PROCEEDINGS OF THE

ENTOMOLOGICAL SOCIETY OF MANITOBA

VOLUME 20 1964

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ENTOMOLOGICAL SOCIETY OF MANITOBA

A society to foster the advancement, exchange and dissemination of entomological knowledge

CONTENTS

INTRODUCTION

A major undertaking of the Society in 1964 was hosting the 37th International Great Plains Conference of Entomologists held at Clear Lake, August 24th, 25th and 26th. The keynote speaker for the Conference was Dr. Bryan P. Beirne, Director, Research Institute, Canada Department of Agriculture, Belleville, Ontario. The International Great Plains Conference began in Manitoba in 1927 and it is noteworthy that at the 1964 Manitoba Conference, after a few years of doubtful existence, delegates endorsed unanimously that the organization should continue. A highlight of the three-day Conference was the banquet, with guest speaker R. H. Painter, Liaison Officer, Research Station, Canada Department of Agriculture, Lethbridge, reminiscing about his entomological experiences in Western Canada. The Province of Manitoba, in recognition of the contribution made to agriculture through entomology by Mr. Painter, presented him with a "Red River Cart".

Meetings for members of the Society were held in the spring and fall. At the one-day spring meeting, apiculture was the theme and included conducted tours of the apiculture research facilities in the Department of Entomology at the University of Manitoba and the honey processing and packing plant of the Manitoba Co-operative Honey Producers Ltd. An evening banquet and program of a short film on beekeeping was followed with dancing.

At the fall meeting an excellent selection of scientific papers was presented by members and these along with reports of the business session of the Society are included in the Proceedings.

I welcome the opportunity to record here the pleasure I had during the past year being President of the Entomology Society of Manitoba. Also to say many thanks to the members of the executive and committees for their hard work and to all members of the Society for their support.

D. R. Robertson,
President.

Proc. Entomol. Soc. Manitoba Vol. 20 (1964)

MERITS OF INTERNATIONAL MEETINGS - SPECIALIZED OR GENERAL

A. G. Robinson
Department of Entomology
The University of Manitoba

Abstract

Meetings such as the International Seminar on the Current Status of Research on Aphids are compared with meetings like the XIIth International Congress of Entomology, and it is concluded that specialized meetings are more valuable to research workers than are general meetings.

There are two kinds of meetings which entomologists may have the opportunity to attend, and this paper is an attempt to discuss their merits. This year I had the privilege of attending two international meetings. From March 23 to 27, 1964, I was at the University of California, Berkeley, at what was termed a "Seminar on the Current Status of Research on Aphids". From July 8 to 16, I was present at meetings of the XIIth International Congress of Entomology, in London, England. At Berkeley there were about 75 persons from 11 countries, all interested in some aspect of research on aphids. In London there were approximately 1,700 entomologists from about 65 countries with research interests in all fields of entomology.

At Berkeley the seminar discussions were divided into four subjects, of one day's duration each, in the following order: Systematics; Polymorphism and Behaviour; Physiology, Nutrition, and Morphology; and Vector-virus Relationships. Each section had both invited and submitted papers. At the end of each day a Chairman gave a summary and there was an opportunity for informal discussions. Questions submitted during the day were answered by a panel of the day's speakers. No sessions were operated concurrently with others, and attendance during the four days was remarkably high.

In London the program was divided into 13 concurrent sections of interest. At any given moment a member was faced with a choice of one of 13 papers, if he had not departed early in the morning on one of the many daily excursions. Only twice did all members come together, for the opening address and inaugural plenary meeting, and again for the final plenary session. Each section had a chairman, and there was a brief discussion period at the end of each paper. Some few papers were invited, but most were submitted. Some papers were well attended, so that there was not sufficient room for all who wished to hear. Others were very poorly attended. I was present for one paper where there were only six people, including the speaker and chairman.

At Berkeley all papers were presented in English. In London many were presented in French or German, and were a total loss as far as I was concerned. I must digress to say here how much I envied many of the European entomologists, including several from England, who were reasonably fluent in all three languages.

The proceedings of the Seminar on aphids were received in August, 1964 by those who attended. Unfortunately, in my opinion, the papers from the Seminar were published in very brief abstract form. I should very much like to have read the complete text of the many extremely valuable papers presented at Berkeley. The proceedings of the XIIth International Congress will also be very much abbreviated when it is published. Invited speakers will be allowed a maximum length of 1, 000 words for their abstracts, all other speakers a maximum of 500 words.

At Berkeley several plant pathologists were present because of their interests in aphids as vectors of plant diseases, thus broadening the experience of the participants. I suspect that they benefitted from the other sections of the 4-day meetings, although the section on systematics may not have stimulated them very much. Even in this section, there were many references to the problems of species complexes, subspecies, races, and strains, some varying in their ability to transmit viruses, and the plant pathologists would thus have a better appreciation of the importance of correct species identification, and of some of the problems of the taxonomists in giving a name to some of the species.

The question arises as to which is the more valuable kind of meeting, one on a very specialized and restricted subject, such as the Seminar on the current status of research on aphids; or the International Congress of Entomology. In this latter category one could place the annual meetings of the Entomological Society of Canada, the North-Central States Branch of the Entomological Society of America, or the parent body the Entomological Society of America. Other examples of the specialized type are national or international meetings on honey bees, locusts and mosquitoes and those which discuss topics such as biological control of insects, control of insects in stored products, social insects, and nutrition of insects.

At this point I should attempt to explain what I mean by the terms "specialized" or "restricted" meetings. I would include as participant at such meetings any person who is using as a test animal any species of perhaps a family of insects, such as the Aphididae, Locustidae or Culicidae. Apiculturists could possibly widen their interests to include other species of bees besides the honey bee.

Both the meetings I attended were extremely well organized and efficiently conducted, with strict adherence to time schedules. A considerable amount of time and effort must have been put into the planning of both meetings, involving for the Congress a large number of people for many months, and for the Seminar many hours of planning by a few people.

In his opening address to the XIIth International Congress, Professor O. W. Richards, the President, made a very strong plea for continued support of meetings such as the Congress, which bring specialists from many interests together. He contended that we should broaden our interests, and learn as much as possible of the research going on in fields of entomology other than our own restricted interests. Yet, I am sure that at the London meeting most members did as I did. Each evening I marked various papers on my program that I intended to try and hear the following day, with a distinct bias towards my own interests in aphids, or occasionally to listen to some "name" entomologist, perhaps only often from a desire to see what he looked like.

What were the values and merits of the Seminar on aphids? Perhaps the most important to me was the opportunity to meet and talk informally with many

of the leading aphidologists of the world, people known previously only through correspondence or through reading their publications. This may be more important for the taxonomist, who depends a very great deal on the goodwill of other taxonomists for the loan of specimens, or for identification of submitted specimens. These personal contacts between taxonomists are invaluable. Secondly, or perhaps it should be firstly, there was the mental stimulation of listening to the ideas and problems of other workers in a field in which I have some personal knowledge. I believe that I even benefitted by listening to papers on neurosecretory cells in aphids, a subject about which I know nothing. Thirdly, the relatively small numbers at Berkeley made it possible to have all members in one room, and there was an opportunity to meet everyone present. In London, because of so many concurrent sessions, it seemed that I spent most of my time rushing from one room to another, or from one building to another. Also because of the very large numbers present it was quite difficult to search out and introduce yourself to someone whom you wished to meet and talk with. Fourthly, I had the impression at the Berkeley meeting that the participants were more inclined to divulge their "secrets", perhaps because of the informality of the meeting, and the feeling that they were among friends. Failures in techniques were discussed as freely as successes. There was more opportunity to discuss "materials and methods". I recall one interesting informal discussion on the most suitable pH of artificial media for feeding of aphids.

One problem that I have not yet mentioned is that of finances. The Seminar at Berkeley was supported financially by the combined assistance of the University of California and the National Science Foundation, Division of Biological and Medical Sciences. Some of the invited speakers were supported by grants from these two sources, for travel and subsistence. Other participants either received financial assistance to attend, from their own grants, or paid their own way, either partially or entirely.

At Berkeley all members stayed in student dormitories and ate meals in the University Cafeteria. This was a very real saving, not possible with the large numbers attending an International Congress. However, both kinds of meetings cost money to operate. It is my opinion that Governments, who directly or indirectly finance most entomological meetings, will in the future have to decide which kind of meeting deserves their financial support, using the criterion of which is most likely to benefit research workers in solving many of the complex problems in entomology.

It is my own personal opinion that national or international meetings on a specialized field, such as the Seminar on the current status of research on aphids, are more valuable to one who is interested in that subject, than a meeting which attempts to cover all fields of entomology. These meetings should be held every four or five years, so that some progress in research can be made in the interim.

Proc. Entomol. Soc. Manitoba Vol. 20 (1964)

PRELIMINARY STUDIES OF THE LIFE HISTORY OF THE EUROPEAN CORN BORER IN MANITOBA

Wm. Hanec and A. J. Kolach[1]
Department of Entomology
The University of Manitoba

Abstract

The European corn borer, Ostrinia nubilalis (Hübner) (Lepidoptera: Pyraustidae) was first reported in Manitoba in 1948. It has since spread throughout most of the agricultural area of the province with the heaviest and most consistent infestations occurring in the southern regions. The borer overwinters as a mature larva in corn stalks. The peak of pupation occurs during the two middle weeks of July but may extend into August. Adult emergence coincides with the pupation period and also extends into August. The extended adult emergence period results in the presence in the field of larvae in various instars during the summer and fall. First instar larvae commence to feed during the second week of July and begin to mature during the third week of August. From 5-10% of the mature larvae pupate to begin an unsuccessful second generation. The remainder enter diapause and overwinter in this state. In the Brandon-Morden-Winnipeg area at least 80% of the larvae survived the winters from 1959 to 1963. During the winter of 1963-64 only 24% of the larvae overwintered successfully in the Winnipeg area. This drop in survival may be attributed to the extreme fluctuations in temperature in this area during the winter of 1963-64.

Introduction

The European corn borer was first reported in Manitoba from the Winnipeg area in 1948. Since then it has been reported from the whole agricultural area of the province, with the heaviest and most consistent infestations occurring in the southern regions where both canning and feed corn are grown. Infestation reports are available mainly from the Altona-Morden-Brandon areas and for some years only from the Experimental Farms at Morden and Brandon. Records of corn borer infestations from 1948 to 1963 were obtained from reports to the Department of Entomology, the University of Manitoba, and from the Canadian Insect Pest Review. The heaviest infestations occurred in 1955 and 1963. In 1955 market gardeners in the Winnipeg area reported up to 40% cob infestation, while in the Brandon-Morden area cob infestations were up to 50% on sweet corn. In 1963 approximately 10% of the sweet corn in the Morden and Winnipeg area was infested. Infestations during the other years were either non-existent or below 5%. It is difficult to evaluate these reports because no systematic surveys were undertaken and only a few fields of commercial corn were examined. Despite their inadequacy, these reports show that the borer populations in Manitoba vary considerably from year to year.

[1] Present address: Extension Service, Manitoba Department of Agriculture.

The establishment of the borer in Manitoba is now certain. Its importance as a corn pest will increase as more corn is grown for human and livestock consumption. For the past several years the acreage of corn grown in Manitoba has increased, e.g., from 28,000 acres in 1959 to 45,000 acres in 1963. This increase in acreage has been primarily due to the increased use of corn both as silage and grain for livestock feed. The feed-corn-growing area has also been extended north into the province from the original corn-growing areas of the south and south-west. Although the borer has not been a threat as yet to feed corn it has shown the ability to adapt itself to the climatic conditions of virtually all the agricultural areas of Manitoba. This adaptation will enable the borer to survive in at least some areas during years when other areas of the province may experience climatic conditions, particularly during the oviposition period, sufficient to drastically reduce populations.

Although infestations of borers were light during the majority of years from 1948 to 1963, these caused losses to the corn canning industry. For the market gardeners even one larva in a cob of corn will ruin the product for the fresh corn market. Effective chemical control requires knowledge of the life history of the pest and such information about the born borer in Manitoba is meager and unrealiable.

The purpose of this paper is to summarize and evaluate the available data on the life history of the borer in Manitoba and to present new information obtained by the authors.

Life History

Mitchener (1956) stated that the European corn borer overwinters in Manitoba as mature larvae in corn stalks or corn stubble. The moths appear early in July and oviposition and egg hatching occur during the same month. The larvae mature in a month or less and the pupal stage lasts from one to two weeks. A second generation may occur. Mitchener also stated that "the two brooded strain" occurs in Manitoba and that "a northward movement of adults may be partially responsible for increased injury". These statements were not supported by data and remain open to question.

Methods and Materials

Investigation conducted in the Morden and Winnipeg areas during 1963-64 were divided into four phases: winter survival of mature larvae; pupation during the following summer; adult emergence; oviposition and development of the larvae in the field.

Larval survival during the winter of 1963-64 was determined at Winnipeg. Infested corn stalks were collected at Morden, bundled and stooked in an open field near the University. From October 1963 to May 1964 about 100 larvae were cut out of the corn stalks periodically, removed to 70 F and the number of healthy larvae determined. As the winter progressed many living larvae were incapable of locomotion and eventually died even when placed under warm conditions. The larvae were termed "paralyzed" and considered as dead in the calculation of survival percentages.

Pupation records were obtained by leaving 80 healthy overwintered larvae in pieces of corn stalks and exposing them to the outdoor elements. These larvae were checked periodically from May until pupation ceased in August. The pupae resulting from the pupation study were left outside and adult emergence noted.

In the Morden area, daily counts were made of adults caught in four modified New Jersey mosquito light traps located adjacent to fields of sweet corn. The oviposition period could not be determined because no egg masses were found on plants.

Larval development was determined by dissecting infested corn plants, removing the larvae and measuring the head capsule width to determine the instar. This was carried out in the Morden area because the borer infestation in the Winnipeg area was extremely light during 1964.

Larval survival during the winter of 1963-64 was over 90% until February 1964, but as the winter progressed the mortality increased until only 24% survived by May (Table I). The low larval survival after March is not consistent with survival records kept from 1959 to 1963 when at least 80% of the larvae overwintered successfully to pupate the following summer. Also, approximately 95% of the larvae survived the winter at Morden during 1963-64.

The only explanation of the low survival may be the cumulative effect of weather conditions on the larvae early in 1964. Several times during January, February and March temperatures rose to record highs and then dropped suddenly below freezing, thus causing thawing and freezing of the larvae with resulting increases in the amount of paralysis and direct mortality. Studies are underway now both under laboratory and field conditions to elucidate this problem.

The condition described as "paralyzed" could be produced in the laboratory by alternate freezing and thawing of the larvae. This procedure also causes higher direct mortality among larvae than constant low temperatures. The more cold-hardy the larvae become the more freezing-thawing cycles that area required to cause paralysis. The initial symptoms were paralysis of the abdominal region. The paralysis then spread to the thoracic and head region and just before the larvae died it could only move its mouthparts. The condition is irreversible and even though the stricken larvae may live for several weeks they eventually die. This condition is probably caused by damage to the nervous or muscular system. Although alternate freezing and thawing cause paralysis and death, borer larvae can survive several months in the frozen state if they are adequately cold-hardened and kept frozen continuously. Many frozen larvae were found in corn stalks during the winter, these thawed and pupated normally under warm conditions.

The period of pupation of borer larvae in 1964 extended from the first week of July to early August (Table 2). Of the 80 larvae, six died during the pupation period and one formed an abnormal pupa on 28 August. The pupation period of the borer is not confined to a few days but extends for about six weeks during July and part of August. Approximately 75% of the pupation occurred during the middle two weeks of July but different climatic conditions during the pre-pupation period in spring might shift the dates of pupation.

The adult emergence pattern was similar to the pupation pattern. Forty pupae were set up outside at Winnipeg and 35 adults emerged. Emergence began on July 9 and continued until August 23 without a definite peak. Another adult emergence study was carried on in the Morden area where four light traps were situated adjacent to corn fields to catch adults (Table 3). The flight activity of female adults was determined by this method. It is assumed that maximum flight activity coincides with peaks of emergence of adults. This method is not as accurate as observing caged material because only a small percentage of the flying moths are captured and if a relatively small number were active it is conceivable that the light traps would not capture any at all.

The maximum flight activity extended from July 14 to July 26 in the Morden area in 1964 with over 90% of the captures in the 10-day period from July 14 to 23. The peak period for oviposition, presumably coincides with the peak in flight activity. The period of adult emergence with caged pupae in the Winnipeg area exceeded the flight activity period of the adults in the Winkler-Morden area by approximately one month. This does not necessarily mean that the emergence pattern of adults was dissimilar in the two areas. There was probably a small number of adults emerging into August in the Morden area but the numbers were too small for samples to be captured in the light traps. Evidence for this hypothesis is that larvae in the second and third instars were present in the field as late as September. The eggs must have been laid by late-emerging females.

Feeding on corn leaves by first instar larvae was first noticed on July 17 near Morden. After this date, infested fields were sampled periodically near Morden and the numbers and instars of the larvae recorded (Table 4). All the fifth instar larvae collected on 12 August and 42 of those collected on 20 August, died because they had not completed feeding. In the Morden area the first instar larvae appeared during the second week of July, reached the fifth instar by the second week of August and began to mature by the third week, although a few larvae were found in the early instars up to November. These probably come from late-emerging females and from those larvae that did not diapause but pupated to produce a partial unsuccessful second generation. Previous field observations indicated that about 5-10% of the first generation larvae pupate to start a second generation. This is always fatal because at this time of the season the plant is no longer a suitable host and the colder weather causes slow growth, retardation of feeding and eventual death of the immature second generation larvae. If there is a bivoltine strain of borer in Manitoba its survival is low.

The European corn borer is a relatively new insect pest in Manitoba. Its significance will no doubt increase as it becomes more widespread and more corn is grown. Apart from its economic importance it should be an interesting subject for study by ecologists and physiologists because of its potential for establishment in the northern regions of the continent, cold-hardiness, the genetics of its uni - and bivoltine strains and many other problems posed by an insect recently established in a new area. Unfortunately this species has so far been virtually ignored in the Prairie Provinces.

References

Mitchener, A. V. 1956. Field crop insects and their control in the Prairie Provinces. Line Elevators Farm Service, Winnipeg.

TABLE 1. Survival of European corn borer larvae overwintered at Winnipeg from 8 October 1963 to 13 May 1964.

Date	Number	Number Dead	Number Paralyzed	Number Healthy	Survival %
Oct. 8	106	4	-	102	98
Nov. 11	94	2	-	92	98
Dec. 12	103	7	-	96	93
Jan. 8	88	4	-	84	95
Feb. 17	100	7	2	91	91
Mar. 19	100	9	4	87	87
Apr. 22	89	23	7	59	66
May 4	129	60	17	52	40
May 13	107	76	5	26	24

TABLE 2. Pupation records of 80 European corn borer larvae during 1964 at Winnipeg

Date	July					August		Total
	2	6	9	13	20	3	13	
No. of Pupae	7	12	13	17	13	8	3	73
% cumulative	10	26	44	67	85	96	100	

TABLE 3. Frequency distribution of 112 adult European corn borer females captured in light traps near Morden in 1964

Date	JULY												
	14	15	16	17	18	19	20	21	22	23	24	25	26
Number	8	22	7	8	1	9	19	13	4	13	2	2	4
% cumulative	7	27	33	40	41	49	66	78	81	93	95	96	100

TABLE 4. Development of European corn borer larvae under field conditions in the Morden area during 1964.

Date	Total	Instar: No. of larvae per instar 1	2	3	4	5	Pupal Cases
Aug. 2	117	4	38	74	1		-
Aug. 12	110	2	13	23	51	11	-
Aug. 20	149	-	5	8	16	114	6
Sept. 4	113	-	2	3	-	104	4
Oct. 13	102	-	-	1	3	92	6
Nov. 4	127	-	-	4	-	116	7

Proc. Entomol. Soc. Manitoba Vol. 20 (1964)

STORED-PRODUCTS INSECT SURVEYS IN CANADA [1]

E. A. R. Liscombe
Research Station, Canada Department of Agriculture

Abstract

Canada enjoys a reputation for producing and exporting the cleanest grain and cereal products in the world. Importing countries are becoming more cognizant of the presence of contaminants in the foods they buy. As technical knowledge becomes more widely known, importers are made aware of the fact that infestation is not inevitable, and that control or preventive measures are most properly applied at the point of origin.

This paper outlines those pests found in Canada and indicates the role of surveys in the detection and distribution of insects and mites. The work of governmental agencies involved in the protection of stored grain and cereal products from attack by insects and mites is described.

Introduction

Insects annually destroy sufficient food to feed 150 million people (Freeman, 1958). Losses are greatest in warmer parts of the world where insect pests thrive throughout the year; damage being magnified by lack of suitable storage and an absence of personnel trained in pest control work. In North America, excellent storage facilities, highly trained personnel, and, in the northern part of the continent, the cold winter weather, all help to reduce losses from insects and mites.

Economic losses from insects and mites attacking grain and cereal products occur at all stages between the producer and consumer: on farms; in country and terminal elevators; in railroad cars; and in grain processing plants. Insects may be in export grain or in finished flour and feed going to the wholesaler, retailer, and consumer.

The growing of grain is one of the mainstays of the economy in Canada. In spite of tremendous expansion in industrial development, the export of grain and cereal products continues to be a major factor in Canadian trade. In the 1962-63 crop year, Canada exported almost 304 million bushels of grain and 19 million pounds of flour (Anon., 1962-63). Canadian grain and flour have a reputation for quality throughout the world, resulting in a distinct market advantage in international trade. To maintain this advantage, Canadian products must be of highest quality and free of insect and mite infestations.

Throughout the world, several hundred species of insects and mites are associated with stored grain or cereal products. Fortunately, many are attracted only to decaying vegetable matter, others are predators that attack grain pests, leaving about 50 species as pests.

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[1] Contribution Number 185, Canada Department of Agriculture, Research Station, Box 6200, Winnipeg 1, Manitoba.

Many of the insects presently associated with stored grain were taken along when grain was first introduced to new areas. Fortunately, conditions throughout the world are not equally favorable for the development of all pests. Insects of major importance in some regions are barley able to exist in others. Those of tropical or subtropical origin thrive in warm, humid climates, but are unable to do well, or cannot survive, in cold, dry areas.

Pests of Stored Grain and Cereal Products

Insects and mites attacking stored products are generally divided into four groups based on their feeding habits.

Primary Feeders

Insects feeding on the sound kernel can be very destructive and are called primary feeders. They also prepare the way for pests that attack damaged kernels but cannot penetrate sound grain. Among the primary feeders are the rice weevil, Sitophilus oryza (Linnaeus), granary weevil, Sitophilus granarius (Linnaeus), lesser grain borer, Rhizopertha dominica Fabricius and Angoumois grain moth, Sitotroga cerealella (Olivier). These pests spend most of their life cycle within the grain kernel. The granary and rice weevils are among the most destructive pests of sound grain. They are not known to survive the winter in Central Canada, but can do so in British Columbia and in Eastern Canada. The lesser grain borer and Angoumois grain moth do not occur in stored grain in Canada.

Germ Feeders

Species which feed primarily on the germ of the grain kernel include the Indian meal moth, Plodia interpunctella (Hubner), cadelle, Tenebroides mauritanicus (Linnaeus), rusty grain beetle, Cryptolestes ferrugineus (Stephens), and the flat grain beetle, Cryptolestes sp. The seed coat must be broken for these insects to gain entrance to the interior of the kernel. Of this group, the rusty grain beetle is the most serious pest of stored grain in the Prairie Provinces. Heavy infestations cause grain to heat and spoil.

Ground Cereal Feeders

Most stored-products pests found in Canada are ground cereal feeders, infesting many products. Among this group are the saw-toothed grain beetle, Oryzaephilus surinamensis (Linnaeus), Mediterranean flour moth, Anagasta kuhniella (Zeller), flour beetles, Tribolium spp., spider beetles, Ptinus spp., Dermestids and mites. Mites are minute and not readily seen with the unaided eye. Several species infest stored grain. Some feed only on dockage while the common grain mite, Acarus siro (Linnaeus), feeds primarily on the germ of the kernel. Grain mites can withstand low winter temperatures and are therefore well adapted to survive in grain stored in the Prairie Provinces. Tough and damp patches are most suitable breeding places for mites.

Insects Associated with Mouldy Grain

Among the insects feeding on out-of-condition material are the foreign grain beetle, Ahasverus advena Waltl, meal snout moth, Pyralis farinalis (Linnaeus), yellow mealworm, Tenebrio molitor (Linnaeus), and fungus beetles. These pests are found in Canada, their presence in stored grain indicates that the grain is not in good storage condition.

Survey Methods

When planning a survey, objectives must be established and techniques best suited to the problem must be determined. Stored-products insect surveys are primarily designed to tell us the distribution and abundance of insects presently found in Canada, and to detect new pests entering Canada on imported goods. Repeated surveys will indicate whether a particular pest is increasing or decreasing in numbers, whether its distribution pattern is changing, and allows an assessment of control measures in current use.

There are two methods of sampling stored-products for insects and mites. Firstly, information may be obtained from samples of the commodity in the field; secondly, information may be obtained from samples taken by the importing country or domestic consumer. In Canada the first method is used to guarantee the customer a product which is of the highest quality and free of contamination.

The large number of locations involved complicates such surveys. For the 1963-64 crop year there were 5,181 licensed country elevators in Canada with a storage capacity of almost 369 million bushels. There were over 100 elevators of other classes bringing the overall storage capacity up to roughly 660 million bushels (Anon., 1949). In the milling industry, 69 flour mills produced almost 18 million pounds of flour daily, and there were roughly 1,500 feed mills or processed feed outlets (Anon., 1956).

Residual insect infestations in stored-products are usually low, making it unnecessary to keep in constant contact with the entire industry. Outbreaks do occur from time to time, as relatively few insects or mites can increase rapidly and cause serious trouble if allowed to go unchecked.

Insect and Mite Detection in Canada

In Canada the detection and prevention of infestation in stored grain and cereal products and conveyances used to transport them are handled by the Board of Grain Commissioners for Canada, the Plant Protection Division and the Research Branch, Canada Department of Agriculture, and the Food and Drug Directorate, Department of National Health and Welfare.

Board of Grain Commissioners - Canada Department of Agriculture

The Board is charged with the responsibility of supervising the inspection and grading of grain, registration of documents of ownership, compiling of statistical information, checking of milling and baking qualities of grain, supervision of all elevators, and the actual operation of interior and terminal elevators owned by the Government of Canada.

In 1941, realizing that a serious storage problem with grain was imminent, the Board of Grain Commissioners added an entomologist to their staff. This

officer is responsible for infestation control in all grain storages under the jurisdiction of the Board. He is assisted in surveys and inspections of terminal elevators by Plant Protection officers and by grain inspectors of the Board of Grain Commissioners who grade shipments of grain at the terminals. The presence of a single live grain infesting insect in an unload sample necessitates a mandatory fumigation of the parcel of grain the sample represents. In this way, infestations are controlled and the number and location of infested country elevators recorded.

Plant Protection Division - Canada Department of Agriculture

Plant Protection inspectors examine incoming agricultural commodities for the presence of insects and disease and certify that grain and cereal products imported to Canada are free of contamination (Anon., 1959). The introduction of new pests has been prevented, and the spread of pests currently established in various regions has been limited by the inspection of incoming commodities.

Many importing countries now demand that a phytosanitary certificate accompany flour shipments they buy, verifying that the flour was milled in a plant substantially free of insect infestation. Inspectors therefore make regular surveys of flour mills supplying the export market.

Insects and mites attacking foodstuffs in storage are also present in ships carrying these commodities throughout the world. Ships have been infested since the earliest days of maritime commerce, and in 1943, Dr. Cotton recorded that from a single shipment of 145 tons of American corn sent to England in 1868, 1 3/4 tons of weevils were screened out (Cotton and Gray, 1948).

The possibility of grain and cereal products from Canada becoming infested in transit was recognized in 1940, and a program for the inspection of empty ships' holds was instituted. This program is continually being strengthened and improved, but the use of old vessels makes some of the inspections very difficult. From 1953 to 1959, over 5,000 cargoes of grain and cereal products from Canada were examined upon arrival in Great Britain by the Ministry of Agriculture, Fisheries and Food (Hurlock, 1963). Only a few cargoes were found infested, with a general decline in infestation during the period. The author stated, "Many of the insects recorded were acquired from the structure of the ships and that the numerous shipments which arrived free of infestation was a tribute to the efficiency of the control that is exercised in Canada over grain and cereal products intended for export and the ships which carry them."

Food and Drug Directorate - Department of National Health and Welfare

This department is responsible to the Canadian people for, among other things, the cleanliness of foods offered for consumption in Canada. Manufacturing plants handling foods grown or processed in Canada and imported agricultural commodities are inspected, monthly reports are made, and data on the presence and distribution of stored-products insects are added to information obtained by other departments.

Research Branch - Canada Department of Agriculture

The Research Station in Winnipeg devises ways and means of protecting cereal crops from insect and mite attack. A sound research program for stored-products pests must be based on the knowledge of which insects are present in Canada, their distribution pattern, and what control, if any, is being used.

Development of Insect and Mite Surveys

Surveys of Flour Mills and Feed Mills

In 1957, reports of an unknown Dermestid in flour mills in Alberta were received in Winnipeg. An investigation showed the insect was Trogoderma parabile Beal, a close relative of the Khapra beetle, T. granarium Everts which is a quarantine insect in the United States and which does not occur in Canada. As nothing was known about the biology, control, or potential danger of the insect found in Alberta, a comprehensive survey of flour and feed mills in Western Canada was necessary. This marked the beginning of organized mill surveys. The work was conducted during July and August of 1957 and repeated during the same months in 1958.

When it was decided that a large scale survey should be undertaken, the first question that arose was where and how should samples be taken. The flow of cereal stock from the head to the tail end of the mill is such that insects present in it may be carried throughout the mill. The milling process therefore, must be understood before sampling, or insect infestations could be overlooked and incorrect conclusions drawn. Samples taken from accumulations of cereal stocks in milling machinery, on structural surfaces and the outer surfaces of milling equipment were examined.

In 1962 and 1964, flour and feed mill surveys were extended to Eastern Canada. The same methods of sampling were used.

Survey of Farm Granaries

In 1959 a survey was made to determine the level of insect and mite infestations in empty farm granaries in the Prairie Provinces. Samples were taken from cracks in walls and floors and on bottom and top plates within the granaries, as well as from grain spills outside the buildings.

Survey of Country Elevators

Prevalence of insect and mite infestations in country elevators was difficult to assess due to a lack of sufficient personnel to conduct field surveys.

In the spring of 1964 a survey was made of grain stored in country elevators in Southern Manitoba. In elevator bins it was practical to obtain samples only from the hoppers of the bins, but in annexes the entire bulk could be probed. Grain-infesting insects and mites were found in many country elevators. It was then necessary to know whether these insects and mites were being shipped to the terminal elevators, and if so, were they being intercepted during the inspection of the car lots before unloading.

A cooperative study by the Board of Grain Commissioners and the Research Branch indicated that visual inspection of samples was not always sufficient. Infested grain which had been cleaned at the country elevator before shipping could have all the free-living beetles removed, and be judged free of infestation by visual inspection. However, by placing samples of such grain in Berlese funnels, it was possible to drive the immature stage of the insect or mite from its hiding place behind the germ of the kernel.

Survey Results

Several species of insects are common in flour mills, the confused flour beetle, Tribolium confusum Duval and the flat grain beetle, Cryptolestes turcicus Grouv. being serious pests. In feed mills the list of species is much larger and insects are generally more numerous because less time is spent on housekeeping. This is important in warehouses and boxcars as cross infestation can occur between piles of flour and feed.

Mites were more numerous than insects at sampling sites in empty farm granaries. The rusty grain beetle occurred in 36%, while the long hairy mite, Glycyphagus destructor Schr. and the grain mite were found in 83 and 42% of the granaries. Most granaries sampled were infested either with economically important insects, mites or both (Liscombe and Watters, 1962). This emphasizes the need for farmers to remove and destroy grain debris from empty granaries, and to clean and spray bins before refilling.

The survey of country elevators indicated that although residual insect infestations are generally low, a few insects or mites can often be found. An educational program is necessary to make elevator personnel aware of the importance of pests, to have them refuse infested grain from the farm, and to clean and spray bins as soon as they are empty.

Less severe climatic conditions in Eastern Canada result in a more severe insect problem. The granary weevil is a pest in soft wheat storages in Ontario because it can survive there all year.

American grain is stored in some elevators in Canada. Warmer climatic conditions in many parts of the United States allow insects to reproduce all year, and they may be present in grain shipped into Canada for storage. Some incoming shipments from the Southern States have been infested with the Angoumois grain moth or the lesser grain borer. Fumigation of these shipments has prevented the establishment of these pests in Canada.

Surveys have uncovered loopholes in legislation and inspection procedures. When oversights are discovered, appropriate action is taken to remedy them. Within the past six months an advisory committee on insect infestation in stored grain has been set up to assess ways and means of implementing changes that surveys have shown to be necessary.

When examining agricultural commodities in several locations, it is necessary to establish standards of inspection to insure uniformity of action. This area needs strengthening. Government must inform commercial interests concerned with the storage, processing and transporting of stored-products, of the damage and loss which can be caused by insects and mites.

To remain a leading nation in the export of clean grain and cereal products requires the efforts of everyone connected with the industry.

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MITES OF STORED GRAIN IN WESTERN CANADA -- ECOLOGY AND METHODS OF SURVEY[1]

R. N. Sinha
Research Station, Canada Department of Agriculture

Abstract

The need for a periodic survey of stored-grain mites in granaries in Western Canada has been indicated because the common grain mites, Glycyphagus destructor (Schrank), Cheyletus eruditus (Schrank), and Acarus siro Linnaeus have been recorded in grain exported from Western Canada more frequently than insects. A knowledge of the life history and ecology of grain mites, farming methods, storage practices, weather conditions of the area, and methods of sampling and detection of mites from grain are considered important for the success of a survey. The months in which the maximum mite population in farm granaries could be expected were determined by an ecological study of three species of grain mites in two 500 bushel wheat bulks at Winnipeg during 1960-63: A. siro, October to February; G. destructor, May to September; and C. eruditus, March to October. A survey of 70 small grain bulks in wooden granaries scattered throughout Western Canada, conducted during April 1964 showed that G. destructor, C. eruditus, and A. siro were found in only 3, 4 and 1% of the grain bulks indicating that mites are generally scarce in early spring. The presence of a cold-hardy hypopus stage in the life history of A. siro and G. destructor, and ability of this stage to survive and multiply well below 20 C were considered to be the main reasons for the dominance of these grain mites over insect pests in stored grain in Western Canada.

Ecological relationships between the grain, fungi, and mites of the genera Acarus, Glycyphagus, Cheyletus, Tarsonemus, Haemolaelaps, Aeroglyphus, Tydeus, and Kleemania are illustrated by means of a simplified diagram.

Methods of sampling and extraction of mites are described. Diagrams of Berlese funnels and detailed instructions for their use are given. Hoyer's solution is recommended for mounting grain mites. A list of stored-product mites based on a literature survey (1873-1960) and the study of museum collections in Canada is appended in the paper.

Mites are important pests of stored grain in many parts of the world, especially where the climate is temperate and large quantities of cereal grain are grown and stored. Serious outbreaks of storage mites in countries with these characteristics are not uncommon, e.g. during 1934-40 in USSR (Megalov 1934, Rodionov 1940) and during 1939-42 in Canada (McLaine 1943). Although over 80 species of mites occur in stored grain (See Appendix III) only a few

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[1] Contribution No. 182 from Canada Department of Agriculture, Research Station, Box 6200, Winnipeg 1, Manitoba.

cause serious loss. The most important of these cosmopolitan species are the grain mite, Acarus siro Linnaeus, the long hairy mite, Glycyphagus destructor (Schrank) (Fig. 1) and a cheese mite Tyrophagus putrescentiae (Schrank). Under favourable conditions these mites reproduce rapidly and large populations often occur. In a heavily infested sample, the population density of the grain mite may reach to 250,000 per 100 cc of grain (Solomon 1945). In most cases, however, the mites are sparsely distributed and easily escape detection.

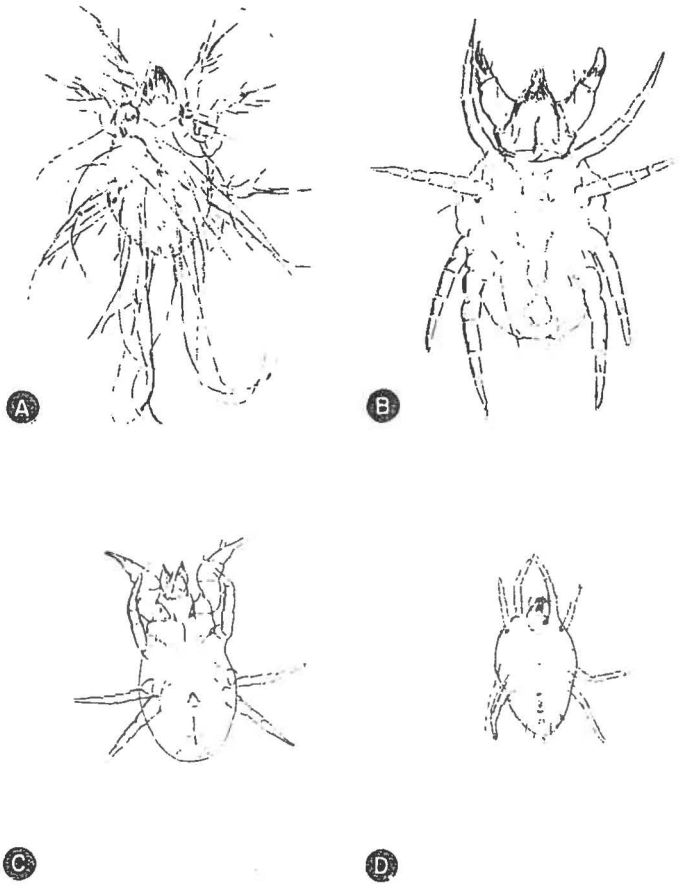

Figure 1 Common Mite Pests of Stored Grain in Western Canada:
(A) Long hairy mite, Glycyphagus destructor (400 μ).
(B) Cannibal mite, Cheyletus eruditus (500 μ).
(C) Grain mite, Acarus siro (350 μ).
(D) Tydeus interruptus (260 μ).

In Western Canada, the commonest species is the long hairy mite (Sinha 1963), but the most important economically is the grain mite. These and several other species commonly found in grain samples in Western Canada are shown along with their feeding habits (Fig. 2).

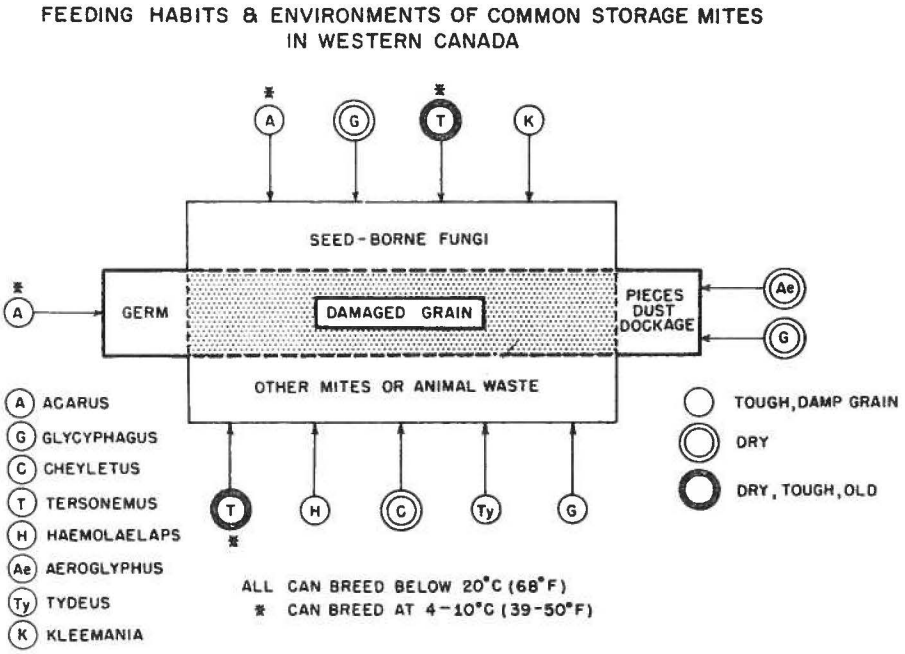

Figure 2 Feeding Habits and Environments of Grain Mites in Western Canada.

Much of Western Canada's grain is shipped overseas. Traditionally, Canadian grain has been regarded by the buyers as of excellent quality because of its high protein content, superior milling and baking properties, and relatively low infestation by insects and mites. Because of stiff competition with the USA and other countries with large stocks of surplus grain Canada must maintain this reputation.

After World War II, some grain importing countries, utilizing advancements in science and technology, developed a systematic and sophisticated inspection system. As a result, Canadian grain shipments are now being subjected to more rigorous inspection at foreign ports of entry than ever before. Two reports on the infestation of Canadian and US produce inspected at British ports during 1953-61, published by the Infestation Control Laboratory, the United Kingdom Ministry of Agriculture, Fisheries and Food, illustrate this change (Hurlock 1963, 1964). Since USA is the largest grain exporting country in the world and often directly competes with Canada in securing new grain markets, a comparison of their grain pest problem to that of ours will be useful. From the British report I have listed, in order of their frequency of occurrence, the seven most commonly recorded species of insects and mites in wheat shipments from northern USA and Western Canada at United Kingdom ports during 1954 (Table 1). Generally, the pattern of infestation was repeated in other years although the total number and the percentage of infested shipments varied.

TABLE I

Seven most commonly recorded species of insects and mites on wheat shipments from Northern USA and Western Canada at UK ports in 1954, listed in order of frequency of occurrence (Data from Hurlock 1963, 1964).

Northern USA 72 shipments	Infestation %	Western Canada 83 shipments	Infestation %
Sitophilus granarius (Linnaeus) Granary weevil	33	Glycyphagus spp., Hairy mites	48
Plodia interpunctella (Hübner) Indian-meal moth	13	Cheyletus spp., Cannibal mites	36
S. oryzae (Linnaeus) Rice weevil	8	Acarus siro Linnaeus, Grain mite	31
Cryptolestes spp., Flat grain beetles	7	Psocoptera, Psocids	17
Sitotroga cerealella (Olivier) Angoumois grain moth	4	Cryptolestes spp., Flat grain beetles	8
Tribolium castaneum (Herbst) Red flour beetle	3	Coninomus nodifier Westwood	6
Glycyphagus spp., Hairy mites	1	Oryzaephilus surinamensis (Linnaeus) Saw-toothed grain beetle	2

The three most common pests of Canadian grain were mites, whereas those of the US grain were insects. The only important insect pest of Canadian grain is the rusty grain beetle, Cryptolestes ferrungineus (Stephens). Fortunately, the Canadian grain authorities are aware of the potential danger involved in shipping this beetle with the grain and take precautions to detect and destroy it before the grain is shipped. Since mites are, beyond any doubt, the most common and well established pests of cereal grain, extensive survey of these organisms in all parts of the grain growing and storing areas of Canada would be the first step towards their control. The aim of this paper is to show the importance of life history and ecological data of pest species in planning mite surveys in stored grain in Western Canada.

To ensure the success of any survey adequate planning is necessary. Careful consideration should be given to the following factors any one of which may influence the results. The surveyor should acquire some knowledge of: the life history and physical limits of the pest or pest species involved, if this is not available, information of a general nature of the group in which the species belongs or that of related species could be useful; the farm and storage practices of the area to be surveyed; the weather of the survey area; and the methods of sampling and detection of mites from grain.

A. siro and G. destructor pass through several immature stages before becoming adults: egg; larva (6 legs), activity followed by rest; protonymph (8 legs), activity followed by rest; deutonymph or hypopus (8 legs), tritonymph, resembles adults; and adult (8 legs). The hypopus or non-feeding deutonymphal stage may occur between the protonymph and tritonymph and serves as a means of distributing the species and also for survival under unfavourable conditions. There are two kinds of hypopi: (1) active ones capable of movement and of attaching themselves to other arthropods or mammals and (2) inert and immobile ones which are dispersed by wind. Both active and inert hypopi are formed by A. siro; the hypopus of G. destructor is inactive and remains enclosed within the protonymphal skin. The inert hypopi of A. siro and G. destructor often have vestigial legs and are capable of feeble movement (Hughes 1961). Berlese funnels, used for extraction of mites from grain samples, are useful only in separating mites which can move away from the heat, the light, or from both, of the incandescent bulb. Therefore inert hypopi are not detected by this method. Examination of samples from Manitoba indicates that mite populations are lowest in March and April (Fig. 3). These low populations are probably due to the cold months and to the destruction of the active stages by a predatory species, the cannibal mite, Cheyletus eruditus (Schrank).

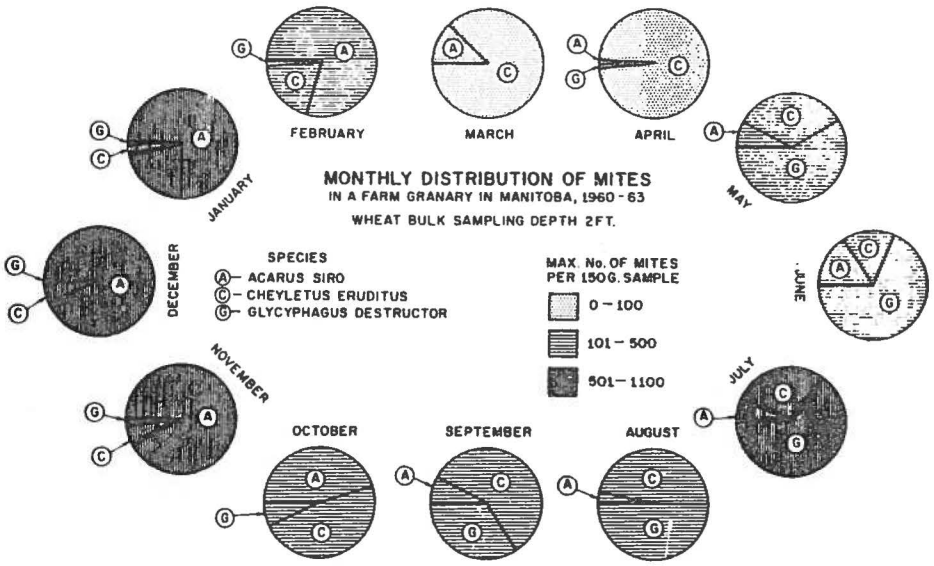

Figure 3 Monthly Distribution of Grain Mites in Manitoba

To obtain large populations of mites from a farm bin, grain should be examined for A. siro in January, February, October, November, and December; for G. destructor between May and September; and for C. eruditus from March to October (Fig. 3). Hence careful planning is important in the selection of dates before a mite survey is undertaken.

Most of the past mite surveys of farm-stored grain in Western Canada were undertaken during summer and early fall. These generally showed infestation of several common species and large numbers of stored-grain mites in grain bulks (Watters and Waddell, unpublished, 1954) and in grain spill in empty granaries (Liscombe and Watters 1962). To detect overwintering mite infestations in stored grain in small wooden farm granaries, a survey was conducted during 7 - 15 April 1964 in Alberta and Saskatchewan (Fig. 4). Seventy 150 g composite samples (samples from five locations in each bin were mixed) from the center and the periphery of 70 bulks of wheat and oats were collected from wooden granaries in Alberta and in northern and western Saskatchewan. Similar numbers of samples were also obtained from grain spills inside and outside the granaries. The first set of samples indicated a general scarcity of stored-grain

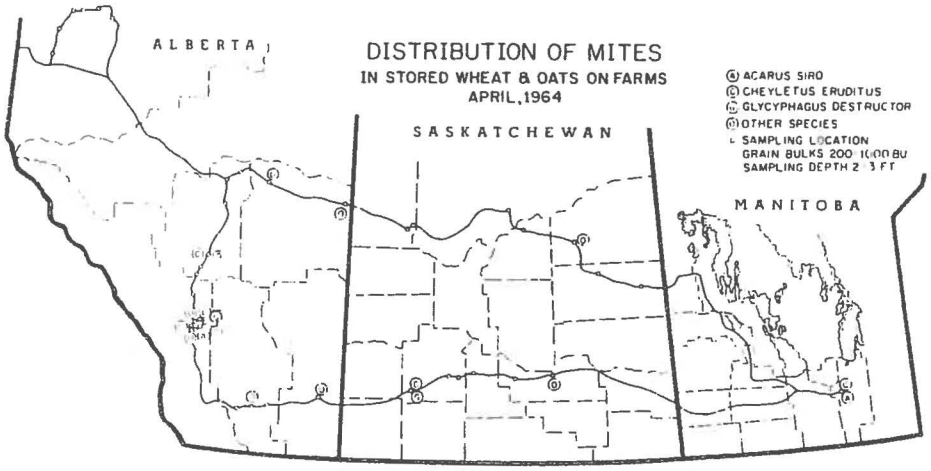

Figure 4 Map of Western Canada Showing the Granary Survey Route

mites. G. destructor, A. siro, and C. eruditus, however, were represented in 3, 1, and 4% of the total samples. Other mites included Tarsonemus sp. which is characteristically found in old grain, Tydeus interruptus Thor (Fig. 1), Haemolaelaps casalis (Berlese) (Fig. 5), and oribatid mites. Mites, mainly of the rodent, soil, and fungivorous types, were common in floor samples.

Although stored-grain mites often occur in association with storage insects, there are usually clear differences in the life history and the physical limits. Although these overlap in many areas, the following generalizations can be made: (i) Storage mites can feed and reproduce at temperatures below 20 C (68 F). Solomon (1962) has shown in the laboratory that A. siro can survive and reproduce at 5-20 C (41-68 F) (Fig. 2) and C. eruditus at 12-20 C (54-68 F). Neither the rusty grain beetle nor any of the common fungus beetles found in Western Canadian grain can multiply at such low temperatures. (ii) The cold and drought

resistant hypopus stage in their life history provides A. siro and G. destructor with an additional advantage over insects during severe winters and other adverse conditions. (iii) The largest storage mite is usually less than 900 microns (0.8 mm) long, whereas most grain insects are several millimeters in length.

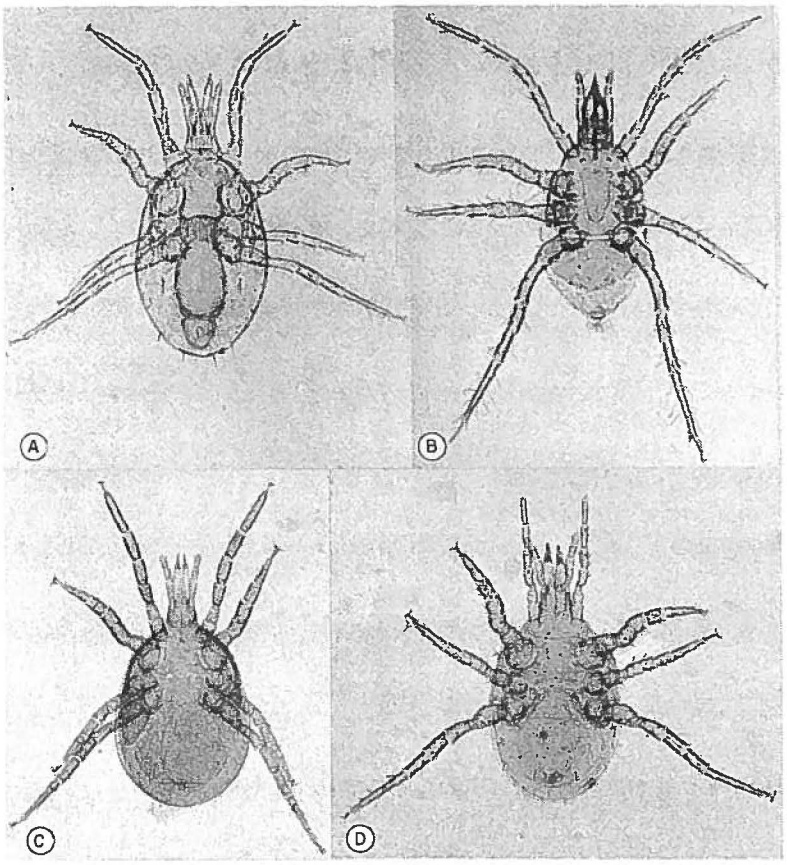

Figure 5 Mesostigmatid Mites From Grain Spill on Granary Floor in Western Canada:
(A) Haemolaelaps casalis (500 μ)
(B) Parasitus sp. (immature form) (650 μ)
(C) Eulaelaps stabularis (1000 μ)
(D) Housefly Mite, Machrocheles muscaedomesticae (950 μ).

Most species of storage mites prefer damaged, moist, and moldy grain, but G. destructor and C. eruditus can multiply in grain with 12 - 14% moisture content. Since these conditions are at least partly regulated by methods of harvesting, threshing, and storing grain, a knowledge of harvesting practices and storage structures would be useful to a surveyor. Weather is probably the most important factor in determining the conditions of grain storage in a granary. Climatic areas in Western Canada are variable. The drier the grain at harvest the more injury is likely to incur in machines, making it more vulnerable to

G. destructor and Aëroglyphus robustus Banks. The higher the moisture content of the grain the lesser would be the kernel injury. Such grain, however, would be a good substrate for the growth of storage fungi. Tough and damp grain is favoured by most grain mites, especially A. siro which can increase in astronomical proportions in the presence of Alternaria, Nigrospora, Mucor, Curvularia, and a few other seed-borne fungi (Sinha 1964). Thus the distribution of mites in a certain year would be determined by rainfall and temperature during harvest and initial storage. The surveyor should be able to select areas of possible mite infestation from weather and harvest data of a particular year.

Methods of collecting acarid mites for study of population density are described by Solomon (1945). Collecting representative samples, whether these are from farm granaries, elevator bins, railway box cars, trucks, wagon or barge loads, is an essential step in surveying grain mites. In the grain industry this is usually done with a double tube brass Trier[2] of suitable size. Sampling methods and plans used in small farm granaries (Sinha 1961) and in large annexes over 300,000 bushels (Sinha, Liscombe and Wallace 1962) have been described with illustrations. Uniformity of sampling methods and the selection of similar granaries as far as possible, will assure reliable results from a mite survey. This is one of the most difficult requirements to fulfill since the environment for survival and multiplication of mites in granaries is rarely duplicated. The best results are achieved by restricting sample collections to one particular type of bin structure for each survey, such as, rounded steel bins with about 1,000 bushel capacity.

Many methods have been used in detecting grain mites (Solomon 1943) but only two are widely used:

A. Sieving of samples, (used in UK, Poland, Japan, and USA). The sample is agitated manually or mechanically in a 20 to 30 mesh (per inch) metal sieve which retains everything except the dust and small particles. This dust is examined under a lens or a low-power stereo microscope, and the mites are picked up, counted, and mounted if necessary. The main advantage of this method is that it extracts all stages of mites, including eggs and inert hypopi. The disadvantages are: (i) a mixture of dust and fine particles with all stages of mites requires a long time for separation; (ii) the chances of making mistakes in distinguishing mites from grain particles are great unless the analysis is done by a trained acarologist; and (iii) a large staff of trained personnel is needed for an extensive sampling program.

B. Berlese Funnel (used in Canada and USSR). This method uses heat and light to drive mobile mites away from the grain into a jar containing alcohol. The funnel design used at the Canada Department of Agriculture Research Station, Winnipeg is illustrated (Fig. 6) and the instructions for its use are given (Appendix I). The efficiency of extraction for each species of mite by this method should be checked by artificially infesting a known quantity of grain by the species concerned and subsequently extracting the mites by the Berlese

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2 Seedburo Equipment Co. Chicago; Probes with deep bin cup size 9 - 15 inches; capacity - 125-265 g; Extensions - 3 ft per section; T handle.

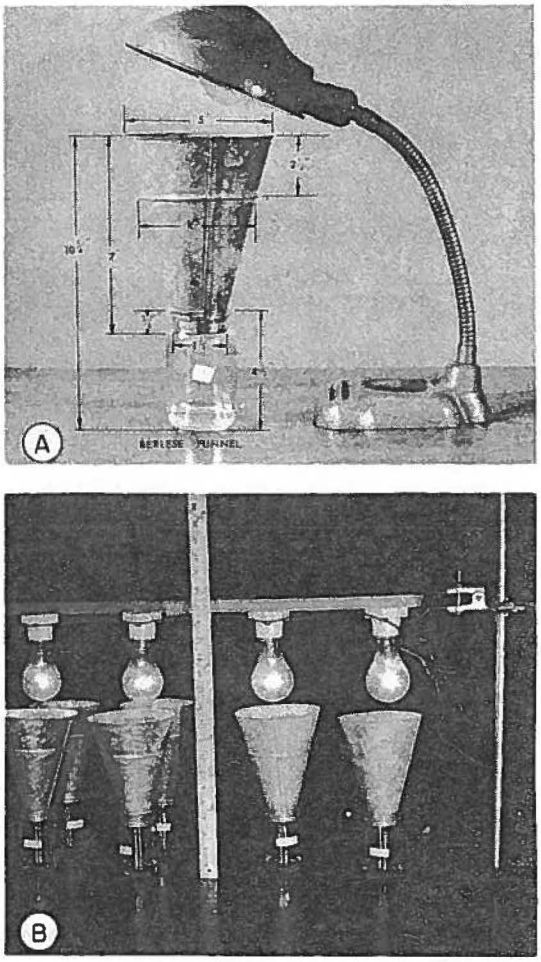

Figure 6 Berlese Funnel Used at the Canada Dept. of Agriculture Research Station, Winnipeg, Manitoba.
(A) Single funnel placed under a goose-neck lamp.
(B) Several funnels used to process a large number of samples.

funnel. This is a convenient and inexpensive method for extracting mites from a large number of samples using a few technical personnel with little training. The accuracy is high for the mobile stages of many common species, e.g. 80% for A. siro, but immobile stages are not extracted and about six hours are required for extraction.

Instructions for examination of living and dead mites, making temporary and permanent preparations, and culturing of mites associated with stored grain are given by Hughes (1961). Useful and workable keys for identification of most of the common storage mites in Canada are also provided.

Instructions for preparing Hoyer's solution for mounting mites used at the Winnipeg laboratory are given in Appendix II.

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Appendix I

Equipment

Short, parellel-stem, metal, Berlese funnel (Figs. 1 and 2)

	Measurements
Top diameter	5 inches
Bottom diameter	1 3/4 inches
Stem height	3/4 inches
Height	7 inches
Distance from upper rim to screen	2 1/4 inches

A 1/10-inch mesh, removable circular metal screen (approximately 4 inches in diameter) is fitted to a circular groove along the inner wall of the funnel, about 2 inches from the wide end; 1/20-inch mesh is used when only mites are to be separated.

The parellel stem of the funnel fits inside the mouth of an 8 oz glass powder jar (inner diameter about 2 inches) which supports the weight of the funnel containing the grain.

A 100 watt electric bulb fitted to a goose-neck lamp is placed directly above the funnel (Fig. 6A). Bulbs can be fitted to a wooden board if many samples are processed (Fig. 6B).

Cost of Berlese funnels varies according to choice of materials.

Prices as of 1964 were:

a. Tin plate (not for prolonged use) - $1.00 each
b. Galvanized iron (in use in Canada Dept. of Agriculture Laboratory, Winnipeg) - $1.50 each
c. Stainless steel - $3.00
d. Polished stainless steel (ideal) - $12.00 each

Extraction of Mites and Insects by Berlese Funnel

Instructions for use:

1. Place an empty Berlese funnel, wide end up, on a piece of white paper.
2. Pour 150 to 200 g of the grain into the top of the funnel.
3. Pour about 2 oz of 70% ethyl alcohol into an 8 oz wide-mouth glass jar. As a substitute, water can be used providing the examination is made within 24 hours.
4. Place a label on the outside of the jar identifying the grain sample.
5. Insert the funnel, in an upright position, gently into the mouth of the glass jar.
6. Transfer the small particles of grain, dust and weed seeds that have fallen through the screen, from the paper to the funnel.
7. Place the glass jar and funnel loaded with grain below a 100 watt bulb fitted to a goose-neck lamp (Fig. 6A) or a socket fitted to a wooden board (Fig. 6B).

The distance from the bulb and the surface of the grain should be about 2 inches.

8. Keep the funnel under the light for 3 to 6 hours and then remove it. Cap the jar tightly until ready for examination.
9. Place the jar with alcohol on a white paper. Look down through the jar and count the number of adult rusty grain beetles, fungus beetles or rodent mites. Use black paper for the larvae of insects and acarid mites.
10. Funnels and jars must be washed thoroughly with hot water and dried before re-use.
11. To detect mites (mainly the grain mite, hairy mite and cannibal mite), pour the alcohol into a petri dish (about 3 1/2" in diameter and 1/2" deep). Place the plate on black or white background and examine under a stereo-microscope.
12. To count specimens of different species move the petri plate with fingers in a circular motion while examining under the microscope.
13. A laboratory counter with up to 8 keys can be used for recording the number of insects and mites.

Appendix II

Mounting Media for microscopie examination, and storage of mites

Remove specimens from alcohol with a medicine dropper, and place directly in a drop of Hoyer's Solution on the slide. Put on a No. 1-120 mm cover slip and apply mild heat (about 40C) over a hot plate. Ring dried slide with Bennett's Zut slide ringing compound (Bennett's, Salt Lake City, Utah, USA). Slides can now be stored in slide boxes, and mites preserved intact for several years.

Hoyer's Solution (A Modified Berlese mounting medium)

Dist. Water	50 cc
Gum Arabic (Clear crystals)	30 g
Chloral hydrate	200 g
Glycerine	20 cc

(Mix at room temperature in above sequence; mount directly from life, water, or alcohol; mount one specimen per slide).

Appendix III

Mites Associated with Stored Products in Canada, 1873 - 1960

The species are grouped under family names. This list was compiled from a survey of Canadian entomological and agricultural literature (1873 - 1960), and of museum records of mites in various parts of Canada. It has been checked by Dr. A. M. Hughes, Dept. of Biology, Royal Free Hospital School of Medicine, London, UK. Identity of a few species in published records could not be verified.

ACARIDAE

Acarus siro Linnaeus
Aleuroglyphus ovatus (Troupeau)
Caloglyphus armipes (Banks)
C. berlesei (Michael)
C. moniezi Zachvatkin
C. spinitarsus Zachvatkin
Eberhardia alberti Zachvatkin
E. pedispinifer Nesbitt
Histiogaster carpio (Kramer)
Rhizoglyphus echinopus Fumouze & Robin
R. rhizoglyphus Banks
R. callae Oudemans
Thyreophagus entomophagus (Laboulbène)
Tyrolichus casei Oudemans
Tyrophagus longior (Gervais)
T. putrescentiae (Schrank)

GLYCYPHAGIDAE

Aëroglyphus robustus Banks
Carpoglyphus lactis Linnaeus
Chortoglyphus arcuatus (Troupeau)
Ctenoglyphus plumiger (Koch)
Glycyphagus destructor (Schrank)
G. domesticus (De Geer)
G. michaeli Oudemans
Gohieria fusca (Oudemans)

ACEOSEJIDAE

Kleemania sp.
K. plumigera (Oudemans)
Kleemania plumosus (Oudemans)
Lasioseius sp.
Melichares keegani Fox
Melichares tarsalis (Berlese)
Proctolaelaps sp.
P. hypudaei (Oudemans)
P. pomorum (Oudemans)

LAELAPTIDAE

Arctoseius sp.
Articholaelaps sp.
Haemogamasus pontiger (Berlese)
Haemolaelaps casalis (Berlese)
H. glasgowi (Ewing)
Hypoaspis sp.
H. smithii Hughes
Eulaelaps stabularis (Koch)

PARASITIDAE

Gamasus attenuipes Banks
Parasitus coleopterorum (Linnaeus)
Parasitus sp.
Pergamasus sp.

MACROCHELIDAE

Machrocheles matrius (Hull)
Machrocheles musaedomesticae (Scopoli)
Machrocheles sp.

CHEYLETIDAE

Cheletomorpha lepidopterorum (Shaw)
Cheyletus eruditus (Schrank)
Cheyletia flabellifera (Michael)
C. trouessarti Oudemans
C. malaccensis Oudemans

BDELLIDAE

Bdella tenella Banks
B. longicornis (Linnaeus)
Biscirus silvaticus (Kramer)
Spinibdella sp.

EUPODIDAE

Eupodes sp.
E. variegatus (Koch)
Etemaeus translamellatus Hamer.

TYDEIDAE

Coccotydeus globifer Thor
Lorryia reticulata (Oudemans)
Tydeus interruptus Thor
Tydeus sp.

PHYTOSEIIDAE

Typhlodromus barkeri (Hughes)
T. marinus (Willman)
T. origonensis (Garman)

PYEMOTIDAE

Acarophenax tribolii Newstead & Duvall Pyemotes ventricosus (Newport)

Pediculoides spinosus (Kramer)

TARSONEMIDAE

Tarsonemus confusus Ewing Tarsonemus sp.

UROPODIDAE

Leiodinychus krameri (G. & R. Canestrini)

LIPONYSSIDAE

Liponissus sp.

RAPHIGNATHIDAE

Mediolata sp.

CERATOZETIDAE

Humerobatus sp.

CUNAXIDAE

Cunaxa womerleyi Baker & Hoffman

CYMBAEREMAEIDAE

Eremaeus sp.

TROMBICULIDAE

Sciurus sp.

ORIBATULIDAE

Trichoribates trimaculatus (Koch)

TETRANYCHIDAE

Bryobia praetiosa Koch

ANOETIDAE

Histiostoma feroniarum (Dufour)

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PROBLEMS ENCOUNTERED IN THE DEVELOPMENT OF LIFE TABLES FOR INSECTS [1]

W. G. H. Ives
Forest Entomology Laboratory, Canada Department of Forestry
Winnipeg

Abstract

Factors likely to create problems in the development of life tables for insects are discussed. Some examples are cited of work done in Canada on forest, orchard, and field crop insects.

Life Tables

The use of life tables as a convenient method for summarizing the amount of mortality occurring in each generation of an insect population was proposed by Morris and Miller (1954). Since then numerous examples of this approach have appeared in the literature, indicating a wide acceptance of the method. However, the feasibility or desirability of developing life tables for a particular insect species depends on a number of factors. A discussion of some of these factors and the problems arising from them follows. However, before discussing the construction of life tables it is advisable to define what is meant by the term, how the form used in studying insect populations differs from the conventional type used by life insurance companies, and the advantages of this approach for summarizing mortality data to assess the effects of various factors on population trends. Allee et al. (1949) refer to the life table as "a device that records in systematic fashion those facts basic to the age distribution of mortality. In short, a life table 'keeps the books on death'." The following column headings are used conventionally in life tables and are arranged from left to right:

- x Age in appropriate units, stated as an interval
- l_x The number surviving at the beginning of the age interval given in the x column.
- d_x The number dying in the age interval given in the x column.
- q_x The number dying in the age interval divided by the number of survivors at the beginning of the interval.
- e_x Life expectation. Mean length of life remaining to each organism at the beginning of the age interval.

Morris and Miller (1954) suggested several changes from the format of conventional life tables. A column headed d_xF adjacent to the d_x column serves to identify the factor causing mortality - an important consideration in ecological

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studies. The unequal age interval in the x column is also an adaptation to an ecological life table, and emphasizes the stage where mortality occurs rather than the chronological age. Figures in the l_x column are more appropriately recorded in terms of actual population for some appropriate unchanging sampling unit. They also note that it is more convenient to use 100 q_x, than 1000 q_x, and that there is little use for e_x in insect life table.

There are several advantages in using life tables to assess the effects of various mortality factors in the epidemiology of an insect. Separate studies of factors affecting one or more stages of an insect often yield valuable information concerning their probable importance. However, unless the effects of these factors can be related to the population trends it is difficult to provide a full assessment of their impact because their effects may be influenced by other factors. Life tables enable any desired comparison to be made, as data for the complete generation are available. One or two life tables will do little more than indicate stages where high mortality occurred, but a series of life tables, covering a wide range of population levels and environmental conditions, should increase the understanding of the population dynamics of an insect. Ultimately it may be possible to predict population trends in relation to major factors in the environment, and by modifying these factors reduce the frequency and severity of insect outbreaks.

Sampling Problems

The compilation of life tables for an insect population requires reliable sampling techniques for estimating the numbers of individuals at different stages in the life cycle. The development of suitable sampling techniques requires a considerable expenditure of time and money, and usually requires a relatively large staff because large samples are generally needed to give acceptable limits of statistical accuracy. Also, a single life table provides little information on factors affecting the species, it is only by replication in time and space that the full value of the data can be realized. The preparation of life tables is therefore a major endeavor, and should receive very careful consideration before being undertaken. In many cases it may be more feasible to consider an intensive experimental study of one particular stage of an insect or factor affecting the insect. This is perhaps especially true of applied control measures such as chemical sprays or dusts against insects on agricultural crops which are harvested annually. It will probably be much cheaper to study the effect of such treatment on an experimental basis than to attempt to collect enough population data for the construction of life tables.

The habits and life cycle of an insect play a large part in determining the feasibility of developing sampling techniques for estimating populations of the various stages. Soil inhabiting insects are especially difficult to sample, as large volumes of soil must be examined in order to recover the insects, and the recovery of eggs and small larvae is often very difficult. Boring insects are another difficult group to sample, as the plant material usually has to be dissected to remove the insects. This can be done with some plants, such as cereals, but becomes a major problem with wood borers. Insects that inhabit more than one universe also present problems, as it then becomes necessary to devise sampling methods for the several universes and to find a common denominator for expressing the populations in each. Overlapping of different

stages in natural populations creates sampling problems, as it is difficult or impossible to select a sampling period when all of the individuals in a given stage are present. Insects with more than one generation per year present additional problems especially if the generations overlap. The activity of an insect also determines the ease with which it can be sampled. Some larvae can be sampled readily in the early instars, but evade sampling at the slightest disturbance during late instars. Adult insects are usually active and very difficult to sample. They also may emmigrate from or immigrate into the study area, thus creating additional problems.

The number of individuals in a population also has a bearing. Some species seldom, if ever, become very abundant, yet may be economically important if, for example, they are vectors for some disease organism. Very large samples will probably be needed for studying such insects. Other insects and mites often become so numerous that simply counting them becomes a major problem.

The size of the individuals being sampled is also important, especially for the egg and early larval stages. Unless the eggs are laid in clusters it is often extremely difficult to obtain an accurate count, and it may be necessary to examine the material under low power magnification, such as a binocular microscope. Extreme care in checking is likely to be needed under such circumstances, otherwise human error will probably seriously bias the counts. In some cases it is necessary to use indirect methods for obtaining the estimate, as it may be virtually impossible to obtain a direct count.

None of the foregoing problems need be considered insurmountable. Some of them are likely to be encountered in the development of life tables for almost any insect species, although some insects will present more problems than others. The investigator studying a particular insect often requires considerable ingenuity in devising a reliable sampling technique. He may be able to modify a technique developed for studying other insects, or he may have to develop a new method suitable for this particular insect. Most of the earlier papers presenting life tables for insects dealt with forest insects, but others are now appearing for agricultural pests. A discussion of some of these papers, the problems encountered and the solutions devised may prove helpful.

Spruce Budworm

Morris and Miller (1954) presented two examples of life tables for the spruce budworm. All stages of this insect inhabit the same universe, the tree crown, and populations of the different stages can be estimated by a suitable sampling unit taken at appropriate times (Morris 1955). Populations are expressed as the number of insects per 10 sq. ft. of branch surface. The sample unit consists of a group of branches collected in the combination 1:1:1/2:1/2 from the apical to the basal quarters of the crown. The first two are whole branches, the last two are longitudinal halves. The above sample unit provides a sample in which the percentage distribution of branch surface is roughly proportional to the distribution for the whole tree. Branches are removed from the tree crowns with extention pole pruners fitted with a clamping device. As many of the trees are over 50 ft tall it becomes a problem to reach the upper branches from the ground. The problem has been solved by using the pole pruners from the top of a 38 ft ladder braced to the tree and secured by guy poles.

Budworm eggs are laid in clusters cemented to the needle surface. The

clusters are relatively small and constant checking is needed to ensure accuracy in the counts. Branches are cut into small twigs in the field and placed in canvas bags for transportation to the laboratory. The number of eggs is estimated by obtaining the mean number of eggs per cluster from a random sample of clusters and multiplying this figure by the number of clusters per sample unit. The egg clusters persist on the foliage for some time, which is both an advantage and a disadvantage. It is an advantage in that sampling can be delayed until nearly all of the eggs have hatched, and thus provides an estimate of the number of first-instar larvae, the number of sterile eggs, and the number destroyed by parasites and predators. It is a disadvantage in that about 25% of the egg masses persist on the foliage until the following year. They can usually be distinguished from newly hatched masses by their bleached and flattened appearance, but about 14% of those retained for one year look fresh enough to be confused with the newly hatched masses. No real solution to the problem of distinguishing between old and new egg masses has been found. Errors are reduced as far as possible by careful timing of the sampling period, by having one experienced worker separate the new and old egg masses, by checking on this segregation from samples collected before and after the oviposition period, and by advancing the sampling date in rapidly declining populations so that most of the eggs are unhatched when collected.

Second-instar larvae overwinter in hibernacula and cannot be found readily. Collections are made from the plot after exposure to winter temperatures and again just before emergence in the spring. The number of emerging larvae is determined by placing the branches in special cages where the emerging larvae are trapped by taking advantage of their photopositive behavioral response. Checks on the accuracy are maintained through similar rearings of branches bearing a known number of hibernacula. Estimates of populations of second-instar larvae in mines, by examination of branch samples collected in May, is not generally done, as it is very time consuming.

Third-instar larvae feed in the opening buds and can be sampled without undue loss. Samples collected when the bulk of the population is in the third and early fourth instar are used to estimate the population at this stage of development. Later instars become too active for easy sampling.

Pupal cases of the budworm are usually firmly attached to the foliage with silk strands, and thus persist for some time. In fact, retention of old cases presents a similar problem to the retention of old egg masses, and similar means of reducing the error are used. Sampling is usually delayed until most of the moths have emerged, and thus provides an estimate of the male and female moth population as well as of those destroyed by parasites, predators and other causes. Pupae removed by birds or small mammals cannot be accounted for and are included with larval mortality.

Lodgepole Needle Miner

The lodgepole needle miner is another forest insect for which life tables have been developed (Stark 1958). The insect has a two-year life cycle and all stages except the adult occur within the needles of the host. The egg is laid in an old mined needle in late July and August and the newly hatched larva immediately enters a needle where it overwinters. Mining of this needle is completed by mid-summer, and a second needle is entered. The larva overwinters in this

needle and transfers to a third needle the following spring. Mining of this needle is completed by early June and the adult moth emerges three to four weeks later.

Development of sampling techniques for this insect was straightforward (Stark 1952). The sampling unit for all stages is the same, and consists of a five-year branch tip. The tips are usually collected from all crown levels, although mid-crown samples provide a reasonable average. The following samples are considered adequate for the construction of life tables: an egg sample in mid-August and a larval sample in late September or early October of the first year; larval samples in the early spring and late fall of the second year; and a larval sample in late May or early June of the third year. The latter is reared in an insectary to provide information on sex ratio, moth population, number of parasites, and mortality due to other causes. In addition, pupal samples are also collected from the field to check for adverse effects due to insectary rearing.

The small size of this insect makes it necessary to be careful when checking the foliage. Old mines have to be dissected to count the eggs, and this phase of the work is extremely tedious, but the larval stages can be detected without dissection and a distinction made between mines containing living and dead larvae. Pupal cases have to be removed from the needles for examination, but this apparently is not as tedious as the dissections for the egg counts.

Larch Sawfly

Life tables have also been prepared for the larch sawfly, although these have not yet been published. The following is a brief description of the life history of this insect in Manitoba. The females are parthenogenetic and deposit their eggs in the current shoots of larch from mid-June until late July or early August. The larvae are gregarious and feed on the foliage for about four weeks. They drop to the ground and overwinter as larvae within cocoons spun in the moss. Pupation occurs in the spring and the adults emerge from early June until late July.

A number of features in the life history of this insect make sampling difficult. Eggs and feeding larvae occur in the tree crowns, while the cocoons are in the moss of the forest floor. These cocoons persist for several years, and accurate separation of old and new cocoons is very difficult. Prolonged adult emergence results in marked overlapping of stages, and some larvae have dropped to spin cocoons before the last of the eggs are laid. Sampling techniques developed for studying the larch sawfly are therefore considerably more involved than for the spruce budworm or the lodgepole needle miner.

Egg populations are estimated from two whole branch samples collected from each of three crown levels after oviposition is complete (Ives 1955). Shoots bearing oviposition scars are removed from each branch and the egg slits counted under a binocular microscope. The branches in each crown level of the sample trees are counted by two observers using binoculars. This number multiplied by the mean number of eggs per branch provides an estimate of the number of eggs in each crown level, which are summed to provide an estimate of the number of eggs per sample tree. The mean number of eggs per sample tree multiplied by the number of trees in the study plot provides an estimate that can be expressed as the number of eggs per acre.

Cocoon populations are estimated by randomly positioned funnels and traps placed to catch falling larvae (Ives and Turnock 1959). The funnels have an area of 2 ft ^{2} and the traps contain moss in which the larvae are able to spin cocoons. Population estimates are expressed as the number per acre.

Adult populations are estimated by emergence traps similar to those described by Turnock (1957). The trap, mounted on the modified version of the inverted 2 ft ^{2} funnel, is held in place with spring clips, and is easily removed. In practice, the traps are interchanged fortnightly, the contents are removed in the laboratory and the numbers of adult sawflies in each trap recorded. Populations are again expressed in numbers per acre.

Mortality during the cocoon stage is estimated by rearing material collected for estimating cocoon populations. When the cocoons are removed from the moss they are examined carefully to determine which contain living larvae (Turnock and Ives 1962). These are packaged and placed under near-natural conditions for overwintering. Those containing dead larvae are removed and the cause of death noted. In the spring the cocoons are again checked and those containing living larvae are placed in small clear plastic containers for insectary rearing. Adults and parasites are removed daily. The adults are weighed and preserved for dissection to determine the potential fecundity.

The percentage of cocoons destroyed by voles and shrews is estimated for each plot by the cocoon planting technique (Buckner 1959). In early fall, healthy cocoons are placed on wired tags inserted in the moss. The following summer, after adult emergence is complete, the tags are recovered and the cocoons examined. Some are removed by small mammals, but the fate of the remainder can be determined by the appearance of the cocoons.

Mortality affecting the egg and feeding larval stages is estimated from weekly collections of egg clusters and associated larval colonies extending over a period of about two months (Ives 1962). The eggs are reared in an insectary to obtain the percentage hatch; larval colonies with their associated shoots are preserved in alcohol. Mortality is estimated by counting the egg slits and larvae for the different instars. Larvae in the last three instars are examined for eggs and scars of the tachinid parasite, Bessa harveyi (Tnsd.).

Premature larval drop and the incidence of B. harveyi parasitism on falling larvae are assessed from yet another technique in which larvae are trapped and preserved as they dropped to the ground.

Three Orchard Insects

Life tables have also been developed for three orchard insects; the eye-spotted bud moth; the pistol case bearer; and the fruit-tree leaf roller (LeRoux and Reimer 1959). Each has one generation per year and five age intervals are assessed: eggs in mid-July; summer larvae (Instars I-IV) from early August to mid-September; winter larvae (Instar V) in October and April; spring larvae (Instars VI and VII) from early May to early June; and pupae in mid-June. The leaf or bud cluster is used as a sampling unit. Eggs and overwintering larvae are examined in the laboratory under a binocular microscope. The other stages are examined in the field without removing them from the trees. This is possible because of visual signs provided by the webbing and leaf remains resulting from feeding by the bud moth and the pin hole feeding and pistol shaped cases of the case bearer. Bird predation on the bud moth is indicated by the shredded appearance of shelters used by spring larvae and pupae.

The life history of the fruit-tree leaf roller differs from the previous two in sufficient detail as to require some additional sampling (Paradis and LeRoux 1962). Egg masses of this insect are laid on the wood, and the insect overwinters in the egg stage. Hatching occurs in May and the first two instars feed on buds, flowers and young leaves. Instars III to V feed on the leaves and developing fruit mostly in June. The larvae pupate in June and July and the adults emerge from mid-June until early August.

Four age intervals are assessed: eggs in October and April; early larval instars in May; late larval instars in June; and pupae from mid-June to early July. The egg masses of this insect are located on the tree and marked for subsequent observation, but are not removed until hatching has occurred. Field observations and subsequent laboratory examination classifies the eggs into several categories on the basis of appearance. Visual signs again enable counts of larval and pupal stages to be made on the trees without removal of the insects. Visual signs also permit classification of the fate of late larvae and pupae into several categories.

European Corn Borer

LeRoux et al. (1963) also presented life tables for the European corn borer in an experimental area in Quebec. The usual crop rotation is not followed, to avoid introduction of mortality due to cultural practices. The corn borer has one generation per year in this area and all immature stages occur on the corn plant (Hudon and LeRoux 1961). Fifth-instar larvae overwinter in corn stalk debris and feeding is resumed in the spring. Pupation occurs in June, in shelters constructed in the stalks. Adults emerge in late June and July and oviposition continues until late July. The first two larval instars feed on the whorl of leaves of young plants and on the tassels and tassel stalks. Third-to fifth-instar larvae tunnel in the stalks.

The sample unit used in these studies is the entire corn plant. Five population assessments are made: eggs in July; summer larvae (Instars I-V) from mid-July to mid-September; winter larvae from late September to early May; spring larvae in May; and pupae.

Eggs are counted in the field without removal from the plants. A hand lens (X14) is used to examine the plants and to classify the eggs into several categories based on appearance. Summer larvae are dissected from the plants in the laboratory. After recording, all live larvae are returned to the plants. The other stages are also dissected from the plants but are not returned to the field. Dead larvae or pupae can be classed into several categories based on appearance. Webbing, frass, and stalk damage provide visual clues to the presence of all immature stages except the eggs.

Diamondback Moth

Life tables have been developed for the diamondback moth on early and late cabbage in an experimental area in eastern Ontario (Harcourt 1963). The early crop is planted in mid-May and is harvested and disced down at the end of July (Harcourt 1961). The late crop is planted in late June and allowed to stand until the following spring. The diamondback moth does not overwinter in the area studied, but arrives as adult immigrants from more southerly areas in late May. The insect has four to six generations in Ontario. Eggs are laid on

cruciferous plants, and all immature stages are found on the host plant. First-instar larvae mine the leaves, the remaining three instars feed on the foliage. Cocoons are firmly attached to the host plant.

The sample unit consists of a crown quadrant. Five population assessments are made: eggs; three larval periods; and pupae. Extreme care is needed in the timing of these samples, as the generations tend to overlap in the field and sampling has to be done quickly because development is rapid. The timing is determined by checking the progress of infestations in an outdoor cage and by a daily comparison of the temperature during the preceding 24 hours with the velocity of the development curves for the various stages. Eggs are counted in the field with a low-powered hand lens. The larval stage is divided into three periods on the basis of when different parasites killed the host: from hatching until the middle of the fourth instar; from the middle of the fourth instar until cocoon formation; and from cocoon formation until pupation. Mortality due to parasites is determined by insectary rearing of field collected material. Populations of pupae are determined by counting the pupae within the cocoons. The rate of parasitism is determined by rearing cocoons containing live pupae. The rate of parasitism cannot be determined in the field because old cocoons adhere to the host plant and parasite emergence from the different generations cannot be separated due to the durability of the cocoons.

Imported Cabbageworm

Sampling techniques have been developed for the preparation of life tables for the imported cabbageworm (Harcourt 1962) in the same study plots that were used for the diamondback moth. The cabbageworm has an average of three generations per year in the study area, overwintering as a chrysalid. Adults emerge in May and all immature stages occur on the host plant although some larvae wander before spinning cocoons. Eggs are laid singly on the outer leaves and there are five larval instars. The sample unit used is the half plant, oriented in the direction of the prevailing wind during the oviposition period. Timing of sampling is again critical and is determined by a twice daily comparison of development curves and accumulated day degrees. Five age intervals are sampled; eggs; three larval periods, and pupae. Egg populations are estimated by direct sampling at the completion of oviposition for each generation; usually the first week in June, mid-July and the third week in August. The larval stage is again divided into three periods on the basis of when major mortality occurs: from hatching to the middle of the third instar; from the middle of the third to the middle of the fifth instar; and from the middle of the fifth instar to pupation. Pupal populations are estimated from 64 plants caged during the latter part of the third larval period to prevent the larvae from wandering before spinning cocoons. Pupal mortality is estimated by collecting an additional sample of pupae from uncaged plants. These are classified into several categories on the basis of appearance.

Colorado Potato Beetle

Harcourt (1964) has also described sampling techniques developed for use in the preparation of life tables for the Colorado potato beetle in experimental plots. Potatoes are planted in the plots at a uniform spacing of 48 by 18 inches during late May and cultivation follows commercial practice, except that hilling

is done early in the season to avoid disturbing the population. The insect has one generation per year, overwintering as an adult. The adults emerge in June and lay their eggs mainly on the lower surface of the leaves. The larvae feed on the foliage and drop to the ground to form pupal cells two to four inches below the surface. The new adults emerge in August and feed on the foliage, mingling with overwintering adults, from which they can be distinguished by the colour of the membranous hind wings. Very little oviposition occurs, and the new adults hibernate in early September.

Two types of sampling unit are required as this insect occupies two universes. The above ground stages are sampled on hills of three stalks each. Soil quadrants 24 x 9 inches, 6 inches deep are used for sampling pupal cells. Six age intervals are samples: spring adults during the first two weeks of July; eggs during the first half of July; the early larval stages from hatching until the middle of the second instar; the remainder of the larval stage; pupae in early August; and summer adults in late August. Timing is important for the larval stages and is determined from developmental curves. All insect specimens in the samples are removed from the field after counting, as the host foliage is destroyed in the sampling process.

Conclusion

The foregoing examples have been confined to work done in Canada and are not intended to be a comprehensive review of the literature. They cover a wide range of problems, however, and serve to illustrate some of the methods used to overcome them. It has been impossible, in the time available, to discuss any particular problem in detail. No mention has been made of statistical reliability or sample size, but this does not mean that this has not been considered. On the contrary, each of these workers has been intensely aware of the necessity for a high degree of accuracy in population and mortality estimates, for without accuracy there is little point in collecting the data.

References have been made from time to time throughout this paper to the use of the appearance of the dead insect as an aid in determining the cause of death. This is a valuable aid and should never be overlooked, but unfortunately it is not always possible to do this if the factor destroying the insect removes it from the population without leaving any clues as to its fate. Allocation of a specific amount of mortality to each of several such factors operating in one sampling interval of an insect is virtually impossible. Measurements of these factors should be made, however, so that they can be included in later analyses.

The development of adequate sampling methods has been presented as being one of the most important problems in the development of life tables. I will conclude any remarks by quoting the six criteria that Morris (1955) considers important in the selection of a sampling unit. These are:

"1. In order for the sample to be representative of the universe, the sample unit should be of such a nature that all units in the universe have an equal chance of selection. This, of course, is a fundamental principal in sampling .....

2. The sample must have stability. That is, the number of units available to the insect population must not be affected by changes in growth habit of the plant caused either by intrinsic factors or by repeated insect damage.

3. The proportion of the insect population using the sample unit as a habitat must remain constant.

4. The sample unit should be reasonably small so that enough units can be examined on a given plot and date to provide an adequate estimate of variance. The other advantage of a small unit is flexibility, so that, after a certain amount of pilot sampling, the investigator will be able to choose the combination of units ..... that will assure the most economic allocation of sampling resources.

5. In absolute population work, where estimates of population per acre are required, the sampling unit must lend itself to quantative assessments of the number of units ..... per acre.

6. An important practical consideration is the facility with which the sample unit can be delineated in the field and collected without serious loss or disturbance of the insect population."

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Proc. Entomol. Soc. Manitoba Vol. 20 (1964)

THE FOREST INSECT AND DISEASE SURVEY IN MANITOBA AND SASKATCHEWAN

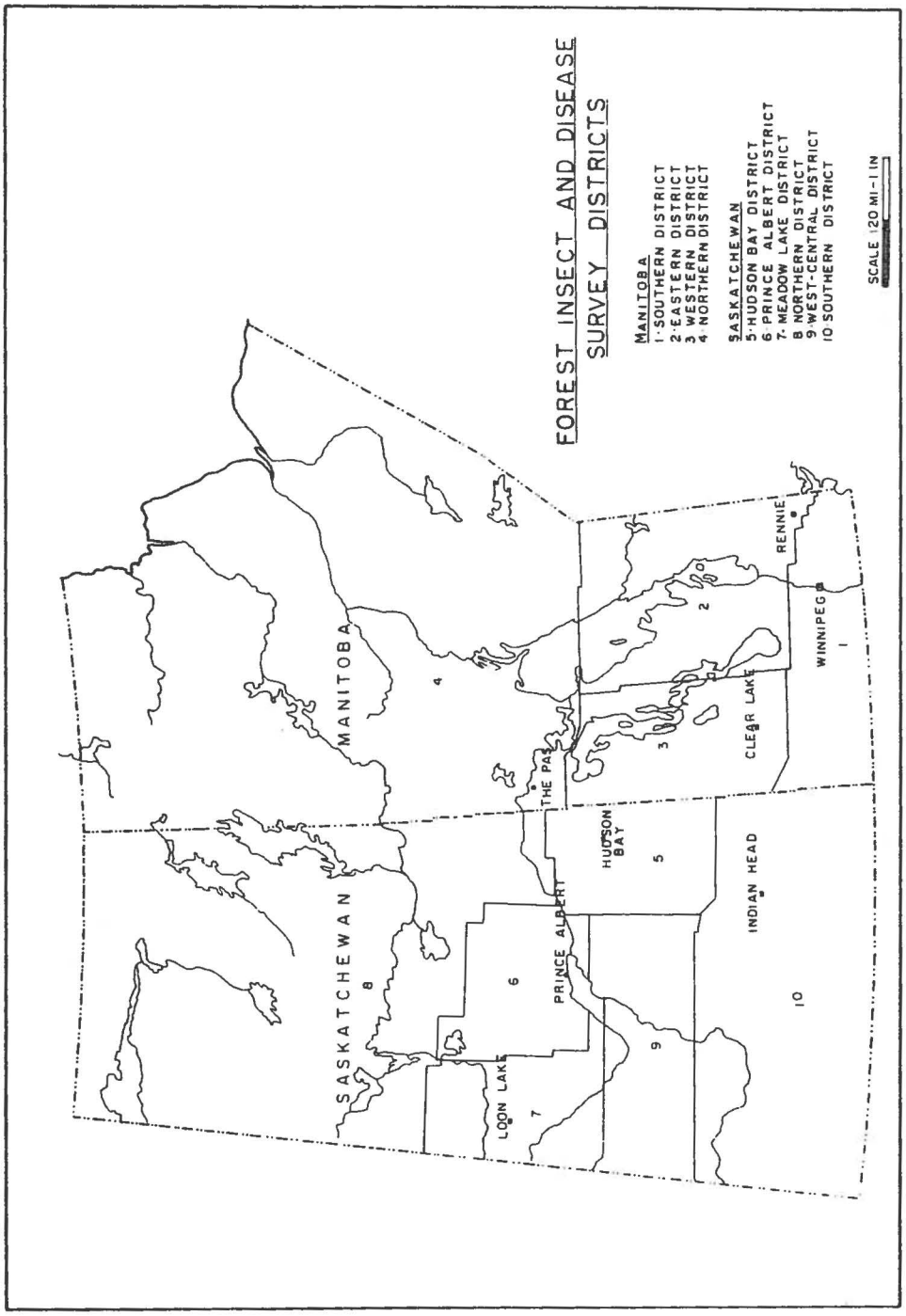
Ken R. Elliott
Head, Forest Insect and Disease Survey,
Forest Entomology Laboratory, Canada Department of Forestry,
Winnipeg

Introduction

The major responsibility for research and surveys of forest insects and diseases in Canada is vested in the Forest Entomology and Pathology Branch of the Canada Department of Forestry, of which the Forest Insect and Disease Survey is an integral part. Although a Departmental reorganization will soon eliminate the present branch structure, insect and disease investigations will be organized as they are now, in seven regions: Newfoundland (including Labrador); the Maritimes (New Brunswick, Nova Scotia and Prince Edward Island); Quebec; Ontario; Manitoba and Saskatchewan; Alberta (including the Yukon and the District of Mackenzie); and British Columbia. Also, the Survey will continue to operate as units within each of the regional establishments with objectives, basic procedures, and national projects coordinated through headquarters in Ottawa.

The original Forest Insect Survey was organized in 1936 as a unit of the Division of Entomology, Canada Department of Agriculture, for the specific purpose of determining the extent and damage of the European spruce sawfly outbreak in eastern Canada (McGugan 1956). Previous to this, however, it had been realized that a separate survey organization would prevent the serious and frequent disruption of research work that resulted when the officers concerned were required to carry out surveys in addition to, or in aid of, their research projects. Therefore, the Survey was broadened in ensuing years to include both forest insects and diseases in general, and extended to the other regions to become a national survey with these main objectives:- (1) to make annual appraisals of forest insect and disease conditions and effects, and to report on these in appropriate national and regional reports; (2) to collect and accumulate records on the identity, abundance, distribution, hosts, natural control, seasonal occurrence, and damage of forest insects and diseases, and make them available for regional and national compilations, reports, and publications; and (3) to carry out research on problems related to Survey functions either independently or in cooperation with other regional or national projects; this includes work on the development of specific sampling techniques as well as studies on the identity, life history, ecology, distribution, natural control, and cyclic abundance of some of the major pests.

This paper presents a brief description of the history, organization, operation, and results of the Manitoba-Saskatchewan Region of the Forest Insect and Disease Survey to exemplify the functioning of the national organization in carrying out the above objectives.


FOREST INSECT AND DISEASE
SURVEY DISTRICTS
MANITOBA
1 SOUTHERN DISTRICT
2 EASTERN DISTRICT
3 WESTERN DISTRICT
4 NORTHERN DISTRICT
SASKATCHEWAN
5 HUDSON BAY DISTRICT
6 PRINCE ALBERT DISTRICT
7 MEADOW LAKE DISTRICT
8 NORTHERN DISTRICT
9 WEST-CENTRAL DISTRICT
10 SOUTHERN DISTRICT
SCALE 120 MI-1 IN
MANITOBA
SASKATCHEWAN
RENNIE
WINNIPEG
CLEAR LAKE
THE PAS
HUDSON BAY
PRINCE ALBERT
INDIAN HEAD
LOON LAKE
1
2
3
4
5
6
7
8
9
10

Regional History

The Winnipeg unit of the Forest Insect Survey was established in 1941 at the existing Forest Insect Laboratory, and commenced full operations as a regional unit in 1943. It was initially responsible for surveys of the forested areas of Manitoba, Saskatchewan, and northwestern Ontario, but coverage of the last was dropped in 1944 and that for Alberta added. Since 1948, the unit has been responsible for surveys of the forested areas of Manitoba and Saskatchewan only; responsibility for the field collection of forest disease material for the Forest Pathology Laboratory at Saskatoon was added in 1951 (after the creation of the Forest Biology Division in the Department of Agriculture in 1950), and that for surveys of the shelterbelt and aspen grove areas was transferred from the Indian Head Laboratory in 1954. The first step in establishing a fully integrated Forest Insect and Disease Survey in this Region was made during the past summer with the appointment of Mr. John G. Laut to the Winnipeg staff as the Disease Survey Officer.

Organization and Operation

The Region is currently organized in ten districts (see map) and staffed by 3 research officers, 13 technicians, and 3 seasonal assistants. (The staff will eventually increase to 5 research officers, 17 technicians, and 4 seasonals as current plans for a fully integrated Survey are completed.) The research officers provide the supervision and research direction, and the technician and seasonal staff the material, records, and observations required in carrying out the main Survey objectives.

The field work is carried out in each District by a technician (Forest Insect and Disease Ranger) who operates from the field headquarters shown in the accompanying map and is under the general supervision of a "Chief Ranger". The latter is assisted by 3 of the senior rangers who, in addition to carrying out regular District duties, serve as Sub-regional Supervisors; they coordinate work in the sub-regions into which the districts are grouped, and carry out the actual field training and guidance of the rangers. Each Ranger spends almost six months in the field and carries out ground and aerial surveys in accordance with a general work plan (which he helps to prepare) and by techniques detailed in a field work manual that is kept up to date by the Chief Ranger. He is provided with living accommodation in the form of a cottage or trailer, with a station wagon or sedan delivery type vehicle, and with all other necessary equipment and supplies. Coverage of his District is accomplished mainly by vehicle, but inaccessible areas are reached by boat or aircraft. The latter are provided through charter contracts with commercial operators or by provincial air services. Large infestation or infection areas are usually defined by aerial sketch-mapping techniques supplemented by ground checks and collections of material. General detection surveys are based on the repetitive sampling of all tree species within selected "sampling areas" that are representative of the main forest types within each District. Samples of diseased tree material are nearly always obtained by "hand-picking" techniques that often involve the sectioning of the aerial parts of the tree, or the digging of roots. Samples, or mass collections of specific insect material are usually hand-picked, and in the case of bark beetles and wood borers this can also involve the sectioning of parts of the trees. However, the great majority of "general" insect samples are

ENCLOSURE SLIP

(All sections to be filled in by Forest Insect Rangers.
Sections 7-12, optional for general co-operators.)

1. Date: Day 15 Month 6 Year 1964
2. Collector L.L. McDOWALL No 02-00-0
   Co. or Service
   P.O. Address
3. Location of Collection Red Rock Block - Nisbet P.F.
   Grid 8-07E-31 County and Forest District 06
   Section or Forest Division 19 Township 49
   Range 25 Meridian W2 Elevation —
4. Tree Species jack pine 5. Type of Collection:
   No. Examined 5 (052) X 1. Beating
   Ave. D.B.H 5" 3. Hand Picked
   5. Ground
   7. Bark or Wood
   9. Frass
   11. Traps (X) Q
6. Perm. Sample Plot —
7. Aspect:
   X 1. Flat 6. S.
   2. N. 7 S.W.
   3. N.E. 8. W
   4. E. 9. N.W.
   5. S.E. 0. Unrecorded
8. Exposure:
   0. Unrecorded
   1. Shaded
   X 2. Partially Shaded
   3. Open
   4. Fringe
9. Were trees sampled representative of that species in the general stand?
   1. N.A 2. S. & I. X. 3.S 4. I.
10. Stand Form:
    1. Overmature
    2. Overmature (2-storied)
    3. Mature
    X 4. Mature (2-storied)
    5. Immature (pole)
    6. Reproduction
    7. Plantation
    8. Woodlot
    9. Old Field
    10. Shade Tree
    11. Nursery
    12. Doubtful
11. Stand History (recent):
    X 1. Undisturbed
    2. Clear Cut
    3. Selective Cut
    4. Burn
    5. Insect Killed
    6. Windthrown
    7. Flooded
    8. Grazed
    9. Doubtful
12. Cover Type jack PINE
13. Remarks: Generally small jP budworm and sawfly larvae. No visible defoliation

9'x9' sheet

SA 351
22472-VSM-157

18-6-64 1375

01 1 larva of the sawfly Neodiprion nanulus nanulus
5-13-03-08 0-1-0-0-1

02 2 larvae of the jack-pine budworm Choristoneura pinus
6-54-08-02 0-2-0-0-2

03 1 adult of the weevil Magdalis gentilis
1-23-37-08 0-0-0-1-1

Figure 1. - The basic Survey record. Left view shows the printed side as completed by the Ranger in the field, and right view shows the reverse side as completed in the laboratory.

obtained by the "beating method" which involves the use of a stick or pole to knock the insects from the branches to a cloth sheet placed below. A small 3' x 3' sheet mounted on a folding wooden frame is used for trees under 10' in height, and a 7' x 9' sheet for taller trees. The beating method is supplemented by the use of pole-pruners fitted with a cloth basket and the pruners are also used for special sampling techniques. The Ranger is responsible for the maintenance of permanent sample plots, the collection of material and records for specific projects, and for maintaining contact with representatives of Provincial and other forestry organizations in his district to encourage cooperation in the collection of material and to arrange facilities required in carrying out the work. The basic Survey record is the "Enclosure Slip" (Figure 1) which is completed every time a tree species is sampled, even when the sample is negative. Upon receipt at the laboratory, the material is identified and the information returned to the field man. This acknowledgement in the case of Rangers is typed or written on the back of a duplicate slip (Figure 1) and in the case of cooperators is typed on a special form designed for the purpose.

In this Region, the insect laboratory work includes the identification, rearing, and recording of submitted material and the transfer of resultant data to punch cards. It is carried out by a technician and seasonal staff under the supervision of a Senior Laboratory Technician. The rearing program is set up to provide adult material for identification and reference purposes, and special attention is given to the mass rearing of particular insects for parasite recovery. The Senior Laboratory Technician also identifies and records diseased insect material, and sometimes carries out short-term field assignments for specific projects. The laboratory work for forest disease material includes the identification, culturing, and recording of submitted material, and is carried out by a technician and a seasonal assistant. Collections are acknowledged in the same manner used for insect material and the information will be transferred to punch cards as soon as a suitable format is worked out. The Disease Survey Technician will also carry out short-term field assignments for specific projects.

The Insect Survey has employed Remington Rand tabulating equipment to record the information provided on each enclosure slip since 1951. The system employs the 90-column, double-bank card shown in Figure 2. All information from the back of the enclosure slip (the date, Survey number, and quantity, stage and name of the insect as shown in typewriting in Figure 1), is coded (shown in hand-writing) and entered in the first 23 columns of the upper bank of the card. Columns 46 to 84 on the lower bank contain the variables appearing on the face of the enclosure slip. The circled handwritten number opposite variable 4 in Figure 1 is the code for the host species shown. Columns 85 to 90 may be used to record the occurrences of insect diseases or parasites and the source of the insect determination. Columns 24 to 45 in the upper bank are not punched on this "host" card but are used to record the identity of parasites on a special "parasite" card on which all of the "host" information is repeated. A separate "host" card is required for each insect species in each collection. Each card is punched by one operator to obtain the single-hole pattern shown in the upper part of Figure 2 and then verified by a second operator who punches the same information to obtain the double-hole pattern shown in the lower part of the figure. Host and parasite cards are filed separately by year in special filing

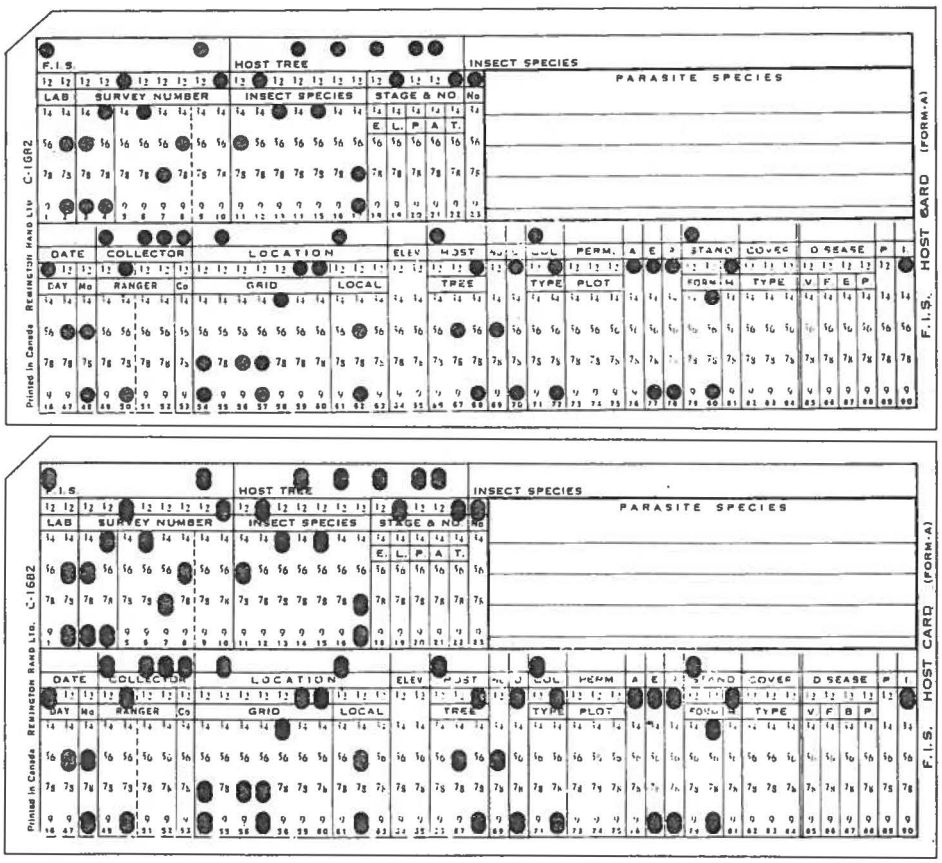


Figure 2. - A completed and verified (lower view) punch card containing the information entered on the enclosure slip shown in Figure 1.

cases. Sorting of the cards is accomplished by a card-counting sorter at the rate of 450 per minute which is suitable for summarizing data involving monthly and yearly totals according to source, location, species, stage, host, etc. However, more complex processes such as correlation analyses in regard to cycles of abundance require a computer and such services will be provided in the future by the Statistical Research Service of the Department in Ottawa.

Results

The results achieved in the Manitoba-Saskatchewan Region by carrying out the Survey objectives noted above are best illustrated by listing the reports and publications in which the results are, or have been, presented. In connection with the first objective: the published Annual Report of the Forest Insect and Disease Survey (Division of Entomology, 1936 to 1949; Division of Forest Biology, 1950; Forest Biology Division, 1951 to 1959; Forest Entomology and Pathology Branch, 1960 to 1963.) is a national summary of forest insect and disease conditions that is widely distributed both nationally and internationally. The mimeographed Annual District Reports (Forest Insect Laboratory, 1946 to 1950; Forest Biology

Laboratory, 1951 to 1960; Forest Entomology Laboratory, 1961 to 1963.) present the regional information in greater detail and are distributed mainly to other Departmental laboratories, and to appropriate forestry and agricultural agencies and to interested individuals in the Region. In addition, mimeographed "Monthly Summary" reports on current forest insect and disease conditions in the Region are prepared several times during the field season and distributed to interested organizations and individuals in the Region and throughout North America. In connection with the second objective: the main use to which accumulated records have been put to date is for a national compilation of forest Lepidoptera in four volumes (Forest Biology Division, 1958; Forest Entomology and Pathology Branch, 1962 and 1963; Canada Department of Forestry, 1965.). And in connection with the third objective: the results of research on problems related to Survey functions in this Region have been presented in a number of papers by Survey personnel directly (Elliott 1961; Hildahl and Reeks 1960; Lejeune and Hildahl 1954; Prentice 1955; Prentice and Campbell 1958; Turnock 1953; Wong 1951, 1954, 1955; Wong et al. 1959), and in cooperation with other projects (Blais et al. 1955; Cayford et al. 1959; Denyer and Riley 1964; Drouin et al. 1963; Ives and Prentice 1958, 1959; Nairn and Prentice 1960; Nairn et al. 1962; Reeks 1960; Riley 1951, 1953; Turnock and Melvin 1963; Whitney 1962). Many of these were listed in the history of forest entomology in Manitoba presented to the 1963 Annual Meeting of the Entomological Society of Manitoba by Webb (1963). In addition, numerous reports on Survey and cooperative projects have appeared in the widely-distributed Bi-Monthly Progress Report (published by the Can. Dept. Forestry since Jan. 1961, and by the Can. Dept. Agriculture from 1945 to 1960), and in various unpublished reports of the Forest Entomology Laboratory, Winnipeg, whose distribution is limited to Departmental laboratories and cooperating agencies or individuals.

In addition, enclosure slip records dating back to and including 1948 have been transferred to punch cards for a total accumulation of some 190,000 "host" and 5,000 "parasite" cards. Although they have been used mainly in summarizing data for use in seasonal and annual reports and in the preparation of the Lepidoptera compilation, they represent a valuable source of basic information on the occurrence and distribution of forest insects and their host associations. Each additional year makes them more valuable, and with the development of more refined and complex computer methods and the availability of associated data such as weather records on punch cards, their potential use from a biological point of view is indeed promising.

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Proc. Entomol. Soc. Manitoba Vol. 20 (1964)

THE OCCURRENCE OF CABBAGE MAGGOT ON RAPE IN MANITOBA AND EVALUATION OF INSECTICIDES FOR CONTROL

W. R. Allen
Research Station, Canada Department of Agriculture

Abstract

In 1958, the cabbage maggot Hylemya brassicae (Bouché) (Diptera: Anthomyiidae) was found on rape in Manitoba. There are two generations per year; the first adults are in flight about the end of June.

This species was recorded from varieties of Brassica napus L.; from B. campestris L. var. annua Reichb., var. sarson Prain, var. toria Prain; B. chinensis Jusl.; B. pekinensis (Lour) Rupr.; B. narinosa Bailey; B. nipposinica Bailey; B. juncea (L.) Coss.; B. nigra (L.) Koch; B. hirta Moench; Hesperis matronalis L. but not from Camelina sativa (L.).

The cabbage maggot was succeptible to the cyclodiene insecticides, heptachlor, aldrin and Telodrin. Organophosphate insecticides were not particularly effective. Included were azinphos-methyl, fenthion, carbophenothion, diazinon, dimethoate, ethion, Nemacide; as well, the carbamate, Bayer 39007. Bayer 25141 was moderately effective.

In 1958 the cabbage maggot was first found in Manitoba by B. R. Stephansson, on the roots of rape. The adults reared were identified by the late A. R. Brooks, Research Station, C. D. A. Saskatoon. This species was not then known to occur in Manitoba or Saskatchewan for Brooks (1951), Wishart (1957) and Kelleher (1958) indicated that it was not present and only Hylemya floralis (Fall.) occurred on rutabagas at Brandon and Dauphin. It is probable that when this insect was discovered it was well established in the Winnipeg district. An extensive acreage of cabbage has been grown for many years, but as this crop is transplanted prior to May 15th, it is not usually destroyed. However, intensive damage to summer turnips seeded at the end of May or to rutabagas, the main crop, which is planted during the second week of June requires control.

As resistance of the cabbage maggot to cyclodiene insecticides had been recorded (Harris, Manson and Mazurek 1962) for the Pacific coast and the eastern Canadian Provinces, the tolerance of this species to these insecticides was of interest. Accordingly, the effectiveness of commercially available organophosphate insecticides and new materials was evaluated for cabbage maggot control. This information is of interest now that the registration of heptachlor has been withdrawn for this use and the status of other cyclodiene insecticides is questionable.

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[1] Contribution No. 184, Canada Department of Agriculture, Research Station, Box 6200, Winnipeg 1, Manitoba.

Seasonal History

The cabbage maggot overwinters in the soil as a puparium. Adults emerge and are in flight by the end of June and the maggots appear on the roots of rape during the first week in July. The first generation pupates during late July in Manitoba, as indicated by the percent puparia which occurred in soil samples in the following years.

	July 21	22	24	26	27	28	29	Number of Maggots and Puparia
1959	19	41	43	--	61	81	90	1,363
1960	30	43	--	67	68	80	85	1,117

Probably two generations a year occur in Manitoba, for in 1961 well developed maggots and diapausing pupae were found on the roots in mid-October.

Brooks (1951) noted that H. cilicura (Rond.) occurs mainly in association with H. brassicae and other phytophagous root maggots. In 1959, it was determined that 58% of the adults reared belonged to the former species; while in 1960 all those reared were identified as H. brassicae. In 1960 a staphylinid parasite was reared from 14% of the puparia, which were in diapause.

Occurrence on Rapeseed, Mustards and other Cruciferous species

In 1959 root maggots were recovered from varieties of rape B. napus; from varieties of turnip rape B. campestris; annua, sarson, toria; and B. chinensis. They were particularly abundant on B. pekinensis, B. narinosa and B. nipposinica. They were also present on the mustard species, B. juncea, B. nigra and B. hirta. As well, they were recorded from the cruciferous species Hesperis matronalis but not from Camelina sativa. However, the distribution and abundance of the cabbage maggot and associated species, on commercial rape and cruciferous crops, is unknown for Manitoba.

Evaluation of Insecticidal Control

Materials and Methods

From 1960 to 1962, field plot tests were used to determine the tolerance of the cabbage maggot to cyclodiene insecticides and to evaluate several organophosphate insecticides. Plots of rape were arranged in randomized blocks in a field of silty clay loam at Ft. Garry, Manitoba. The plots were single 20 ft rows of rape. These were replicated four times in each block; the rows were spaced 1 ft apart. All insecticides used were granular formulations supplied by chemical companies. Insecticide granules and rape seed var. Golden, were applied to the seed furrows with a V-belt plot seeder. The granules were applied in quantities to provide the rates of active toxicant shown in Tables 1-3; rape was seeded at 5 lb per acre, between May 18 and 25 each year.

In 1960 the effectiveness of each insecticide was determined by sampling the root maggot population in late July, and by rating the amount of damage to roots contained in these samples (Table 2). Plants taken at random along the rows were cut-off just above ground level, and removed in a core of soil 4 inches

in diameter 4 inches deep, which contained the root maggots and roots present along the row. Eight samples per row were taken, placed in polyethylene bags, and stored at 60 F until examined. Maggots and puparia were retrieved from the silty clay soil by spreading it out in thin layers.

Root damage was rated according to a system derived from the method devised in British Columbia (King and Forbes 1954) for rutabagas. Root damage was categorized as follows:

Ratings	Category	Description of Damage
0	Clean	No evidence of root feeding.
1	Light	1- 4% of root surface scarred; healed over
2	Moderate	5-50% of root surface scarred.
4	Severe	over 50% of root surface scarred.

'Infestation indices' were calculated as described by Finlayson (1963). Percentage control was evaluated as the percent reduction in 'Infestation index' attributed to treatment. This procedure was shown to be valid for rape (Table 2) so it was used thereafter.

Results and Discussion

In 1960 and 1961 the cabbage maggot was evidently not resistant to heptachlor because 1 lb of hepatchlor gave excellent results and rates beyond 2 lb did not increase control (Table 1). To avoid a rapid increase in the resistance of this insect to heptachlor, the application of 12 lb of 20% granular per acre to the seed furrow, was suggested for the protection of turnip and rutabaga crops.

Table 1 Effect of Heptachlor rate on cabbage maggot infestations at Winnipeg

Heptachlor formulation	Actual insecticide lb. /acre	1960		1961	
		Infestation index	Control (%)	Infestation index	Control (%)
20% Granular	7.5	0.2	99		
5% "				1.6	96
20% Granular	5.0	0.2	99		
5% "				1.0	98
20% Granular	2.0	0.4	97		
5% "				1.3	97
20% Granular	1.0	1.7	89		
5% "				4.2	90
Untreated		15.5	--	43.0	--

The cyclodiene insecticides, heptachlor, aldrin and Telodrin were more effective than lindane and endosulfan and much more effective than the organophosphate and carbamate insecticides tested (Table 2, 3). Only Bayer 25141, at 2 lb per acre was moderately effective. Although diazinon was formulated on "Walnut Shell" in 1962 performance was not improved. Doubling the rate

of application of fenthion, Nemacide, diazinon and carbophenothion had no important effect. Ethion, dimethoate, azinphos-methyl, and the carbamate, Bayer 39007 were not effective.

Table 2 Effect of insecticides on cabbage maggot control at Winnipeg, 1960

Treatment	Actual insecticide lb./acre	Total No. of Maggots and Pupae	Control (%)	Infestation index	Control (%)
Heptachlor 20%	1.0	11	93	4	92
Aldrin 5%	1.0	19	88	6	86
Lindane 1%	1.0	30	81	15	68
Dieldrin 5%	1.0	89	44	27	42
Fenthion [a] 5%	1.0	90	43	26	42
Diazinon 2 1/2%	1.0	120	24	40	13
Ethion 5%	1.0	133	16	37	19
Dimethoate 5%	1.0	167	0	39	16
Carbophenothion[b] 5%	1.0	169	0	41	10
Endosulfan[b] 5%	1.0	188	0	48	0
Untreated	None	158	--	46	--

[a]Bayer 29493 supplied by Chemagro Corp. Kansas City, Mo.
[b]Trithion and Thiodan in order listed supplied by Chipman Chemicals Winnipeg, Manitoba.

Table 3 Effect of insecticides on cabbage maggot control at Winnipeg, 1961 and 1962

Treatment	Actual insecticide /acre	1961		1962	
		Infestation index	Control (%)	Infestation index	Control (%)
Heptachlor 5%	1.0	4	96		
Telodrin 5%	2.0	9	78		
	1.0	12	72		
Diazinon 5%	2.0	22	49	11	50
Fenthion 5%	2.0	22	49		
Nemacide[c] 5%	2.0	25	41		
Carbophenthion 5%	2.0	38	13		
Ethion 5%	2.0	38	12		
Bayer 25141 10%	2.0			6	74
Azinphos-methyl[d] 10%	2.0			14	39
Bayer 39007 5%	1.0			28	0
Untreated		43	--	23	--

[c]V-C_{13} supplied by Tiger Brand Chemical Co., Aldershot, Ont.
[d]Guthion supplied by Chemagro Corp., Kansas City, Mo.

It is important to note that the concentration of active insecticide applied to 1000 ft of row for rape was one half that now used for rutabaga crops. Accordingly, these tests on rape only provide comparison between insecticides at the rates of application used. With the higher concentrations used in the row to protect rutabagas Finlayson (1963) and Morris (1964) have shown that phytotoxicity may be serious. Therefore, more information on controlling cabbage maggot on rutabagas will be required in Manitoba.

Insecticide terminology conforms to "Common names for pest control chemicals" Canadian Standards Association, Z143, 1964. Chemical names for proprietary products referred to are as follows:

Telodrin: 1, 3, 4, 5, 6, 7, 8, 8-octachlor-1, 3, 3a, 4, 7, 7a, hexahydro-4, 7-methanoisobenzofuran.

Nemacide: (0-2, 4 dichlorophenyl 0, 0-diethyl phosphorothioate)
Bayer 25141: (0, 0-diethyl 0-p-(methylsulfinyl) phenyl phosphorothioate)
Bayer 39007: Baygon, (o-isopropoxyphenyl methyl carbamate)

Acknowledgement

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Proc. Entomol. Soc. Manitoba Vol. 20 (1964)

BEE RESEARCH IN THE DEPARTMENT OF ENTOMOLOGY

S. C. Jay
Department of Entomology, The University of Manitoba

Six research projects are currently underway, some of which are being done with the co-operation of the Manitoba Beekeepers Association which provides apiaries and material. These are:

(1) Orientation Behaviour of Honey Bees.

In commercial apiaries, where hives of one colour are often arranged in straight rows with their entrances facing one direction, the bees become "confused"and up to 30-50% will usually join other colonies at some time during their life. "Drifting" (as this behaviour is termed) of the bees occurs in certain patterns which require considerable time and labour on the part of the beekeeper to correct.

Methods of preventing "drifting" are being examined using marked bees in apiaries, where (1) coloured boards are put above colony entrances, (2) hives are faced in different directions, or (3) where various apiary designs are used. To date it has been found that facing hives in different directions in rows or arranging hives in snake-like patterns reduces "drifting" to the greatest extent. At least 5-20 pounds more honey per colony has been obtained when drifting has been reduced to a minimum.

Behaviour studies of marked bees at hiving in spring have shown that "drifting" of bees between colonies is a small problem compared to the number of bees that enter no colony but fly out of the apiary and are lost (up to 50% in some situations). Ways of preventing loss of bees from apiaries at this time are being tested.

(2) Queen Losses after Hiving.

Annually, about 140,000 packages of honey bees are imported from the U. S. A. into Canada, and often 10 to 15% of the queens in these packages die at some time after hiving. American shippers of package bees and Manitoba beekeepers combined to test a new wide mesh queen cage as a means of shipping queens in packages of honey bees. Various features of the cage appear to make queen introduction both safe and easy: In addition, the queen appears to be better fed before her release, and better accepted after her release. Other factors affecting queen losses are also being studied, e. g. disease, mating problems, handling, queen rearing and queen storage.

(3) Caste Differentiation and Laboratory Rearing.

Techniques are being developed to study the development of the larvae of queens and workers under controlled laboratory conditions. The natural diets are being altered and extracts of honey bee pheromones are being used in the diets.

(4) Miniature Colonies

A Ph. D. candidate, Mr. Eric Nelson, is attempting to establish and maintain colonies of bees consisting of a queen with 100-300 bees of specific ages. Trials have been fairly successful. Temperature has been shown to be critical and ways of artificially heating the hives are being studied. With the reduced number of bees certain studies will be facilitated (e.g. division of labour, queen behaviour, innate and adaptive behaviour etc.).

(5) Bumble Bee Research

Mr. Christopher Plowright, a Ph. D. candidate is attempting to mate bumblebees in large indoor cages and subsequently have them establish nests in the laboratory with a view to releasing large numbers of fertile queens on specific dates for pollination purposes. His studies also include aspects of caste - differentiation and field behaviour.

(6) Bee Flight and Rearing Room

This room, which is part of the Bee Research Laboratory, has already provided (a) adult bees and brood year round for research, teaching, and demonstrations: (b) accommodations for the development of techniques during winter months for use during the short outdoor research season, and (c) the material and environment for studies which can only be done under controlled conditions. Mr. Nelson describes one of the tests he is conducting in this room in another article in this issue.

Proc. Entomol. Soc. Manitoba Vol. 20 (1964)

PRELIMINARY OBSERVATIONS ON THE CYCLIC ACTIVITY OF HONEY BEES IN A FLIGHT ROOM

E. Nelson
Department of Entomology, The University of Manitoba

Abstract

Preliminary studies of the flight activity of honey bees under controlled conditions suggest the presence of a daily activity cycle on which shorter temperature-dependent cycles may be superimposed.

A bee flight and rearing room, having dimensions of 9 x 9 x 17 ft, was completed at The University of Manitoba in 1962 as part of the Bee Research Laboratory. Temperature can be maintained from 10 to 33C within ± 1C and relative humidity from 40 to 80% within ± 5%. Lighting is controlled by three time switches which simulate twilight, each turning off 1/3 of the lights in sequence. Lights are turned on at 0800 hours and the last bank of lights goes off at 2030 hours (see Jay 1964). The room has since been partitioned into three sections using screened panels to give: (1) a large flight area 9 x 9 x 10 1/2 ft, (2) a small flight area 9 x 3 x 6 1/2 ft, and (3) a work area 9 x 6 x 6 1/2 ft.

It was observed that bees in the room show periods of intense flight activity alternating with periods of slight activity. A study was begun to determine the significance of these activity periods. For this study conditions were usually maintained at 24 ± 1C and 45 ± 5% relative humidity.

In the initial experiments, flight activity in the large flight area was recorded by amplifying the flight sounds and recording them on a Heathkit 20A servo recorder. In addition, counts of flying bees were made by means of photoelectric cells and counters. A very close correlation was found to exist between the number of flying bees and the volume of flight sound.

Examination of the recordings showed a daily cycle of activity which began when the lights came on at 0800 hr, reached a peak slightly after 1200 hr and gradually decreased until at 2030 hr (when the lights were turned off) there were practically no bees flying.

When the temperature of the room was allowed to cycle from a low of about 20.5C to a high of about 28C and back to 20.5C during a one hour period, it was found that flight activity of the bees closely followed these temperature cycles (Fig. 1). There was a short delay, however, in the flight activity reaction to temperature. These hourly cycles were superimposed over the daily cycle discussed above.

Therefore, it appears that honey bees in a flight room have a daily cycle of activity on which shorter temperature-dependent cycles can be superimposed.

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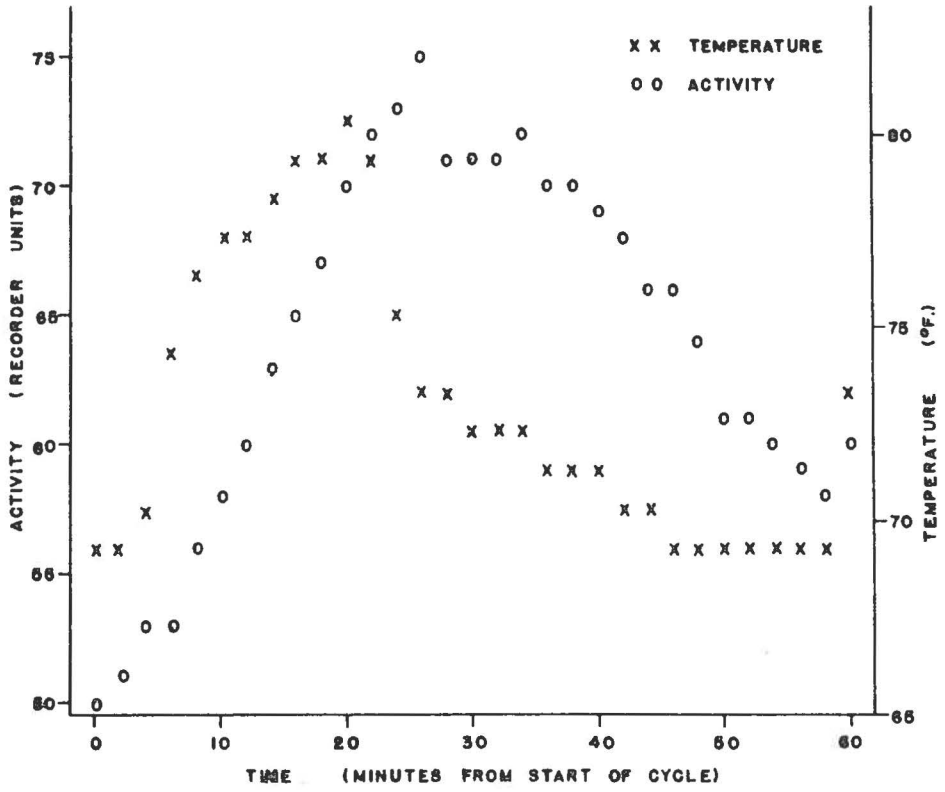

Figure 1. - Comparison of temperature and honey bee flight activity cycles during a 60 minute period in a bee flight room.

Proc. Entomol. Soc. Manitoba Vol. 20 (1964)

THE BIOLOGICAL CONTROL PROGRAM AGAINST THE LARCH SAWFLY [1]

J. A. Muldrew
Forest Entomology Laboratory, Canada Department of Forestry
Winnipeg

There is considerable evidence favoring the view that larch sawfly, Pristiphora erichsonii (Hartig), (Hymenoptera: Tenthredinidae) was relatively recently introduced into North America from Europe. If this is true the prospects for achieving success through biological control are high. Entry via the Bering land bridge during the Pleistocene is unlikely as it supported only tundra vegetation. An earlier entry during the Tertiary is unlikely as it implies that not only the larch sawfly but two species of its parasites, whose European and American populations are also identical, have not evolved during approximately six million years of isolation.

The parasite Mesoleius tenthredinis Morley was introduced from England into Canada in the years 1910 to 1913 and at first was highly successful. A loss of effectiveness in Canada was first noted in Manitoba about 1940 and was found to be associated with the encapsulation of parasite eggs by the blood cells of the host. Since then outbreaks of the resistant larch sawfly have occurred over a progressively larger area that now extends from New Brunswick to the western limit of tamarack in British Columbia.

The resistant strain of larch sawfly in Canada may have arisen due to a mutation appearing spontaneously in several regions or through the spread of the resistant strain from a locus in Central Canada. This strain may have been introduced from England in 1912 and 1913 with the release of M. tenthredinis because these releases were made by placing out imported larch sawfly cocoons, some of which were not parasitized.

Evidence from infestation maps suggests that the larch sawfly can disperse at a rate of about 60-70 miles in a year in forested regions and can find isolated plantations at least 100 miles from other host stands. This evidence supports the hypothesis that the resistant strain has spread from a locus.

Recent experiments have indicated that M. tenthredinis from Bavaria have a greater ability to avoid or overcome encapsulation in resistant Canadian larch sawfly than the 'native' M. tenthredinis. Hybridization experiments indicate that this characteristic of the Bavarian form is transmitted as a dominant factor. Releases of the Bavarian strain have been made in Manitoba to test the possibility that a more effective strain of this parasite will arise through natural selection acting on a population having a greater degree of genetic variability than existed prior to the releases of the Bavarian M. tenthredinis.

Six species of parasites, five from Europe and one from Japan, have been released during the recent biological control program against the larch sawfly in Canada. One of these, Holocremnus sp. nr. nematorum (Tschek), is now well established at two locations in Manitoba. Intensive studies to estimate its impact and spread are continuing.

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1 A summary of a paper delivered at the fall meeting of the Entomological Society of Manitoba, November 20, 1964.

APPENDIX I

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Winnipeg 1, Manitoba

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717 Norquay Building
Winnipeg 1, Manitoba

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Winnipeg 1, Manitoba

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Hanec, Wm. Dept. of Entomology, The University of Manitoba, Winnipeg 19.

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Jay, S. C. Dept. of Entomology, The University of Manitoba, Winnipeg 19.

Kolach, A. Manitoba Dept. of Agriculture, Norquay Building, Winnipeg 1.

~~Liscombe~~, E. A. R. Canada Agriculture Research Station, Box 6200, Winnipeg 1.

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Peschken, D. Entomology Research Institute for Biological Control, Belleville, Ontario.

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Riess, C. H. 877 Wall Street, Winnipeg 10.

Richardson, H. P. Canada Agriculture Research Station, Box 6200, Winnipeg 1.

Robertson, D. R. Manitoba Dept. of Agriculture, Norquay Building, Winnipeg 1.

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Romanow, W. Canada Agriculture Research Station, Box 6200, Winnipeg 1.

~~Sellen, R.~~ Canada Agriculture Research Station, Box 6200, Winnipeg 1.

Sinha, R. A. Canada Agriculture Research Station, Box 6200, Winnipeg 1.

Smith, D. L. Manitoba Dept. of Agriculture, Norquay Building, Winnipeg 1.

Smith, L. B. Canada Agriculture Research Station, Box 6200, Winnipeg 1.

Thorsteinson, A. J. Dept. of Entomology, The University of Manitoba, Winnipeg 19.

Turnock, W. J. Forest Entomology Laboratory, Box 6300, Winnipeg 1.

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Watters, F. L. Canada Agriculture Research Station, Box 6200, Winnipeg 1.

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Westdal, P. H. Canada Agriculture Research Station, Box 6200, Winnipeg 1.

Wong, H. R. Forest Entomology Laboratory, Box 6300, Winnipeg 1.

APPENDIX III

FINANCIAL STATEMENT AS OF NOVEMBER 12, 1964.

Balance as of November 20, 1963		$ 424.91
Receipts		
Dues, ENTOMOLOGICAL SOCIETY OF CANADA	$ 328.00	
Dues, ENTOMOLOGICAL SOCIETY OF MANITOBA	102.00	
Refund from ESC Centennial Fund	21.47	
Interest on Savings Account	11.70	
Total Receipts	$ 463.17	$ 463.17
		$ 888.08
Expenditures		
Dues, ENTOMOLOGICAL SOCIETY OF CANADA	$ 328.00	
Postage	15.00	
Cost of Proceedings	40.37	
1963 Annual Meeting (coffee)	19.60	
Spring Banquet (Gratuities and Entertainment)	21.15	
Bank (Service Charge)	6.00	
Outstanding Cheques	10.27	
Total Expenditures	$ 440.39	$ 440.39
Balance		$ 447.69
Bank Balance		
Current Account		$ 6.10
Savings Account		$ 441.59
		$ 447.69

Submitted by M. A. Ashraff, Treasurer.

Audited by A. G. Robinson and P. H. Westdal.

APPENDIX IV

ADDITIONS TO THE LIBRARY OF THE ENTOMOLOGICAL SOCIETY OF MANITOBA

Acta entomologica musei nationalis Pragae. Suppl. 5, 1964.

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