new materials, is being appraised by the entomologists for its effectiveness as an insecticide, it is at the same time being studied by officials of the Department of National Health and Welfare for its mammalian toxicity and possible hazard to human health. If the danger in using the chemical outweighs its possible agricultural value then registration will be denied or withheld until further investigation can be made. Products carrying some potential hazard have been accepted for registration provided the labels bear complete caution to be observed in the handling and use of the materials.

District offices of the Department are located at strategic points across Canada. Each office is kept informed of all new registrations, and renewal of old registrations, (which takes place on January 1st of each year). At the present time registration numbers have reached the 4,000 mark, indicating there have been that many pesticides placed on the market. Inspectors representing the Department call on manufacturers, wholesalers, retailers, and often are called upon by consumers. We are supplied with copies of all correspondence from Ottawa to registrants in our district. The Dominion Customs Department keeps each district office advised on shipments of pesticidal materials being imported, so that a check can be made on the intended use of the material by the importer.

At certain periods of the year when stocks are being prepared or are moving into dealers hands many samples are taken and submitted to analysts appointed by the department. These samples represent all pesticides for which a satisfactory method of analysis is possible. This is a means of checking the chemical analysis of samples and comparing the results with the guaranteed analysis. Because of other work carried on by our department, inspectors travel extensively and this makes possible a wide survey. Quite often we come across unregistered pesticidal materials being offered for sale. In this case the manufacturer is advised on the necessary procedure, and sale of the product is ordered withheld until registration is arranged. If it is found necessary all stocks can be placed under detention until the regulations are complied with, and if this is not done the stocks may be confiscated and disposed of, I might say such drastic action is seldom found necessary.

Liaison Between the Research Worker and the Farmer: - Stewart Pugh.

I imagine that everyone here realizes that a very serious gap exists between the research worker and the farmer. I use the term farmer in an all inclusive sense. He is the largest user of pest control chemicals, but the term consumer, or grower, would be equally applicable. May I proceed on the assumption that all of you realize that a serious gap in liaison exists and this fact need not be labored.

A great economic waste occurs if the end products of research are not made available to the public. This is true of research, whether it be industrial, chemical or entomological. Research costs money. Where this money comes from, be it industry or government, is another matter but just the same it costs hard cold cash. If therefore the end products, the benefits of research, do not get through to the consumer there is an economic waste.

I know you may say, "Well, that is primarily an extension problem. That is so and so's job". All right, it may be. We all realize that our extension facilities are wanting but are we doing all that we can to solve this problem?

Here are a few suggestions that in my opinion bear consideration by this group.

(a) Let us continue to work towards a recommendation chart or charts that cover(s) all Manitoba insect problems. Unless we put something into the hands of the people who are in a position to carry recommendations to the farmer we are wide open to criticism by those charged with the responsibility of extension. This society may in large measure provide that service and by so doing perform a very worthwhile and useful function.

(b) We may have to creep before we run but let us continue the start already made. The recommendation chart now under consideration for Manitoba vegetable insects is an excellent beginning, but let us not sit back and assume that the job has been completed once that chart has been prepared. It should be reviewed, extended to other fields and brought up-to-date as and when required.

(c) Let us keep our recommendations simple, streamlined and practical, in other words, tailor our recommendations to suit the Manitoba need. To be specific, recommend one, or if necessary two commonly available insecticide materials that will give known control rather than "throw everything in the book" at the grower.

(d) We can also facilitate the dissemination of information by working with the Manitoba Agronomist Conference through the Insect and Rodent Committee. Other groups use this organization as a means of getting their recommendations out to the farmer. Would it not be sound to utilize facilities such as these?

My suggestion would be to aim at a set of recommendations that ultimately embraces fruit, garden and field crop insect control. The field of plant disease and insect control overlaps to quite an extent. Thus there should be a coordination between the recommendations on insect control and plant disease. I am not suggesting that we usurp the field of the plant pathologist, but let us be broad enough in our thinking so that our recommendations are practical from the grower's point of view. A grower or farmer does not care whether the "trouble" with his crop or garden is specifically a pathological or an entomological problem. Where there is an overlapping we should face up to the matter and deal with it by cooperating with the plant pathologist so as to bring in practical recommendations.

From the above please do not think that I am proposing that we endeavor to get out a spray calendar similar to that prepared for the Okanagan Valley each year in British Columbia. The spray calendar in use there is a very excellent piece of work but I do not feel that the need here is the same. Thus my suggestion, made earlier, that the problem here be treated in such a manner so as to fit it into the Manitoba need.

Techniques and Exhibits:- Chairman - W.J. Turnock.

An apparatus designed for use in sexing large numbers of Tribolium pupae was demonstrated by F. Watters of the Stored Products Insect Laboratory. The equipment consists of a large cloth belt which conveys pupae under the field of a binocular microscope. One or two persons load the belt with pupae and another sexes and separates them as they pass under the microscope.

Mr. W. Silversides spoke on the design and uses of a new type of insecticide applicator, the lindane vapourizer. This vapourizer will be rigidly controlled in Canada, both in design and use. Its use will be limited to mess halls, restaurants, offices, factories and other places where people spend only part of the day. The applicator is designed to control flying insects. At present lindane is the only insecticide used in the vapourizer but mixtures of lindane with other insecticides may be used in the future.

Mr. J. B. Wallis spoke on the preparation of genitalia for the taxonomic study of Coleoptera. Genitalia are very important characters in several groups of Coleoptera but in the study of many specimens the technique of mounting genitalia on balsam on slides often proves excessively laborious. In certain groups, such as the Gyrinidae, Mr. Wallis has found that the genitalia may be quickly mounted on an ordinary insect point with a drop of Household cement thinned with acetone. This method greatly facilitates the examination of a large series of specimens.

Dr. R.D. Bird discussed some of the photographic techniques used in the Brandon Entomological Laboratory. He showed samples of work done in duplicating graphs for reports and in making photostats of articles from journals. Pictures showing structural details of the body of Calosoma were also shown. Dr. Bird explained the use of the micro-sumnar for this type of study.

THE ANNUAL MEETING

The Business Session

The business session of the 1952 Annual Meeting of the Society was convened in the Department of Entomology, University of Manitoba, at 9.30 a.m., October 21, 1952. The President, Dr. W.R. Allen, presided.

The minutes of the last general meeting were read. It was moved by F.L. Watters, seconded by G.L. Warren, that the minutes be adopted as read. CARRIED.

The Treasurer's report was read by F.L. Watters.

Professor A.V. Mitchener, reporting for the Committee on Common Names, stated that there was nothing to report. W.P. Stephen suggested that F.L. Watters and W.R. Allen act as representatives of the Society at the meeting in Quebec and that they present the list of suggested common names to be added to the existing list of common names.

W.R. Allen, reporting for the Insecticide Committee, stated that a bulletin for field crop insects should be prepared as was done for vegetable insects in 1952, and that the vegetable insect bulletin should be brought up to date for the spring meeting of the Entomological Society of Manitoba.

A.V. Mitchener commended R. Coleman for his work on compiling the list of available insecticides. W.R. Allen suggested that a similar list should be prepared for the spring meeting and discussed at that time.

A.V. Mitchener reported on the resolution concerning the Canadian Entomologist. The resolution and the Editor's reply to the resolution were read. A statement supporting the resolution was read. In the discussion that followed, it was decided that a summary of this statement should be added to the original resolution. A.V. Mitchener moved that these amplifications in support and explanation of the resolution be forwarded to Mr. Wigmore. The motion was seconded by W.P. Stephen. CARRIED.

The Nominating Committee presented a list of names for the offices of President, Vice President, Secretary, and Treasurer. It was moved by T.V. Cole and seconded by L.O.T. Peterson that the proposed nominations be accepted. CARRIED.

Dr. A.J. Thorsteinson was declared President by acclamation. The following other officers were elected:

Vice President	- F.L. Watters
Secretary	- P.H. Westdal
Treasurer	- G.L. Warren

For Editor-Librarian, Dr. Thorsteinson nominated R.J. Heron and W. Romanow nominated R. Prentice. W.P. Stephen moved nominations closed and the motion was seconded by W. Romanow. R.J. Heron was elected.

R. Wong moved a vote of appreciation for the retiring officers; seconded by W.P. Stephen.

W.P. Stephen moved the meeting adjourn; seconded by J. Howden.

The meeting adjourned at 12 noon.

Scientific Business.

The scientific session of the regular fall meeting was held in the Department of Entomology, University of Manitoba on October 20, 1952. The program consisted of four invitation papers dealing with recent developments in insecticides, their application and assessment. The speakers were Drs. H. Hurtig and J.J. Fettes of the Suffield Experimental Station, Ralston, Alberta, and Messrs. C.Y. Hovey and O.B. Hitchcock of the Forest Biology Laboratory, Indian Head, Saskatchewan and U.S. Industrial Chemicals, Inc., Portland, Oregon, respectively. Mr. Hitchcock concluded the program with the showing of a recent film entitled "Beat the Weevil".

The papers are presented in the following pages of these proceedings.

RECENT RESEARCH ON THE APPLICATION OF INSECTICIDES

H. Hurtig
Suffield Experimental Station, Ralston, Alberta.

One word in the title of this paper is very fitting -- that is "Recent" -- for if we attempt to work up a bibliography on this subject we'll soon find that it has been only in the last decade that serious attention has been paid to the subject. This of course can be partly associated with the rapid development of the new organic insecticides in this period. Other factors have stimulated research in this field; one has been a need to satisfy the requirements of the armed forces with regard to the control of insect borne diseases; the second has been an economic one, the high price of labor as compared to machinery and chemicals; another is the high price currently being paid for agricultural products which has resulted in the farmer considering it economical to use sprays instead of cultural control or baits for the control of grasshoppers and cutworms and to use chemicals to replace cultural methods for the control of certain other insects and weeds. Whether or not these changes in practice are wise ones are not for me to say and they are not the topic of this discussion. I do not propose to discuss application equipment per se, rather I would like to review some of the principles which should influence the design of this equipment.

To cover this entire field is out of the question at the moment. Instead I prefer to discuss a few phases that I am familiar with myself. I propose to review briefly some of the more pertinent literature, then discuss a laboratory research project and finally a field research project that we have been interested in in the past few years. Dr. Fettes will discuss how well these things work in practice.

Historical.

The term "aerosol" which is now well known in entomology is often considered to be relatively new; however aerosols per se are not new. This term may be applied to any system of fine solid or liquid particles in air or gas, as a smoke, fog or mist (Whytlaw-Gray and Speakman, 1923). Gibbs' (1924) excellent monograph on disperse systems is a comprehensive survey of the properties of aerosols; Whytlaw-Gray and Patterson (1932) also discuss the physical properties of aerosols from the standpoint of industrial fogs and smokes. However, all these treatments of disperse systems are largely confined to the discussion of aerosols in the colloid size range. Gibbs (1924) distinguished between "clouds" or "cloudy aerosols" and "smokes" or "smoky aerosols" by limiting the first category to those particles too large to exhibit

Brownian movement at ordinary temperature and pressure. The more highly disperse systems have received much attention by the physical chemists as they are the simplest forms of colloidal systems and have afforded an almost ideal opportunity for studying Brownian movement. Unfortunately the aerosols whose size makes them of importance in entomology have received but scant attention from research workers.

Those of you who may be serious students of this subject should refer to an excellent pair of chapters in Dr. A.W.A. Brown's recent book on "Insect Control by Chemicals" (1951).

In order to delimit the size range considered in entomological investigations, David (1946, b) considered that the largest particles with diameters above 200 microns gain in velocity as they fall according to Newton's Law. The velocity of these drops is limited by the fact that when the diameter of the water droplets exceeds 200 microns they fall as rain and can break up when the force of air resistance due to speed is greater than surface tension; (Gibbs, 1924). The second group of droplets, 200 to one micron in diameter, increase in velocity until a terminal velocity is attained at which there is no further increase in rate of fall, droplets in this group therefore are governed in part by Stokes Law. The third group, which does not concern us at the moment, contains members whose droplet size approach the mean free path of molecules of air (10^{-5} cm.) and are subject to Brownian movement.

The problem of optimum particle size has been the subject of several investigations before the discovery of DDT. Smith and Goodhue (1942) have summarized some of the earlier work on the relation of particle size to insecticide efficiency and concluded that the toxicity of solid insecticides increased with a decrease in particle size. This was correlated with the increase in surface area per unit weight with a decrease in size. The correlation between toxicity of liquid spray materials and their droplet size has received less attention than the same problem in connection with powdered solid insecticides.

The relation between the droplet size of oil in emulsions has been the subject of a few investigations. Considering that quick-breaking emulsions are more suitable for insecticidal purposes, de Ong (1925, 1927) correlated the larger size of the oil droplets in the quick-breaking emulsions with greater effectiveness. This was confirmed by Griffin (et al) (1927) who reported greater toxicity to Aphis rumicis from emulsions containing oil droplets eight to twelve microns in diameter than with similar emulsions in which the droplet size of the oil was two microns or less. Determinations of oil deposits revealed more oil deposited from the large-droplet than from the small-droplet emulsions, and this was considered to be the reason for the greater toxicity.

Early work with oils alone was carried out by Burdette (1938) who applied the term "air-float" to a fog of petroleum oil droplets whose toxicity was tested on honeybees. Half of the droplets making up the fog were greater than one micron with the remainder ultramicroscopic. Maximum toxicity was found in that portion of the aerosol from one to ten microns in diameter. Searls and Snyder (1936) concluded from their work with cattle sprays that very small drops were unsatisfactory because they failed to impact on the surface being treated. These are essentially the major contributions in this field of work prior to the last decade.

The shortage of pyrethrins in England during the last war stimulated research on the more efficient use of space sprays for indoor use. David's (1946a, 1946 b, 1947) carried out a series of studies on the interaction of insecticidal aerosols and flying insects. While the work was done during the war years his papers were not published in the open literature for security reasons until 1946 (et seq.). They were the first reports of studies correlating droplet size and the efficiency of pick up by flying insects. The significance of the effect of evaporation of the insecticide carrier and its stabilization demonstrated in this work has been the basis of other investigations which separated physical synergism from true drug synergism.

At the same time, in America, cooperative studies were carried out by the Bureau of Entomology and Plant Quarantine, U.S.D.A., and Division 10, N.R.C. at Beltsville, Md., on the relation between the droplet size of DDT-oil aerosols and their toxicity to mosquitoes. The results of these studies suggested that the optimum droplet diameter for the control of mosquitoes in open terrain was 10 microns, (Scoville, 1946). In these studies no attempt was made to elucidate or distinguish between other physical characteristics which would produce control from residual deposits. Also I would like to point out that while the 10 micron droplet diameter represents the optimum droplet size for ground operated aerosol machines, unfortunately if aerosols of this size range are emitted from aircraft their aimability becomes nil; in fact a 50 micron droplet is about the lower limit of a spray that can be aimed with any success from an aircraft.

The foregoing investigations provided confirmation of a theoretical treatment by Winsche (1944) of Sell's studies (1931) on the efficiency of different shaped objects in removing dust from the air. The basic principles evolved by Winsche from Sell's work were that deposition on the insect, and hence toxicity, would be dependent on the square of the diameter and the first power of the wind carrying the aerosol. This was derived from the fact that when air is moving horizontally relative to the surface, a droplet in the air will be deposited by both settling and impaction on vertical surfaces. In horizontally moving air, a droplet tends to move around any vertical surface unless there is a relative movement between the droplet and air. On the other hand, inertia will tend to keep droplets moving toward such a vertical surface instead of swinging laterally around it, and this motion is dependent on the square of the diameter of the droplet. The problem was investigated by Sell for several regular geometric shaped objects and deposition efficiency was established as a function of the dimensionless parameter P.

$$P = 4.65 \times 10^{-6}\, e\, \frac{vd}{D} \qquad (1)$$

where D = length (ft.) e = drop density, v = velocity and d = drop diameter (microns).

Further theoretical calculations showed that the point at which effectiveness started to decrease as droplet size increased was dependent on the number of drops required to actually deposit on the insect to produce mortality (LaMer et al, 1944). This in turn is directly proportional to the concentration of insecticide, the insecticide, the solvent and the insect itself.

A rather comprehensive treatment of the relationship between particle size and insect control has been reported by Potts (1946) in which it was suggested that for ground applications, droplets of from thirty to eighty microns were the most satisfactory. No data was cited, but the recommendation was based on the observation that "a field of resistance surrounds all objects, including plants and insects, and repels most individual particles of small size as well as droplets smaller than 30 microns". I don't believe Potts was aware of Sell's work in 1931.

The various journals on applied or economic entomology contain numerous papers on comparisons of the efficiency of various insecticide formulations in controlling various pests on various crops etc. Few of these papers take into consideration the manner of application or the physical properties of the formulations in evaluating the results. Great strides are being made by our own well known Dr. James Marshall in developing his concentrate sprayer and here careful attention is being paid to these properties. However, millions of acres of field crops are being treated annually in Canada with a wide range of chemicals for both insect and weed control with but scant attention being paid to these physical properties. All too frequently the investigator is satisfied with reporting that he applied "a pound of DDT per acre". Most empirical and unscientific.

With the new organic insecticides it is becoming increasingly important to separate the various effects of all the ways in which the insecticide applied can reduce insect populations, i.e. gross reduction (not necessarily mortality) can be the sum of (a) contact of individual droplets with individual insects, (b) residual contact kill, (c) repellent effect or (d) the irritant effect of sub-lethal doses contained in droplets of the aerosol size ranges. I have a feeling that if we seriously examine what happens when an anti-mosquito airspray is applied we'll find that very few insects are killed initially by the spray and that the major reduction of population is achieved by first of all the original population moving out ahead of the fringe of the finer spray droplets and secondly by the population reinfiltrating the area being killed by resting on contaminated foliage.

Before closing off these introductory remarks I would recommend to the serious students of this field of research the work of the Anti-Locust Research Group and the Colonial Insecticide Research Unit in the United Kingdom and Africa.

Laboratory Investigations.

In order to stimulate your interest in this subject I thought that I should describe some procedures and results obtained in work of this type. A few years ago I became interested in trying to determine the factors that would contribute to building up residual deposits of insecticide. After attempting to carry out this work in the field, it soon became apparent that I would have to take the problem into the laboratory where so many of the variables could be controlled. A wind tunnel offered the most promise of providing the desired results. The initial experiments were carried out with fine water sprays or mists and here as in the case of later work with oil clouds, sampling difficulties developed. The most useful apparatus for sampling the spray for droplet size studies was found to be the Cascade Impactor developed by May (1945). A survey of the various types of slides coatings for collecting and preserving spray droplets resulted in rather unsatisfactory results and new coatings were developed which caught and retained droplets in their original spherical shape. These have been described by Hurtig and Perry (1951). The actual counting techniques have been discussed by Fairs (1943) and the statistical work for computing the various size parameters can be found in Dalla Valle (1943).

Since these studies did not involve biological evaluation of the deposits the insecticide was replaced by dyes of various types. Uranine W.S. was found to be very useful for water solution as it not only gave an intense color at 0.15 per cent concentration which made it possible to carry out precise quantitative determinations, but it exhibits very strong fluorescence under ultra-violet light, thus making it extremely useful for estimating qualitatively the distribution of deposits on foliage. Sudan Red B.B.A. and Fluorol were used for similar purposes in oil solution.

Field experiments with wettable DDT sprays indicated that the rate of evaporation of water from such aerosols influenced the deposition to a very marked degree. The possibility of separating desirably sized fractions of the material to be used as wettable powder was eliminated due to the technical difficulties involved in obtaining a practical yield. A more promising line of research seemed to be an investigation of the deposits obtained at various wind speeds with or without surface active compounds since Rideal (1925), Langmuir (1927) and Sebba and Briscoe (1940) have found that monomolecular layers of compounds of this type distinctly retarded the evaporation of water. As a preliminary to the study of the effect of surface active agents it was necessary to establish a series of reference points for the purpose of comparing deposits. To obtain these calibrations, deposit studies were made of dyed distilled water aerosols at four wind speeds, 0.7, 1.4, 4.3 and 7.7 miles per hour. Samples of these atomized sprays were obtained as deposits on bottles exposed vertically and on glass slides exposed horizontally and vertically at various points downwind from the point of emission. Analysis of these deposits showed, as expected, that there was an overall increase of deposits on the vertical bottles as the windspeed increased and a corresponding decrease of the deposits on the slides exposed on the floor of the wind tunnel. As these experiments proceeded it was discovered that the greater proportion of the deposits at 4.3 and 7.7 miles per hour were made up of dry dye and not liquid spray droplets. Subsequent examination and analyses of deposits on the Cascade Impactor's last two slides revealed that at these wind speeds, at 28 feet from the point of emission, as much as 39 per cent of the spray cloud itself was made up of dye crystals. These crystals varied in size from single needles of approximately 3 microns on the last slide to large aggregates 70 microns across on the first slide. The deposits at the 28 foot sampling point probably were made up of these dry aggregates and this effect was present to a lesser extent at the nearer sampling points.

In conjunction with the foregoing deposit studies an investigation was carried out on the droplet size distribution of water aerosols at the various wind speeds. Results of the first series of tests indicated that in some cases the maximum droplet size at the 28 foot sampling point was larger than the maximum droplet size at the 10 foot sampling point. This suggested that aggregation of the cloud was taking place, therefore, the experiments were repeated several times to obtain accurate data on this effect. Complete analysis of droplet size distributions was complicated by the presence of dry dye crystals, however sufficient data were obtained from the microscopic observations alone.

The results of the experiments with surface active agents for controlling the evaporation from water aerosols were disappointing. However, some interesting observations were made in connection with these experiments. From a large series of surface active compounds the representatives of both anionic and cationic types were selected. Before testing these compounds in the wind tunnel, preliminary observations were made microscopically on gross effects on evaporation. The most constant feature of evaporation of water when the surface active agent is present was that the droplets evaporated in situ with little reduction of the area covered by the original droplet, due of course to the wetting power of the agent. Without a surface active agent present, evaporation of water was accompanied by a gradual decrease in the droplet diameter. In the wind tunnel tests in addition to the surface active agents a few examples of hygroscopic compounds were also tested.

None of the compounds tested showed any promise of increasing efficiency of deposit. Glycerol did show some slight improvement over an untreated solution but the results were not found to be too significant. In fact some compounds, for example sodium NA-xylene sulfonate, actually reduced the depositing efficiency. While the results of work cited by other authors definitely indicated that these surface active agents could retard the rate of evaporation from water surfaces due to the fact that the obstructing power of these molecules was formed by an unusually tough film, it was found that wind or dust destroyed these films too quickly to be of any use in preventing the evaporation of water from a droplet or surface in a turbulent or unclean atmosphere. In other words a surface active film on a droplet moving in a wind tunnel or in the open has little chance of reducing the evaporation due to the continual rupturing of the film due to movement, turbulence, or the presence of minute or impure substances on the surface.

The unusual effect of the growth of aerosol droplets prompted further investigation of this effect with insecticides in solution. Initially field experiments were carried out on the control of the hop aphid, Phoroeon humuli with aerosols of HETP and nicotine-sulfate applied to a heavy infestation of aphids on full grown hops. This test showed that better control was obtained with the nicotine-sulfate aerosol. When droplet size analyses were made of the Cascade Impactor samples taken in the hop yards at the time of application, it was found that the droplet size of the nicotine-sulfate aerosol was smaller than HETP aerosol. In the wind tunnel aerosols of 5% HETP and 5% nicotine-sulfate were used. Ammonium was added to the nicotine-sulfate solution as is done in the practical use in the field. Again the results indicated that the original observation was correct. The Mass Median Diameter of the nicotine-sulfate aerosol at 10 feet was 6 microns and 4.75 at 28 feet. On the other hand the HETP aerosol showed evidence of increasing the droplet size, the Mass Median Diameters at 10 feet and 28 feet were 9 and 11 microns respectively with the maximum droplet diameters found to be 56 and 63 microns respectively.

The better control of the hop aphid with nicotine-sulfate aerosols may now be tentatively explained. The addition of ammonia caused a very rapid release of nicotine which increased the evaporation rate of water from the aerosol droplets. In effect, the aphids were fumigated by the free nicotine thus released with secondary minor mortality effects from actual deposition of aerosol droplets on the insects. HETP on the other hand is a slightly hygroscopic compound and has only a very slight vapour pressure as compared to nicotine-sulphate. The control achieved with this compound was probably entirely due to contact action.

The results obtained in the droplet size studies with water aerosols were so interesting that it was deemed advisable to repeat these with oil base sprays. At first it was believed that in the case of water the growth of the droplets in size as the cloud aged was associated with the evaporation of water and recondensation on the larger droplets. However, when these studies were repeated with a light-medium spray oil, similar effects were found. The light-medium spray oil is a relatively non-volatile substance, but in order to insure that this effect was not associated with volatilization and recondensation similar tests were carried out with high-vacuum pump oil. This material is about the most non-volatile substance available to laboratory workers. While the effect was not quite as pronounced there was very distinct evidence of significant growth in droplets size as the cloud aged and moved downwind.

In economic control operations the information regarding the deposit on the back (of a leaf) is as important as similar data for the front. Sell's data indicated that a study of deposit on the back versus the front would be of value. It was demonstrated experimentally that there was an aggregation of droplets behind certain surfaces which resulted in larger droplets being formed and these droplets actually depositing with greater efficiency on the back side of objects of certain sizes and shapes.

These experiments served to illustrate that the decreasing order of collection efficiency by the various shaped surfaces considering all wind speeds is (1) a flat plate, (2) cylinder, (3) sphere. This agrees with Sell's data. However, consideration of deposits on the back of these objects indicates that the over-all picture of aerosol deposition as predicted by Sell's curves must be subjected to some revision since the deposits on the back of an object make up an appreciable portion of the total and often are very important from the standpoint of pest control. Here it is apparent that two important additional factors are responsible for deposition, namely aggregation and turbulence. The degree of turbulence set up by the sphere was sufficient to raise deposits on the back above those on the front for the two low wind speeds. This is in part due to the shape of the surface since the aerosols droplets can follow the air stream around a curved surface much more readily than around a flat surface, but once past the widest part of the surface the droplets are subjected to the low pressure area set up behind the plate. This shape would cause less aggregation on the front than in the case of a flat plate due to the lower resistance to the air stream afforded by the curved surface, except at the higher wind speeds. The greater horizontal area afforded by the sphere on which settling takes place at the lowest wind speeds accounts for the higher deposit per unit area on the front and back at the lowest wind speed. The effect of the diameter on the deposit on the back of an object is demonstrated by comparing the deposits on the glass slides of the two different widths. There is a suggestion here that while both turbulence and aggregation interact to cause increases in deposits the degree of each change is definitely related to the velocity at which the droplets are carried. In effect, at levels below 4 miles an hour aggregation proceeded rather rapidly since the airborne concentrations of material are high and turbulence at those wind speeds promoted aggregation. At higher wind speeds aggregation proceeds more slowly since the airborne concentrations at any given point are lower and the degree of turbulence is reduced. However, at very high wind speeds the pressure of the area behind the object is decreased and more of the droplets are drawn in close to the surface where the resulting turbulence promotes deposition. In other words, at low wind speeds aggregation plays an important part, more important than turbulence but at the higher wind speeds the roles are reversed.

Now after hearing all these physical data you can say quite justifiably to me, "well what is the significance of all this?" My reply of course, which is more of a defence than a reply, is that these factors have become extremely important in the design of concentrate sprayers. These sprayers rely on applying the insecticide in a concentrated form using a low volume of spray solution. In order to achieve uniformity of deposit and adequate coverage it has been found that blowers must be added to this spraying equipment. The design and performance of these blowers will greatly influence the uniformity of the deposit and the resulting coverage. Of course the factors that I have outlined to you in the foregoing discussion of the wind tunnel experiments will play a very important part in how adequate these deposits are.

Also when we consider the bewildering multitude of commercial formulations that confronts the user today we can readily appreciate that many common insecticides have adjuvants of various types as well as the insecticide in the concentrate solutions that are available. The adjuvants can have a great effect on the droplet size where they are used in concentrate sprayers or in aeroplane sprays. This indicates that great caution in judgment must be exercised in selecting the type and amount of wetting agent, emulsifier, etc. to be incorporated into materials of this type. Also where oil emulsions are to be applied in the form of concentrate sprays it is important that the droplet size of the oil in the original emulsion is not too small as deposits low in oil content will result. Many of the prepared paste type emulsions have the oil droplets suspended as tiny droplets. The mass median diameter of droplets of several commercial pastes examined was less than 5 microns with a maximum droplet diameter rarely exceeding 10 microns. Droplets of this size would have a very low deposition potential once the water carrier evaporated and the bulk of the material atomized would be wasted. Thus it becomes readily evident that the proper formulation of materials to be used in concentrate and airplane spraying applications is of greater importance than in the conventional spraying practices.

The experiments with nicotine-sulfate and HETP have indicated that under certain conditions, where the active ingredient is volatile, evaporation of the carrier is beneficial rather than detrimental. This is the case where a quick release of the active ingredient is desired and would probably hold true in greenhouse insect control. Furthermore, some of the newer insecticides, such as parathion and the gamma isomer of benzene hexachloride, have appreciable vapour pressures as well as being contact poisons. Thus there is a possibility that small droplets depositing on a leaf, etc. need not necessarily contact all the insects directly but toxic droplets may also kill by fumigation in the immediate area of the deposit. Since there are no quantitative or qualitative data on the nature of the films of such insecticides required to produce lethal effects, an investigation of these points may afford a fruitful line of investigation. Before leaving this subject of laboratory investigations, I would like to very briefly mention some of the new aids that have been developed recently for carrying on laboratory studies correlating these physical factors with biological effectiveness.

A new type of apparatus for applying single or multiple drops of a predetermined droplet size topically to any given site on an individual insect has been developed by Rayner and Hurtig (1952). It consists of an electro-magnet, driven by an electronic device which is made to vibrate a steel blade at its natural frequency. Oil based, dyed insecticidal solution is fed at a constant rate through a hypodermic needle. When the vibrating blade tip is introduced into the liquid accumulating at the tip of the needle, a succession of drops is thrown off. The drops detached are of equal mass and follow the same trajectory. When a piece of paper is passed through the stream the falling drops leave a single row of stains on it. The paper may be directed so that an insect placed on it intercepts the stream. The position of the stain row in relation to that of the insect, and the number of drops missing from the row, give the position and number of drops that have fallen on the insect. The drop size is known, and therefore the amount of insecticide deposited on the insect may be calculated quite precisely.

This apparatus will prove to be quite useful in studying (a) relative mortalities at various loci of application, (b) the relationship between drop size and toxicity, and (c) the relative effects of different oil based insecticides.

Since in the concluding section of this paper I propose to discuss field research on airplane spraying it is apropos that I mention a very valuable piece of laboratory equipment which will be useful in carrying out laboratory studies related to this field of investigation. The spinning disc cabinet affords a means of reproducing in the laboratory segments of a spray similar to that which might be recovered from an actual airplane spray in the field. We hope that this apparatus will be useful in separating some of the factors contributing to gross mortality in the field.

In work of this type we are continually confronted with sampling problems. In developing airplane spray equipment we have arrived at a fairly standard set of procedures which may be of interest to this group. Let us assume that all the work on equipment design and development has been completed. That in itself is quite an assumption. The next task, therefore, before we attempt to carry out what we call user trials, is the actual calibration and assessment of the performance of the equipment. Let us assume then that we are going to assess an apparatus for the dispersal of insecticides from an aircraft. First of all, in order that the results obtained from one day to the next may be comparable, we must carry these tests out under similar meteorological conditions. Quite frequently we are asked, "Why do you people from Suffield always carry out your experiments in the ungodly hours of the morning or time in the evening when everyone else is having dinner?" Well unfortunately, it is during these two periods that the atmosphere is most stable and we can find the more reproducible conditions. In other words we seek conditions which will give us zero temperature gradient or slight lapse or again slight inversion conditions. Quite naturally the next step of course is to find out what type of droplet size distribution is obtained from the spray apparatus under these standardized conditions and the droplet density or the number of droplets produced per unit area and finally the total deposit over the area over which the insecticide has been applied. We find it more convenient to dye the sprays and to analyse for the dye rather than actually carry out analyses for the insecticide. For this purpose, samples of the spray are caught in petri dishes of known and constant area and following colorimetric analysis of the dye it is possible to calculate the deposit in terms of pounds of active ingredient or gallons of solution per unit area, most commonly per acre. For droplet size determinations we have been confronted with quite a problem here because of the large number of samples which have to be handled in order to give the statistically significant parameters which are required and in the past we have used a specialized absorbent paper surface called "jump cards", magnesium oxide coated slides on which the droplets leave craters which are replicas of the droplets producing them and finally a new type of paper. Recently we have come to the conclusion that we will be abandoning the jump card and magnesium oxide coated slides. The reasons for this are that the jump cards are very unreliable in the droplet size range below 125 microns, that is to say that the stains produced by droplets whose diameters are smaller than this are not reliable. Also, the magnesium oxide slides are difficult to handle in the field and their assessment by microscope is quite tedious. Elliott (1951) developed a dyed paper surface for large scale operations in the forest. This paper was a calendar type surface paper which was impregnated with an acetone solution of a red dye. When undyed spray material hits this paper it leaves a bleached area which contrasts to the darker red background. From standards prepared ahead of time, it is claimed that adequate assessments can be made of the coverage obtained from aircraft sprays in the forests. We examined this paper with the hope that we could adopt it for our purposes and were delighted to find that if we used the undyed paper and a dyed spray for experimental purposes this was very practical and provided a very good contrast for counting purposes. Fortunately, also, while the spread factor for the stains within various size ranges varies the spread factor within any single size range is constant. We are almost at the point now of using this paper exclusively for all future droplet size work.

Now to go on with our assessment. First of all single runs are assessed in order to provide the necessary data on the physical make up of the deposited spray. Once these data have been obtained it is possible to calculate what the effective swath width is going to be and overlap trials can be carried out under semi-operational conditions. In other words, these are the next steps towards carrying out user trials under control operation conditions.

Field Research on the Control of the Spruce Budworm with Sprays Applied from Aircraft.

For the past three years one of the major projects that we have been carrying out has been a field and laboratory study of the effectiveness of airplane sprays in controlling the spruce budworm. This project was taken on by the Defence Research Board at the request of the Forest Insect Control Board of Canada and the Division of Forest Biology. The Division of Forest Biology supported this project financially and also seconded personnel to Suffield to assist on this project. This therefore accounts for the presence of Dr. Fettes at Suffield as he is a leading student of spruce budworm ecology in this country. What we are attempting to do is to examine the airplane spraying in an attempt to establish quantitative indexes of effectiveness in terms of (a) the number of droplets per unit area required for the control of various vulnerable instars of the larvae, (b) the relation of droplet size toxicity and (c) the relation between insecticide content and volume of solution and toxicity. In effect we are trying to provide a simple index and a simple method for the foresters to assess a control operation without following it too closely with biological assessments. Of course I will hasten to point out that without paralleling such determinations with biological assessments the whole operation would be subject to question. I will recount very briefly for you some of the methods that we have used in approaching this problem from this field standpoint, and Dr. Fettes will provide you with an account of the biological effectiveness of the sprays and some of the attempts to correlate this biological effectiveness with the physical and chemical properties of the spray.

' The preliminary work was carried out with dummy sprays in the Bow River Valley near Banff, Alberta. In the preliminary work we were interested in finding out just what did happen when the spray was applied from an airplane. Samples were taken at the top of the trees, in four quadrants part way down the tree, in four quadrants at a second level two-thirds of the way down the tree and finally in four quadrants under the tree. Trees were selected which would give us examples of trees that were dominated by other types of trees, for example poplar trees overtopping young spruce, and trees out in the open unshaded by other trees and finally trees which could be expected to provide normal examples of normal clumps of infested trees. In these studies much valuable experience was gained in the handling of samples under the conditions that were encountered. Also we were able to determine that if we examine quantitatively the total amount of spray deposited within a tree that at any given level there was no marked difference between the amount of spray reaching the top, a third of the way down, two-thirds of the way down and actually penetrating to the forest floor. In other words, with spruce there was relatively little screening in relation to various horizontal planes up the tree. Incidentally, this sampling system was patterned after a population sampling system developed by Dr. Fettes.

After gaining information at Suffield on the performance of a boom spray emission apparatus the next step was to carry out single swath emissions over infested forests in the Kenora district. From these single emissions it was possible to delineate the effective swath width that could be expected under operational conditions and also at this time preliminary attempts were made to obtain samples which would correlate some of the physical properties of the spray with biological effectiveness. Here again, however, we learned several lessons which greatly aided in the design of our experiments in 1952.

This year we carried out a rather extensive series of trials again in the Kenora district in which we attempted to replicate as far as possible the various deposits which might give us varying degrees of biological effectiveness and yet provide deposits made up of droplets of different droplet sizes. Also, large crews were employed to attempt to carry out adequate biological sampling to separate as many of the factors as possible that contribute to the gross mortality. Most of the plots were approached by road to a landing site and then water transportation was required to reach the experimental sites. In one of our largest plots there were three lines. Two of these were 1140 yards long each and the other line was 1740 yards long. Every 30 yards along each line a sampling point was established. At each of these sampling points we chose a "chemical tree", that is a tree on which we were going to sample for deposit and droplet size distribution within the tree itself and under the tree, and nearby, as close as possible, we chose a "biological" tree which was as similar to the chemical tree as possible. Also, nearby the sampling point an open spot was located or cleared in order to obtain a sample of the spray that might fall on open terrain. The lane chopped out through the forest along the sampling lines was marked with red bunting. We have found it much superior to blazes on trees for this purpose. In previous years we have found that when large scale sampling was desirable it was a man-killing job to have all the sampling points rigged, even on the day preceding the trial. Also, we found quite often that trials had to be cancelled due to unfavourable weather, etc. and certain precautions had to be taken to protect the actual sampling equipment from the weather. Therefore, an automatic sampling unit which could be tripped from the ground was designed. The automatic sampling units were placed half way up in the green growth of the tree crown on the upwind and downwind side. The unit is made up of an aluminum cover which when withdrawn by a length of nylon elastic, exposes a petri dish and a length of jump card bearing a 2 x 3 inch piece of the new sampling paper that I have already mentioned and a magnesium oxide coated slide. We found that these units stood up very well to rain and to high winds. Similar sampling units were placed on the ground, under the periphery of green growth under the tree. However, when you consider that it took us roughly two weeks to prepare the sampling layout for this particular trial, and when we consider that only a few minutes of actual spraying by an aircraft can mean either success or failure of one of these trials, you can understand why it is that we take such precautions to make sure that everything will go according to schedule.

Communication with aircraft is an absolute necessity on experimental trials of this nature. Occasionally it is necessary to bring the ground communication set out as near as possible to the site. Last year fortunately we were operating on the Lake of the Woods, and it was possible to bring our radio truck out to the actual trial site on a barge. On the trials this year it was impossible to ferry out the radio truck. However, we were able to provide ground radio sets which provided communication from the command point to the radio truck on shore, which relayed messages on to the aircraft. As you have already gathered, it is important that the aircraft fly precisely along the flight paths that we would like to have followed in these experiments. Since the terrain was difficult, even aerial photographs did not provide the necessary landmarks for precise flying. Fortunately we were able to work out a system using smoke puffs fired from the ground. Along each of the flight paths we stationed personnel who had radio communication with the control point. At the proper time these people fired smoke puffs which were used by the aircraft as aiming marks. These smoke puffs were visible for quite a distance. Early in our work it became apparent that wind speeds required on the ground were not necessarily directly related to wind speeds above forest. Those of you who work in the forest can readily appreciate that while the wind may be blowing at 10 miles per hour above the forest the wind on the ground may be 2 or 3 miles an hour or even a dead calm may prevail. Therefore, it became necessary for us to work out a means of determining the wind speed at the height of release of the spray material. A Hill's mirror was found to be the most practical solution to this problem. White smoke puffs were fired from the ground in front of the mirror and the height of burst measured with a theodolite. The puff moved through the sky at a rate which of course was dependent on the wind speed at that particular height. By tracing the path of the smoke puff in the mirror and measuring it for length of trace over a given period of time and also measuring the angle we were able to calculate, not only the wind speed at that particular height, but also the direction. This of course made it possible for us to have a very precise control over where the spray was going to fall. As a further check on some of the other variables in experiments of this type, we also closely check atmospheric stability.

In conclusion reference should be made to the various types of aircraft used in laying down the insecticide. A Dakota (C-47) aircraft is located at Suffield for these experimental trials. While this is not necessarily the best aircraft for spraying, the aircraft was (a) available and (b) carries a big pay-load of the type required for mile square trials and finally was flown by experienced pilots, that is to say pilots who are experienced in our trial requirements. This craft was fitted with two tanks each holding 250 gallons of spray solution. The Canadian-built De Haviland Beaver aircraft has been found to be an extremely useful aircraft for this type of work. While in Kenora this year and back at the Suffield Experimental Station, we carried out a series of calibration and performance trials with this aircraft. Where large scale work is going on, such as forest spraying or the application of insecticides or weed control agents to large areas such as on the prairies, this aircraft is very safe and reliable. The pay-load of the aircraft is 200 Imperial gallons.

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RECENT DEVELOPMENTS IN THE BIOLOGICAL ASSESSMENT OF INSECTICIDE EFFECTIVENESS AS APPLIED TO FOREST INSECT INFESTATIONS

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The study and control of forest insects has gained considerable momentum within the last few years. This has been the result of similar activity in other biological sciences, but a most important factor has been the rather sudden realization that there is actually a limit to the formerly limitless empire of commercial forests. Not only is there a limit but that limit is now a foreseeable reality.

With the shrinking of forest reserves and the expansion of forest industries there has been increasing interest in developing ways and means of minimizing competition for forest products with destructive agents. Our most serious competition has come from fire and biological factors. Of the biological factors, destructive insects rank first. Research on the control of forest insects has followed many courses, but until recently chemical control has received little more than token consideration.

Chemical control has been approached cautiously in Canada and has had intermittent attention since 1944, but not until quite recently on a scale capable of producing concrete results. The reasons for the caution with which we have embarked on a research program are many. It has been suggested that chemical control over large areas could not be made feasible either practically or economically. Biologists have postulated that the balance of beneficial populations would be so upset by widespread application of insecticide that chaos would result. Economists have suggested that once begun we would be embarking on a continuing economical drain which would eventually become more costly than present insect losses. Some authorities have pointed out that the political implications would be overpowering. While yet others have denied any faith in the proposition whatever. Consequently we have forged ahead in numerous fields in forest insect research, but have almost excluded from our thinking the dramatic and immediate possibilities of forest protection by chemical means, which has been a bulwark of research in all other branches of plant protection, both food and industrial. It is heartening that, at long last, chemical control has come into the plans so we may at least investigate thoroughly the possibilities of forest protection by chemical control.

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The use of chemicals for the control of forest insects is not advanced as a cure-all for our insect troubles, but is conceived as a special weapon to be used in an emergency and where its use can be expected to have beneficial effects. There are insect infestations which flare up in relatively localized areas but which we know have, from our past experiences, the potential to spread over large areas and to cause serious damage to valuable timber. There are timber stands which may be threatened by widespread infestations but which are economically or aesthetically valuable enough to warrant considerable expenditures in order to protect them. There are conditions under which forests may be saved by a season or two of respite from defoliation, especially where there are definite indications that an insect population has passed its peak but which may continue until many trees are fatally damaged. In all these instances chemical control could well be the only answer to the problem of serious loss by insects.

It is almost inconceivable that the application of insecticide to large forested areas could be by any other means than by aircraft. Having settled on the medium of application we are immediately beset with numerous problems in engineering, many of which will have to be solved largely through trial and error. Most of the principles which have worked out admirably for slow-moving insecticide applicators do not hold when the applicator is carried through the air at 80 to 150 mph. To mention but one of the problems encountered in the new development, conventional nozzles are at a disadvantage where the slip stream determines the spray break-up by the shearing action of the wind.

The measurement of the biological effectiveness of insecticide application is in a sense the end point in the research on our chemical control. Biological assessment is wholly and fundamentally a problem in population measurement, fluctuation and sampling, and it is to this end that a great effort should be devoted.

Forest entomologists will readily agree that wild forest insect populations pose serious sampling problems. Variability within these populations is always discouragingly great; so great that the statistician will suggest enough work to keep busy an army of workers. The subtle environmental factors which cause population differences are most annoying. A spruce budworm sample taken ten feet up or down the crown from a given point may show a difference of 50% in numbers. If the forest composition between neighbouring stands differs from 50% balsam fir to 25% balsam fir the spruce budworm population may be less by one half. Should the distance between samples take one from a valley to a hill the population may be double one season or half in another. A heavy rain storm or an exceptionally warm afternoon may (or may not depending on defoliation or larval stage) result in the disappearance of half the population. This lament could be prolonged indefinitely but serves to illustrate the difficulties facing the biological assessor. Despite these difficulties, however, the assessment must be sufficiently precise to satisfy the chemist who is sure his measurement of insecticide deposition is accurate and who wishes to see a correlation between deposition and insect mortality; and the toxicologist who has faith in his well controlled laboratory experiments and may question your field methods unless there is good agreement between your findings and his.

It is regrettable that in most of the field experiments in the past the biological assessment has been rather inadequately considered. It seemed quite easy to arrange for aircraft, aircrew, tons of insecticide, radios, vehicles, etc. but all too difficult to obtain adequate biological sampling personnel. Consequently the biological data have rarely approached the standards reached by the other phases of the operation. All this in face of the fact that the biological story was the end point and without which the entire operation became meaningless. The reason for this attitude is somewhat obscure.

During the last 2 1/2 years there has been an advantageous cooperation set up between the Defence Research Board and the Division of Forest Biology whereby we have worked together toward a common goal, Under Dr. Hurtig of the D.R.B. Entomology Section at Suffield Experimental Station the facilities of the entomology laboratory and workshop were devoted to the chemical, toxicological and engineering aspects of airplane spraying while the Division of Forest Biology seconded personnel, to take advantage of the opportunity and to lend our own training to the biological phases of the problems. During this period we have been able to solve some of our problems and to learn enough about other phases of the work to consider returning to the Division of Forest Biology to continue a research program already well started and for which we are better prepared.

In a discussion of this nature it would be best to take up the subject of "Problems in population measurement" and to illustrate the solution of some of them from the data obtained in early and recent field experiments. The references to field research are confined entirely to the spruce budworm since, as Canada's number one insect enemy of the forests, it has received most of the attention. However, the principles involved will be similar to those anticipated for other insects.

Plot Selection

As a first step in the field experiments the selection of a suitable forest is of prime importance. The specifications for an experimental plot, when examined in detail place a high premium on suitable sites. These are the specifications decided upon, mid-winter last, when the 1952 trials were being planned.

1. The infestation must be (a) heavy enough to provide an abundance of larvae, (b) not so heavy that mid-season starvation would cause excessive natural mortality.
2. The forest must be predominantly balsam and white spruce (a) tall enough to be a representative forest, and (b) short enough to allow mid-crown sampling.
3. The forest must have sufficient dominant balsam fir trees to provide sampling stations near all points dictated by surveyed lines.
4. The plots must be easily accessible by boat or water or both.
5. The terrain must not present serious flying hazards.
6. The plots must be centrally located within a few miles of accommodation.

Bearing in mind that most of the commercial spruce budworm type forest of Eastern Canada has long since been killed by this enemy, the location of a suitable forest was challenging to say the least.

Last February after several days of flying over and examining close at hand all of the forest between Vermillion Bay and Kenora, Ontario, suitable areas were found about 25 miles southeast of Kenora.

Sampling Methods

With an understanding of what we are trying to do, both chemically and biologically, the description of the method of securing the biological data in the field is presented. At the sampling stations within the plots a biological sampling tree and a matching chemical sampling tree were selected. Insect samples could not be taken from the same trees on which chemical sampling kits were secured because the jarring of the trees during the operation would have disturbed the larvae and probably caused many of them to be shaken out of the foliage, To secure a larval sample the crews employed tree pruners which had extensible handles. A basket was attached under the shears to catch the branch sample and any larvae that may have been dislodged. After lowering the sample the larvae were taken from the foliage and tallied by instars. Then the new shoots were counted. This was done for two sides of the tree; the sides designated as upwind or downwind for a predetermined wind direction at the time of treatment.

As an illustration of the amount of effort expended on one large plot, during the season the sampling crews examined over 1/8 million shoots and identified over 30,000 larvae.

Population Measurement

The measurement of forest insect populations must continue to be a compromise between precision and available assistance. As previously suggested, variability of distribution in forest insects is usually so great that the effort required to take samples of sufficient size and of a sufficient number to reduce the sampling error to the usual experimental standards, say 3 to 5%, is virtually unattainable. Thus, at the outset we have to learn to live with large sampling errors and evaluate our results accordingly.

In earlier work, the investigation of a number of sampling techniques and the study of the distribution of the immature stages of the spruce budworm, it was concluded that a population measurement based on the density of insects per feeding site would provide the most accurate measurement of the population. These studies also showed that the insect numbers taken from foliage near the middle of the crown would most likely be representative of the insect density on the entire tree. In this work a new shoot was identified as a feeding site and the larval density became, simply, the number of larvae divided by the number of shoots present on a sample of foliage. Since the results were to be in terms of per cent a sample size of 100 or more new shoots was needed to make the final estimates of mortality meaningful.

The Treatment of the Data

(a) Check Plots and Natural Density Decrease

In many of the biological assessments for which we have reports, mortality due to treatment has been presented without regard for natural mortality. This may sound a bit fantastic to some but it is true nonetheless. Depending on the age and condition of an infestation of spruce budworm the natural mortality may vary from 50% to 98% during the larval period. Thus, if natural mortality is not carefully measured an apparently high mortality due to the application of insecticide may be largely due to natural decrease. With this in mind much thought has been given to handling of check plot data.

As one proceeds along a sample line in an infested forest one is struck by the great range of population levels accompanying small changes in forest composition; forest age, soil moisture, or forest density. It is immediately obvious that these levels will have to be treated as individual populations when their numbers are changed by treatment with insecticide. It is at this point that the importance of adequate natural mortality data is realized.

To measure the effect of the treatment one important assumption is made. "That in a relatively small area the decrease in larval density over a given period will be similar throughout the area". Again, referring to earlier work (Fettes 1951) this assumption has a sound basis. Thus, by measuring the natural decrease on several check plots and noting that the trends are in close agreement we may calculate an expected larval density for sample stations in the treated plot and conclude that a deficiency is due to the treatment. The expected density is based on pre-spray samples and the assumption that the natural decrease for each tree will follow the trend of the untreated populations. Figure 1 shows the trend for two check plots associated with the Mile Square Plot, Kenora, 1952, and is based on a per cent decrease between samplings. That is, considering the population at treatment as 100% then the expected density one day later is 96-1/4% of the original and so on until 15 days after treatment the expected density is only 45% of the original.

A calculation to determine the per cent deficiency of observed over the expected density determines the per cent mortality due to the treatment. That is, if the expected is 1.00 and the observed is 0.25 the per cent mortality is 75.

Mortality Mile Square Plot, Kenora, 1952

As an illustration of the results of biological

FIGURE 1

LARVAL DENSITY DECREASE IN THE

CHECK PLOT BUDWORM POPULATION

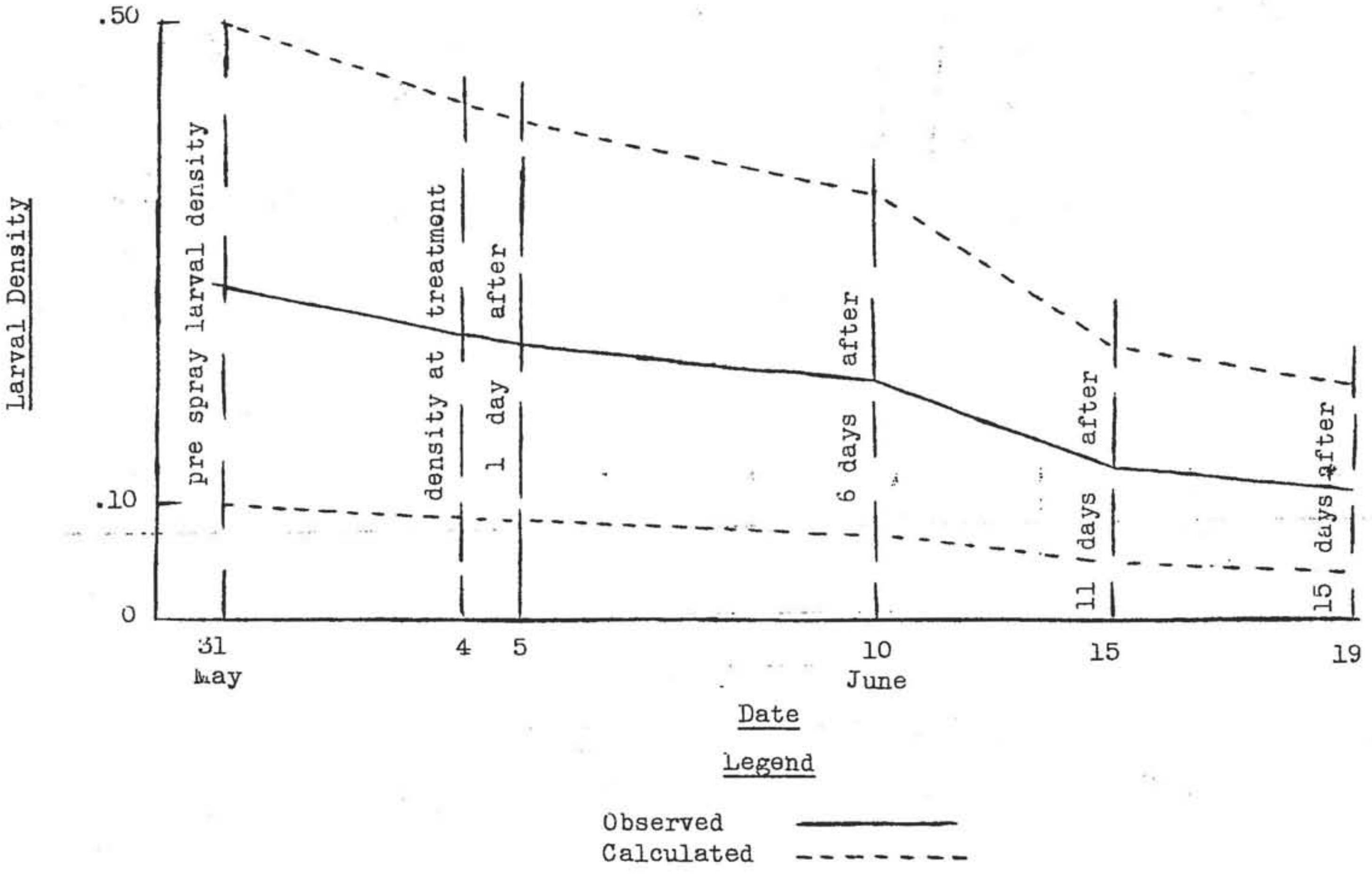
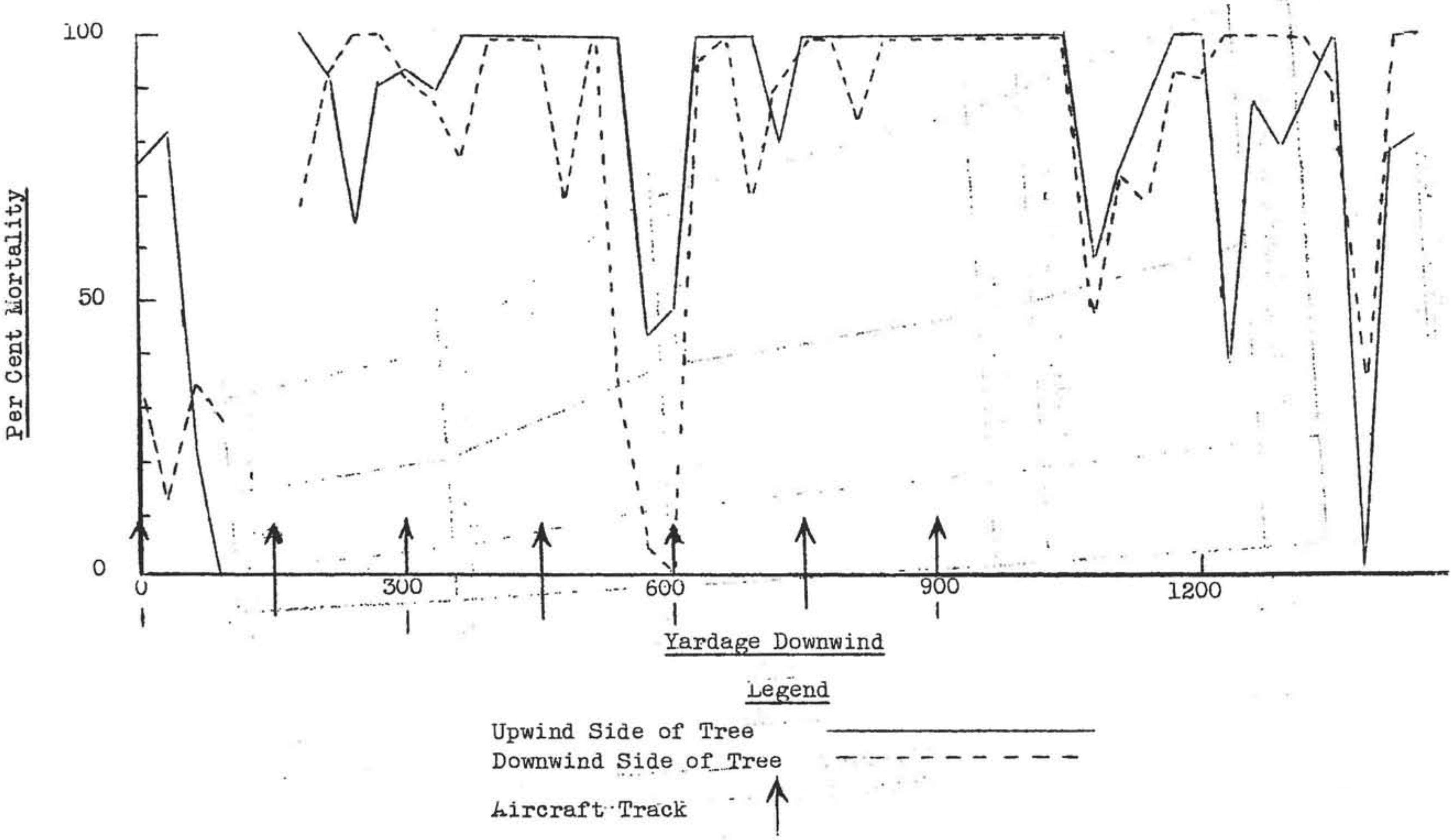


FIGURE 2

EFFECT OF AIRPLANE SPRAY DEPOSIT

ON SPRUCE BUDWORM POPULATION

Mile Square Plot - Kenora 1952



assessment, figure 2 represents the calculated mortality due to the insecticide for a part of the data from the Mile Square Plot of the 1952 Kenora Trials. These data are from the centre sampling line of the plot and are a good representation of what can be expected in a well controlled operation. There are several points of interest in the graph.

The solid line represents the mortality on the upwind side of the trees and the broken line the downwind side. While the effect is not consistently lower on the downwind side, 65% of those pairs which are not equal at 100% mortality are lower on the downwind side. This indicates that there is a definite screening of the spray droplets by the tree crowns. It appears that in some instances the opposite may occur. Toward the left end of the graph note that many of the downwind samples show a lower mortality and at the opposite end of the graph the sequence is reversed. Descriptions of the sample trees show that the trees at the left had open crowns, were smaller and the droplets could drift to the crown on undisturbed air currents giving a heavier deposit on the upwind side. The trees on the right end of the line were large with full, dense crowns which interrupted the air currents to cause swirling behind the crown to give heavier deposit on the downwind side. This phenomenon is borne out by the work on deposition by Dr. Hurtig for round objects and has been observed frequently for mist on such objects as vehicles. We have certainly noted similar deposition on our vehicles when parked in the wrong place at one of our trials.

Going from left to right and noting the aircraft tracks and wind direction there is evidence of the cumulative effect of the deposition as one swath overlaps the next, the area of almost complete extinction of the budworm population in the centre and the tapering off of the effect at the right. The 150-yard swath width allows for generous overlap so that the heaviest deposition does not occur until the third swath is applied. From beyond the 300-yard mark to about the 1100-yard mark the average mortality is over 95%. The valley at the 600-yard mark is not readily explained, but could be caused by a gust of wind which could blow one swath beyond its mark, or might be caused by a ridge, which ran through the plot at this point. The sun on the ridge could cause an updraft which could keep the smaller droplets from settling. These are pure theory, since the cause was not observed. However, it is a good illustration of the type of gap that can be expected even in a carefully controlled operation. It is believed that this sort of thing is inherent in airplane spraying and a wide margin of safety would be necessary to minimize such misses which become ideal re-infestation areas. Note that a high degree of mortality continued for 150 yards beyond the final aircraft track at the 900-yard mark.

In Dr. Hurtig's paper he led you to expect that I would be able to present some of the data which shows a correlation between spray deposit on the trees and larval mortality. I regret to say that this portion of the data has not yet undergone complete analysis and no presentation can be made. The preliminary graphs have been ocularly compared and it suffices to say that there is evidently quite good agreement of the trends of deposition with trends of mortality.

There are several factors of importance which will be compared. The aim of the comparisons is to determine the spray break-up that will produce the highest kill. The chemical sampling method produced three basic measurements (a) the number of droplets per unit area, (b) the droplet size spectrum per unit area, and (c) the actual amount of insecticide deposited per unit area. Which factor or combination of factors is most effective should emerge from the data at hand. There are reasons to suspect that the number of droplets per unit area above a certain minimum size will prove to be the key to effective sprays. When this is determined we will be in a better position to improve spray equipment to produce optimum spray break-up.

Beyond this problem there are others. If droplet numbers proves to be a key then concentration of insecticide in solution can be varied, all with an aim to the optimum deposit most economically applied.

Timing

Timing of insecticide application must be considered at several points in the operation and is often a critical decision. In the first place there is the question of whether or not a forest should be sprayed as a protective measure during a given season. Our experience with spruce budworm has indicated that the insect population goes through the stages of (i) build-up, (ii) a period of high density populations and (iii) a period of decline, all in the space of about ten years. Population vigour is so great and environmental conditions are so favourable during the build-up period that nothing short of virtual extinction of the population would give lasting protection. This condition continues for several years until adverse environmental factors such as parasites, disease, predators and possibly food shortages begin to weaken the population so that the stage is set for the period of decline. In the course of this cycle the host trees reach a point where further defoliation threatens to be fatal. This occurs after three to five years of serious defoliation. The application of an insecticide at a time when the trees are still healthy and putting on some annual girth would protect the forest for the remainder of the infestation cycle and the remaining population would follow its normal trend and decline in an unaltered cycle.

FIGURE 3

COMPARISON OF DEFOLIATION HISTORY
SHOWING PERIOD OF EFFECTIVENESS
OF SPRAY APPLICATION

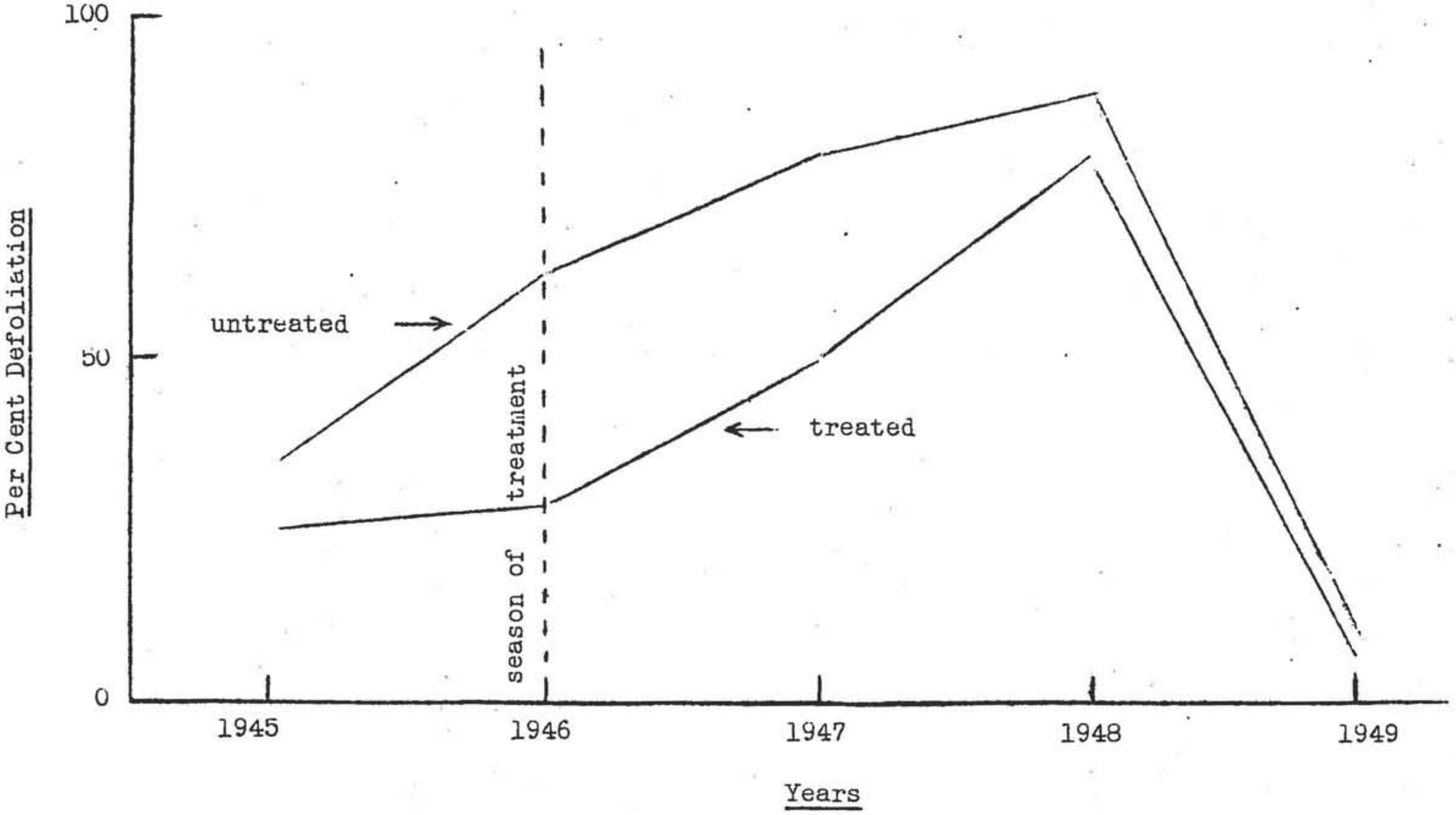


Figure 3 is taken from a report on the Eaglehead Lake Airplane Spray trials when 45 square miles were treated in 1946. The history of defoliation was followed until 1949. Comparing the defoliation means for all the years in the treated and untreated forests there was a significant difference in 1946 and 1947 only. The conclusion to be drawn is that the forest was protected the year of the application and the year following. In two years the treated insect population had recovered fully. Most remarkably, the treatment did not alter the general trend and the populations in the two areas declined sharply in 1949 as did all other populations over several hundred square miles in the general area of Eaglehead Lake.

This particular timing was not planned nor were the results expected. It was pure accident that it was sprayed at that time, since we knew little of cycles and declines of spruce budworms at the time.

There is another question about "When to spray" which is suggested by population studies of the spruce budworm. For the most part, budworm outbreaks have begun in quite definite forest types and age groups. The overmature white spruce-balsam fir forest has been the focal point of the outbreaks with which I am familiar. These focal points may act as reservoirs of drifting larvae and be the cause of the establishment of dense populations in areas which in themselves could not develop outbreaks. The momentum thus begun continues indefinitely. I have often thought that an early detection and immediate and repeated spraying of that focal point to the virtual extinction of the population might have prevented damage to thousands of square miles of forest. The focal point of the Nipigon infestation was less than 75 square miles or 48,000 acres. It is pathetic to contemplate that an investment of say $100,000 to spray the entire focal point heavily twice might have saved millions of dollars worth of pulp and timber.

It is important that a spray be applied during the period or periods of greatest vulnerability and susceptibility in the life history of the insect. At present it is conceded that the most susceptible period for spruce budworm is between the end of the third larval stage (which usually corresponds with the opening of the host tree buds) and the end of the fifth larval stage although young sixth stage larvae are quite susceptible as well. Our laboratory experiments indicate that minute quantities of insecticide will kill second stage larvae but it is problematical if their protective feeding habits (mining needles, buds or flowers) would provide an opportunity for spray to reach them. This problem is one which is scheduled to be investigated at first opportunity.

Mature larvae (sixth stage) have proven in the laboratory to be extremely resistant to D.D.T. This might lead to the conclusion that spraying at the time of larval maturity would not be effective. Rearings of larvae collected from trays under sprayed trees showed that most sixths survived to pupate while nearly all younger larvae died. Examination of the data of 1952 shows no evidence that there are more surviving sixths than would be expected by ratio comparisons between treated and untreated samples and also between residual populations on foliage and those collected from trays beneath the sprayed trees. It is likely, while large sixths are resistant to D.D.T. they are irritated by rather small amounts and the resultant activity causes them to fall out of the trees. It is questionable that these larvae regain feeding sites after falling to the ground. In other population studies it has been established that decreased larval densities due to storms or high temperatures do not rise again as they would if the deposed larvae returned to the foliage.

It might then be practical to lengthen the period of spraying to include all larval stages. Certainly this would be so if the residual effect of D.D.T. would last long enough so that the young larvae would come into contact with it upon emerging from hibernacula or proceeding from one feeding site to another.

Initial Larval Knock-down and Residual Effect

Larvae may be eliminated by insecticide in several ways: (a) by contact with falling droplets, (b) by crawling over deposited insecticide, (c) by ingesting contaminated food, or (d) by irritation from the insecticide either by measurable droplets or by aerosol or fumes. There are still a number of questions on mode of elimination yet to be answered. Which manner of killing accounts for the greatest number of insects? How important is initial knock-down? How much of this knock-down is actual kill? How much is simply irritation? How does later mortality come about? By contact? By ingestion? The answers to these questions and many others will have a bearing on future concepts of effective spray coverage. It is more economical to distribute small droplets if they will do the job. Contamination of the foliage may be more important than immediate contact with a droplet containing a lethal dose. Contamination for residual effectiveness may well become the ultimate aim.

FIGURE 4

THE RESIDUAL EFFECTIVENESS OF D.D.T. SPRAY
DEPOSIT ON SPRUCE BUDWORM ON BALSAM FIR

Mile Square Plot Kenora 1952

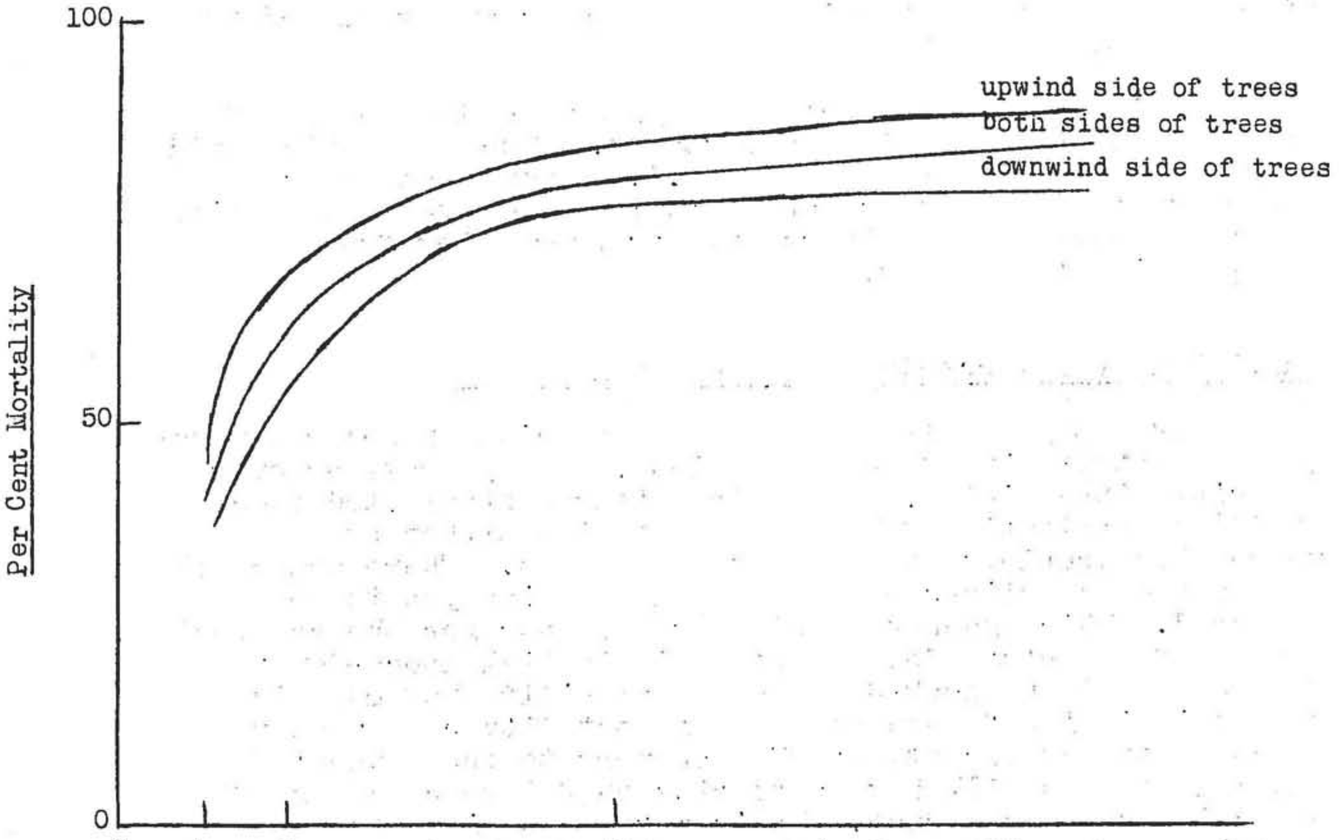
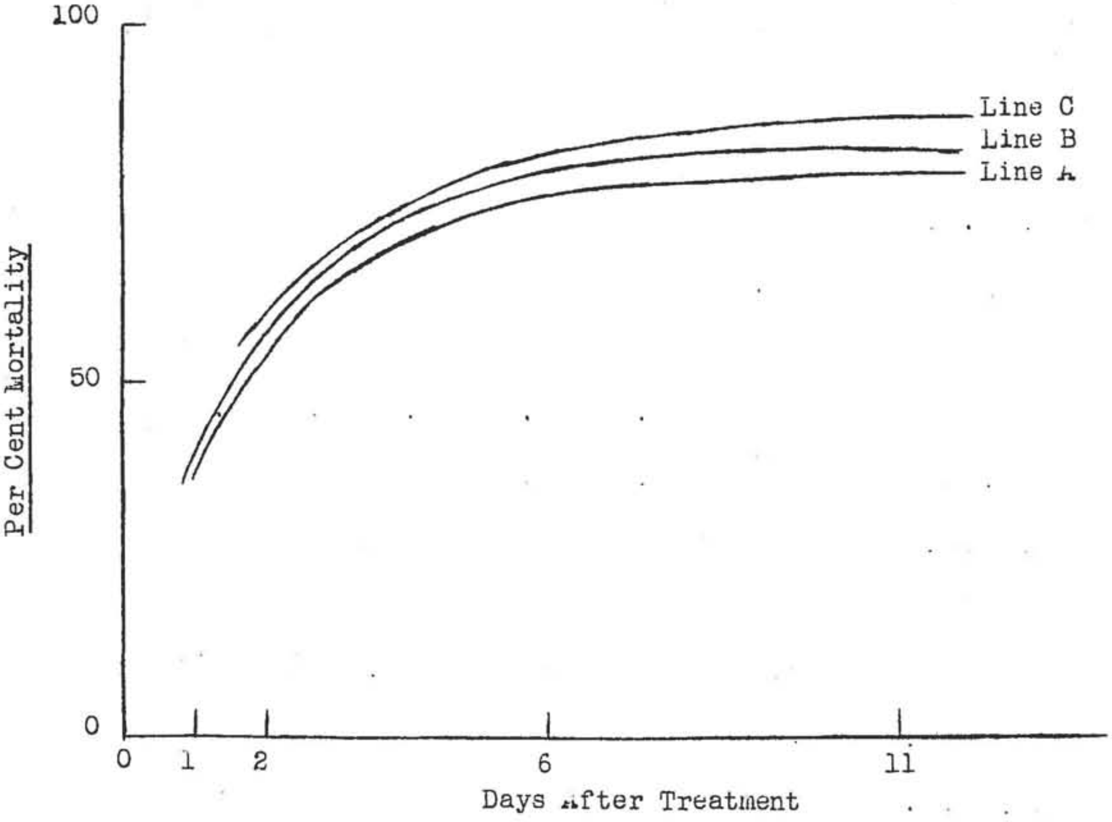


FIGURE 5 BUDWORM MORTALITY INCREMENT AND UNIFORMITY FOR SAMPLING LINES

Mile Square Plot Kenora 1952



The curves in figure 4 show per cent mortality plotted against time after treatment. When the final mortality is in excess of 80% the initial knock-down is less than 40%. It is apparent that most of the kill takes place after a 24-hour period and that most of the kill has been effected by the 6th or 7th day. The graph shows, too, that a period of at least 8 days should elapse after treatment if one sampling is to determine mortality. Note that the mean mortality for the upwind side of the trees is consistently greater than that of the downwind side. Another treatment of the same data (figure 5) shows the consistency of the results between the sampling lines of one plot.

This paper may seem more like a statement of the problems rather than a solution of them and is a good indication of the stage of the work. Some advances have been made but mostly the way is being shown by our experiences.

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METHODS USED IN THE STUDY OF THE CONTROL OF INSECTS IN SHELTER BELTS WITH CHEMICAL SPRAYS

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In this paper it is proposed to deal with methods which have been employed in the field by workers at Indian Head in developing practical chemical control recommendations for shelter-belt pests. Essentially, this work is of an ad hoc nature. It can be justified only on the basis that information obtained has made it possible to develop measures which have prevented serious defoliation or other injury to the trees during the year of application or for a period following it.

The recommended measures are employed on a small scale by a large number of individual owners of shelter belts and shade trees, and occasionally for operations on a larger scale. The amount of toxicant required therefore has little bearing on the economics of the operation and in this regard differs markedly from the treatment of orchards, field crops and forests where the cost of the insecticide is an important factor. In other words it is of little consequence from the cost standpoint in treating shelter belts and shade trees, whether one pound or five pounds of the toxicant per unit area or per unit volume of spray are used, so long as the desired results are obtained; namely, protection from the pest, without damaging the trees with the chemical. In the case of chemicals which are highly toxic to warm-blooded animals, greater judgement in the amount which can be safely recommended must be exercised.

To date, all spraying recommendations developed are for use with standard high-volume, hydraulic equipment.

In all methods used, just enough spray material was applied to wet the foliage sufficiently for dripping to begin. This provided a rough limit to the amount of chemical applied, and is also the criterion followed, generally, by the owners of shelter belts and shade trees.

In the main, because of the gross nature of the field work, averages and percentages were used and Abbott's formula employed to arrive at the magnitude of mortalities effected, instead of the more critical statistical practices based on data from randomized sampling.

Abbott's Formula:

$$\frac{x - y}{x} \times 100 = \% \text{ control achieved,}$$

when $x = \%$ living in untreated,

$y = \%$ living in treated.

In expressing mortality as a percentage of the total population the importance of the total surviving population must be kept in mind. In the case of some defoliating insects such as the cecropia caterpillar, with only one generation a year, a relatively low percentage mortality might well mean a highly successful operation. With species which have a rapid rate of reproduction such as the spruce spider mite, however, even a high percentage mortality may still mean only temporary relief from injury, since the residual population, though small, may increase rapidly to or beyond the pre-spraying level.

The methods used have differed according to the nature of the pest concerned and can be grouped into (1) methods used for chewing insects such as caterpillars and sawfly larvae which are capable of moving relatively long distances on the host tree, and (2) methods used for sucking forms such as the spruce spider mite, pine needle scale, and aphids which are relatively sedentary. The latter usually have a rapid rate of increase and are frequently localized, causing an uneven distribution over the tree.

One of the practices used for obtaining data on mortality of caterpillars and sawfly larvae was to ascertain population levels by actually counting the numbers of larvae present on a series of branches before the treatment was applied and tagging the branches in such a way that recounts could be made at the conclusion of the test period. With sawfly larvae this practice was not too difficult to employ and appeared to have considerable merit. Sawfly larvae do not roam about over the foliage or drop from branch to branch to any marked degree except when forced to do so to obtain food. Population levels per unit length of branch do not fluctuate rapidly therefore and relatively accurate counts can be made, as demonstrated by the following data from a series of untreated branches:

First count	12	15	25	22	17	7	12	56	21
Second count (24 hour interval)	12	13	22	20	17	8	11	56	20.

The foregoing practice was not satisfactory, however, for the fall cankerworm. This species is extremely active and difficult to handle. Furthermore, on warm, calm days during the later larval stages it readily drops from the foliage and is suspended at the end of a silken thread, and even on untreated branches a recount may differ considerably from the original count. To avoid the large discrepancies caused by this shifting population, treatments against the fall cankerworm were carried out without making the pre-spray counts. The differences in population levels caused by the sprays were found by making counts at the conclusion of the test period on unit-length sample branches showing comparable defoliation, from treated and from untreated trees. This method would have been more acceptable if pre-spray population counts had also been made on similar series of unit-length samples to establish population levels.

In a somewhat different approach, whole-tree populations were used to ascertain the degree of mortality which may be expected from spray applications. This method required the selection of small trees so that the complete population could be considered. Each tree was treated individually and a ground sheet spread beneath the canopy to catch fallen larvae. These larvae were collected at regular intervals, counted, and retained in cages to observe what recovery would occur. After larvae ceased to drop to the ground sheet, all those remaining on the tree were removed and the living and the dead recorded. Treatments and checks were replicated several times.

Advantages of this method were that speeds at which various toxicants produce noticeable effects on the larvae could be compared and the effects on the various larval instars present could be observed under field conditions.

The need for ground sheets limits the use of this method to populations on open-grown or widely-spaced trees. This method has been used to advantage in studies on the control of the fall cankerworm, yellow-headed spruce sawfly, and citheroniid caterpillars, Anisota spp.

With the spruce mite which is relatively localized on the host tree, and the pine needle scale which is a sedentary species, two methods have been used in the study of chemical control. Both methods are similar in idea but differ in their application to the problem. In the first method individual branches of spruce trees were treated, with several materials being used on one tree, and the entire series replicated on several trees. Contamination of adjacent branches was prevented by using a plastic funnel or shield to enclose the branch to be treated. This type of shield can be fitted or removed readily and is easily cleaned after each application. One untreated branch on each tree was designated as a check to give a uniform method of sampling for making mortality counts. Population and mortality counts were made on twigs clipped from each marked branch. These twigs were not necessarily of the same length, but measurements of the twig lengths were recorded.

This method was suited for preliminary studies and for the rapid elimination of materials which were ineffective against the spruce spider mite, and the pine needle scale. Since several treatments could be used on one tree it had the advantage of eliminating variation due to different hosts and also permitted better utilization of a limited number of trees. The chief disadvantage of this method was the difficulty of finding trees with uniform populations so that the replicates could be arranged with various exposures. With this method as many as five toxicants can usually be applied on one tree at a common level.

The second method followed in the study of chemical control of the spruce spider mite and pine needle scale is more applicable to field tests. In this method entire trees are sprayed, with the exception of one or more branches which are protected from contamination by plastic sleeves. These branches provide checks on normal development and natural mortality.. In direct sunlight it was necessary to open the outer end of the sleeve immediately after a spray had been applied, and to remove the sleeve as soon as all danger of contamination from dripping had ceased. The actual application procedure differed with the type of tree stand. Ornamental trees standing alone were treated as a unit and one or two branches were used as checks. Trees close together in a single row were usually treated in small groups with one check branch retained on each tree. In dense stands of two or more rows, blocks of trees were treated with two or three check branches set up for each block.

The methods employing a plastic funnel and plastic sleeves have distinct limitations. They can not be used with chemicals such as parathion which are strong fumigants, or which will penetrate the plastic material. It was found when a whole tree with the exception of a single covered branch was sprayed with parathion in pine needle scale control studies, that the mortality of the pine needle scale on the unsprayed covered branch was almost as great as on the sprayed branches. That this mortality was caused by the parathion was indicated by the abnormal formation of the scale covering which is a typical effect produced by treatment with parathion.

ALLETHRIN, PYRETHRIN AND SYNERGISTS

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In 1949 Schechter, Green and La Forge announced the successful synthesis of the allyl homolog of Cinerin I. Previously Dr. La Forge and his co-workers had shown that the natural active principles of pyrethrum flowers were actually four compounds which they isolated and identified as pyrethrin I, cinerin I, pyrethrin II and cinerin II.

This announcement of the synthesis of allethrin which is the compound closely analogous to cinerin I, caused a great amount of speculation as to whether or not it would take the place of natural pyrethrum in the insecticide field. This seemed to be especially pertinent since the press releases described the synthetic-like compound as six times more toxic to houseflies than the combined active principles of pyrethrum flowers.

It should be pointed out that the synthetic chemical is not identical in structure with natural cinerin I and that cinerin I itself is only one of the four insecticidally active constituents isolated from pyrethrum flowers.

Since the first production of allethrin there has been considerable interest in it. A great amount of testing work has been done with this material both in comparison with natural pyrethrins and in combination with synergists. The purpose of this paper is to briefly discuss some of the results of these tests in an effort to determine the advantages and disadvantages of these materials when used alone and in combination with the available synergists.

In a direct comparison of allethrin with pyrethrins against houseflies using the Peet-Grady method, Dove (1) found that at low concentrations allethrin is less effective, while at high concentrations it is more effective than pyrethrins. For example, allethrin is more effective above concentrations of 150 mg. per 100 ml. and less effective than pyrethrins at lower concentrations.

In tests against cockroaches, using the direct spray method, they found that allethrin is inferior to pyrethrins. At a concentration of 100 mg. per 100 ml. pyrethrins gave 98% knockdown in one hour and 93% kill in twenty four hours. Allethrin at the same concentration gave 48% knockdown and 64% kill. When the concentration of allethrin was doubled 84% knockdown and 64% kill was obtained.

Against stored product insects and truck crop insects, the relative effectiveness of the two materials varied greatly with the species used, but in most cases allethrin was less effective than pyrethrins.

In comparing allethrin and pyrethrins as sprays against three species of mosquitoes, Aedes aegypti, Anopheles quadrimaculatus and Culex pipiens, Fales (2) found that for Aedes aegypti females the LC 50 of allethrin was eight times that of pyrethrins. With Anopheles quadrimaculatus twice, and with Culex pipiens approximately 5½ times the amount of allethrin was required.

The development of pyrethrum synergists has been an extremely important advancement in the insecticide field. At present we have a number of synergists which are being used to increase the effectiveness of pyrethrins. These materials in combination with pyrethrins generally cause a fast knockdown, give a higher percentage of kill with considerably lower concentrations of pyrethrins, and they have a stabilizing action which makes it possible to obtain relatively long residuals that are effective in controlling insects.

Pyrethrum synergists are also being used with allethrin, however the degree of synergism among these varies considerably and is generally of a lower order of effectiveness.

In his work with pyrethrum synergists in fly sprays, Gearsdorff (4) found allethrin to be about 2½ times more toxic against houseflies than pyrethrins. The relative effectiveness of pyrethrins and allethrin with and without synergists was in the following ascending order;
(1) Pyrethrins (2) pyrethrins plus synergist 264
(3) allethrin (4) allethrin plus synergist 264
(5) pyrethrins plus N-propyl isome, allethrin plus N-propyl isome, allethrin plus piperonyl butoxide (6) pyrethrins plus piperonyl butoxide. The butoxide pyrethrins spray was about thirteen times as toxic as pyrethrins alone. With allethrin it was about 2 ½ times as toxic as that material without the synergist. The synergistic effect was about five times as great with pyrethrins as it was with allethrin.

Because of the greater toxicity of allethrin however, this disparity was decreased somewhat, and the mixed sprays containing the synthetic product were about half as toxic as those containing the natural product.

The synergistic effect of N-propyl isome was about three times as great with pyrethrins as with allethrin. The allethrin mixture was nearly as toxic as the allethrin with piperonyl butoxide, but was less than half as toxic as pyrethrins and piperonyl butoxide. Synergist 264 increased the effectiveness of the spray by two-thirds with pyrethrins and one-third with allethrin.

In tests conducted by Jones (5) it was reported that in all cases against houseflies knockdown values particularly at three and five minutes are somewhat lower for allethrin and piperonyl butoxide combinations than for equivalent concentrations of pyrethrins with this synergist. Against German cockroaches, tests showed that even three times the concentration of allethrin and piperonyl butoxide did not approach the effectiveness of the combination of pyrethrins and piperonyl butoxide. In laboratory tests against truck crop insects, a combination of allethrin and piperonyl cyclonene was generally less effective than that of pyrethrins with piperonyl cyclonene but the differences in effectiveness varied greatly with insect species. For example, against Mexican bean beetle adults and larvae, the allethrin cyclonene dust gave almost the same mortality as the pyrethrins cyclonene dust, while against squash bug adults and nymphs the allethrin combination was much less effective than the pyrethrins combination.

Another important factor in the consideration of pyrethrins and allethrin and their combination with synergists, is their relative stability and effectiveness as residual insecticides. Garnett (3) in his laboratory tests found that, when exposed to ultraviolet light, heat, and room conditions, allethrin was considerably more stable than pyrethrins. When freshly prepared aqueous emulsions were tried on mosquito larvae allethrin was about half as toxic as pyrethrins. When exposed to an approximate equivalent of one day of midday sun, allethrin was 1.2 times more toxic than pyrethrins. When subjected to heat (110° F. for twenty-four hours and 120° additional for 48 hours) allethrin was almost three times as toxic. Under exposure to room conditions for one week allethrin was more than 1.3 times as toxic.

In tests of residual application to plywood panels with houseflies as the test insect, 144 mg. per square foot of allethrin in acetone remained effective for at least three months. Pyrethrins caused considerable knockdown up to one month but kill was poor even at one week. At 144 mg. per square foot in the emulsion form allethrin was highly effective up to three months. At six months knockdown was still good but kill had declined to 70%. Pyrethrins gave good knockdown up to one month but kill was low.

When applied to glass in acetone, allethrin effectiveness lasted two months. Pyrethrins gave no appreciable knockdown or kill even at one week.

In emulsion form on glass at 144 mg. level allethrin was effective for three months. The glass seemed to favor the emulsion of pyrethrins since it was still giving 100% knockdown and 90% kill after one month. Combinations with synergists allow a reduction in the amount of active ingredients. Allethrin and pyrethrins at 72 mg. in combination with sulfoxide at 360 mg. as acetone solutions resulted in a definite boost in knockdown and kill, and an extension of time of effectiveness. This was especially true for the mixture with pyrethrins.

In other synergist tests, combinations were made with piperonyl butoxide at 288 mg. while the allethrin or pyrethrins were applied at 28 mg. per square foot. At this level allethrin effectiveness dropped off after one week, where as when the synergist was used mortality and knockdown was almost 100% at the second month test period. Although the mortality from residual applications of the pyrethrins mixture was not so high as that from allethrin, pyrethrins plus synergist, too, were effective up to two months.

From the information and data available at the present time it appears that allethrin is generally less toxic to most insects than pyrethrins. The fact that it is more stable than the natural product does give it some advantage as a residual insecticide.

Synergists increase the effectiveness of allethrin but to much less degree than with pyrethrins. The stability of allethrin plus synergists and pyrethrins plus synergists as residual sprays against houseflies is about the same.

No predictions as to the usefulness of allethrin as an insecticide are possible at this time. Relatively large amounts of it are now being used in fly sprays and possibly other uses will be developed. In any event it will be an important material to supplement the usually short supply of pyrethrum.

CONCENTRATION REQUIRED FOR 50 PERCENT MORTALITY OF HOUSEFLIES

			MG per 100 ml		Relative amounts required for 50% mortality
Synergist	Ratio	Material Pyrethrins	Allethrin	Synergist	
N-propyl Isome	1-5	32	--	160	Pyrethrin + N propyl isome 1.00
" "	1-5	--	63	315	Allethrin + N propyl isome 1.97
264	1-10	89	--	890	Pyrethrum + 264 1.00
264	1-10	--	92	920	Allethrin + 264 1.03
Sesame Oil	1-3.75	51	--	191	Pyrethrum + Sesame 1.00
" "	1-3.75	--	86	322.5	Allethrin + Sesame 1.69
Piperonyl Butoxide	1-8	17	--	136	Pyrethrum + Piperonyl Butoxide 1.00
Piperonyl Butoxide	1-8	--	46	368	Allethrin + Piperonyl Butoxide 2.70

RELATIVE EFFECTIVENESS OF INSECTICIDAL MATERIALS WITH AND WITHOUT SYNERGISTS AGAINST HOUSEFLIES

Material	Ratio of Toxicity to Pyrethrins based on actual insecticide.
Pyrethrins	1.00
Pyrethrins + synergist 264	2.11
Allethrin	2.69
Allethrin + synergist 264	3.89
Allethrin + N-propyl isome	6.91
Pyrethrins + N-propyl isome	7.27
Allethrin + Piperonyl Butoxide	7.81
Pyrethrins + Piperonyl Butoxide	16.3

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Stoddard, R.B., & W.E. Dove	Cinerin I Homolog tested Soap and Sanitary Chemicals 25 (10: 118-121 & 161. 1949
Fales, J.H., O.F. Bodenstein, & P.G. Piquett	Effectiveness of allethrin and pyrethrins as sprays against three species of mosquitoes. J. Econ. Ent. 45 (4): 743-44 1952.
Garnett, P., D.P. Connola & J.V. Lembach	Laboratory tests of allethrin for stability, residual action and toxicity. J. Econ. Ent. 44 (4): 552-57 1951.
Gearsdorff, W.A., R.H. Nelson, & N. Nitlin	The relative effect of several pyrethrum synergists in fly sprays containing allethrin. J. Econ. Ent. 44 (6): 921-27 1951
Jones, et al	Biological tests of allethrin with synergists. Soap and Sanitary Chemicals Special issue, Official Proceedings, C.S.M.A. Vol. XXIV, No. C.S.M.A. (1)

APPENDIX I

CONSTITUTION AND BY-LAWS OF THE ENTOMOLOGICAL SOCIETY OF MANITOBA

As revised and approved at the General Meeting
March 14, 1952

Article 1. Title

This Society shall be known as the Entomological Society of Manitoba in affiliation with the Entomological Society of Canada.

Article 2. Object

The object of the Society shall be to foster the advancement, exchange, and dissemination of entomological knowledge.

Article 3. Membership, Dues, and Expenditures.

a) Any person interested in entomology may become a member on application in writing to theSecretary of the Society.
b) A member may withdraw from the Society upon giving notice in writing to the Secretary.
c) An annual fee necessary for the operation of the Society shall be levied from each member as provided for in Section 1 of the By-laws.
d) The Executive shall have power to meet expenses required in the normal operation of Society business. Such expenditures shall be subject to subsequent ratification at the annual meeting by the majority of the members present.
e) A member who neglects to pay the annual fee for two consecutive years shall automatically cease to be a member.

Article 4. Meetings

Meetings shall be called each year by the President at times and places suitable to the majority of the members. The fall meeting shall be considered the annual meeting.

Article 5. Nature of Meetings

The meetings shall be informal insofar as possible.

Article 6. Officers

The officers of the Society shall consist of President, Vice-President, Secretary, Treasurer, Editor-Librarian, and immediate past President. These officers shall constitute the executive with full power to act on behalf of the Society within the bounds of the constitution and to appoint committees as necessary.

Article 7. Elections

Elections shall be held once a year at the annual meeting and officers so elected shall remain in office until the next annual meeting. The office of President shall not be held by the same member for more than two consecutive years.

Article 8. Alteration of the Constitution and By-laws

The constitution may be altered or amended at any official meeting of the Society with the approving vote of three-fourths of the members present and in good standing. Such alterations must be made by notice of motion which shall have been sent to the Secretary and a copy of such forwarded to all members at least two weeks before the general meeting. By-laws may be changed by a motion approved by the majority of the members present at any general meeting.

Article 9. Minutes

The preparation and custody of the minutes shall be entrusted to the Secretary who shall also hold all books and records.

By-Laws

1. a) The annual fee for full members shall be $1.00.
   b) A student membership fee shall be set at one-half the local regional fee.
   c) The fiscal year of the Society shall coincide with the calendar year; fees are payable in advance at the annual meeting.
2. The President of the Society shall be the representative on the Board of Directors of the Entomological Society of Canada. The President is at liberty to appoint a substitute to represent him at the Annual Meeting of the National Society in the event that he is not able to attend.
3. a) A financial statement is to be presented at the first general meeting following the end of the fiscal year.
   b) Two auditors shall be elected at each annual meeting to examine accounts of the current year.

APPENDIX II

Additions to the Approved List of Common Names.

Professor A.V. Mitchener, chairman of this society's Committee on Common Names, reports that the Committee on Common Names of the American Association of Economic Entomologists has acted on proposals which were submitted from the Entomological Society of Manitoba in 1951.

As reported in the minutes of the March general meeting names for eight species were forwarded. The following names have been approved in committee and appear in a list of nineteen adoptions published in the December, 1952 issue of the Journal of Economic Entomology, page 1114.

Coccinella _transversoguttata_ Fald.	transverse lady beetle
Corythucha _arcuata_ (Say)	oak lace bug
Malacosoma _lutescens_ (N. & D.)	prairie tent caterpillar
Perillus _bioculatus_ (F.)	two-spotted stink bug
Psylla _negundinis_ Mally	boxelder psyllid

APPENDIX III

Additions to the Library of the Entomological Society of Manitoba.

During 1952 and early 1953 a number of publications were received by the society in exchange for the Proceedings. These are listed below. This list together with that published in the appendix to volume seven include all the library holdings at the time of publication of this volume.

University of Washington Publications in Biology
Received in exchange from the University of Washington Library, Seattle, Wash.:
Vol. 1,No1. The Spiders of Washington - L.G. Worley (1939).

Vol. 1,No2. Coleoptera of Washington
Chrysomelidae
S. Beller and M.H. Hatch (1932)

Vol. 1, No. 3. Coleoptera of Washington;
Silphidae
M.H. Hatch and W. Rueter, Jr. (1934)

Vol. No. 4. A Bibliographical Catalogue of the
Injurious Arachnids and Insects of
Washington - M.H. Hatch (1938).

Vol. 1, No. 5. Coleoptera of Washington;
Carabidae; Cicindelinae,- M.H. Hatch
(1938)

Vol. 4, No. 2. Pleaoptera of Washington
Gertrude N. Hoppe (1938).

Vol. 9, No. 1. The Araneida of Washington,
Agelenidae and Hahniidae
Harriet Exline (1938)

Vol. 9, No. 2. The Butterflies of Washington,
B.V. Leighton (1946)

Vol.10, No. 1, 2 &3 The Coleoptera of Washington, Carabidae;
Agonini - B. Gray and M.H. Hatch
Sphaeritidae and Histeridae
R.M. McGrath and M.H. Hatch
Buprestidae - F.M. Bur and M.H.Hatch (1941)

Vol. 10, No. 4. An Annotated List of the Scolytoidea of Washington
G.K. Patterson and M.H. Hatch (1945).

Vol. 12, No. 2. A List of the Fleas of Washington
Ruth D. Suihla (1941)

A series of publications and reprints received in exchange from Dr. Jean Leclercq, University of Liege, Belgium.

Sur trois espèces de Lestica (Solenius) (Hym. Sphecidae, Crabroninae) - J. Leclercq.
(from Bull. et Ann. Soc. Entom. de Belgigue, 87, VII-VIII - 1951).

Notes systematiques sur les Anacrabro (Packard,1866) (Hym. Sphecidae, Crabroninae) - J. Leclercq.
(from Bull. de la Société entomologique de France, Apl. 1951. pp. 61-64).

Sur quelques Neodasyproctus (Arnold, 1926) nouveaux ou peu connus (Hym. Sphecidae, Crabroninae)
(from Rev. Zool. Bot. Afr. 44 (4): 333-338. 1951).

Vitamins and proteins in the nutrition of Tenebrio molitor larvae - J. Leclercq.
(from. Proc. Physiol. Soc., J. Physiol. 114 - Apl. 1951).

Application des series log-arithmiques de Fisher - Williams a la classification des Hymenopteres crabroniens. M. Dehalu and J. Leclercq (from, Annales de la Société Royale Zoologique de Belgique. Vol. 82 - 1951).

Introduction a l'étude dos Tabanids et Revision des Espèces de Belgique, Bruxelles, Institut Royal des Sciences Naturelles de Belgique, Memoire No. 123 - 1952.

Received in exchange from Prof. A. Melis, Editor Redia, Florence, Italy -
Redia - volumes 31 to 37 (1945-52) inclusive.

Received in exchange from the Entomological Society of British Columbia: -
Proceedings of the Entomological Society of British Columbia. Volumes: 39 (1942); 40 (1943); 41 (1944); 42 (1945); 44 (1948); 45 (1949); 46 (1950); 47 (1951); 48 (1952; 49 (1953).