PROCEEDINGS OF THE

ENTOMOLOGICAL SOCIETY OF MANITOBA

VOLUME 15

1959

NOTE

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Entomological Society of Manitoba
c/o Regional Librarian
Canada Agriculture Research Station
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Winnipeg, Manitoba

Wm. Hanec
Editor-Librarian

Proceedings of the

ENTOMOLOGICAL SOCIETY OF MANITOBA

Vol. 15 1959

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*Life member

ENTOMOLOGICAL SOCIETY OF MANITOBA FINANCIAL STATEMENT

FOR THE YEAR ENDING DECEMBER 31, 1959

Receipts

Balance on hand, Dec. 31, 1958		$ 253.12
Members' dues, 1958		1.00
Members' dues, 1959		117.00
Members' dues, 1960		228.00
Registration 1959 spring meeting	11.00	
Sale of tickets for banquet	58.00	69.00
Sale of 1959 fall meeting banquet tickets		114.00
Sale of Proceedings		2.50
Bank interest		3.48
Cheques outstanding		150.00
		$ 938.10

Expenditures

1958 cheques outstanding cancelled	$ 102.00
Subscriptions to Ent. Soc. of Canada	246.00
Spring meeting 1959 expenses	66.00
Fall meeting 1959 expenses	164.20
Banking expenses including exchange	8.93
Stationary and stamps	2.90
Cost of Proceedings	25.00
E. J. Stansfield Memorial Fund	10.00
Cash on hand	18.15
Bank balance on hand, Dec. 31, 1959	294.92
	$ 938.10

Audited and found correct - Jan. 11, 1960
E. A. R. Liscombe
D. R. Robertson

Proceedings of the

ENTOMOLOGICAL SOCIETY OF MANITOBA

Vol. 15 | A society to foster the advancement, exchange and dissemination of entomological knowledge | 1960

INTRODUCTION

The publication of these proceedings culminates another successful year for the Entomological Society of Manitoba. Following the trend of recent years the spring meeting was limited to a business session and banquet with emphasis on a good scientific session at the annual meeting. The scientific program for the fall meetings was designed to cover a wide variety of interests in order to attract people from other disciplines for a consideration of mutual problems. This proved highly successful as was evidenced by the very large attendance and interesting discussions at all sessions. The highlight of an extremely fine banquet held in the evening at Zoratti's was the outstanding illustrated travelogue given by Dr. R. D. Bird on his recent trip to Africa.

I am very pleased to acknowledge the contribution to the program made by Dr. R. K. Chapman, University of Wisconsin, Mr. E. F. Bossenmaier, Game Biologist, Province of Manitoba, Dr. W. E. Sackston and A. L. D. Martin, Canada Agriculture Research Station, Winnipeg, and also to those members of our society who participated in the program.

I wish to thank the University of Manitoba for the use of their splendid auditorium which contributed largely to the success of the meetings. I appreciate greatly the fine co-operation and assistance given me by the executive and others who contributed towards the very successful year for the Entomological Society of Manitoba.

P. H. Westdal
President

SPRING MEETING

Business Session

The spring meeting of the Entomological Society of Manitoba, under the chairmanship of the President, P. H. Westdal was held on April 17, 1959, in the Auditorium of the Agriculture Building, University of Manitoba, Winnipeg, Manitoba.

Minutes: The minutes of the annual meeting of November 27-28, 1958, were read by the Secretary and adopted as read on a motion by W. G. H. Ives and W. R. Allen.

Business arising out of minutes:

1. Honorary membership.

Moved by F. L. Watters, seconded by W. Romanow, that R. D. Bird, A. J. Thorsteinson and A. G. Robinson be appointed as a committee to investigate the qualifications of Professor A. V. Mitchener and Mr. J. B. Wallis for honorary membership in the Entomological Society of Canada.

Following discussion, it was pointed out by R. M. Prentice that a strong supporting statement was required.

An amendment to the above motion to the effect that the Regional Director's name be added to the above committee was made by W. J. Turnock and seconded by W. Romanow. Carried.

Report of the Editor - S. R. Loschiavo: The 1958 Proceedings are now ready for publication and should be ready for distribution within two or three weeks. In the past year we received several requests for back copies. Available ones were sent out at $1.00 each. Unfortunately some of the orders came through book selling brokers and we did not know what person or institution made the request. We started an exchange of publications with the Pest Infestation Laboratory of the Department of Scientific and Industrial Research at Slough, England and recently received from them copies of their Annual Report for the years 1947-56. The University of Nebraska Library is sending us all the publications of the University of Nebraska College of Agriculture on an exchange basis.

A motion at the fall meeting called for the new Executive to investigate the possibilities of a new format for the Proceedings and financial support for a printed journal. In accordance with this motion the new Executive has appointed an Editorial Committee consisting of- R. M. Prentice, R. J. Heron, A. G. Robinson, W. R. Allen and S. R. Loschiavo. This Committee intends to discuss fully the future of the Proceedings and to consider how it may best serve the members of the Society.

The Editor's report was adopted on a motion by S. R. Loschiavo and R. M. Prentice.

On a motion by S. R. Loschiavo and L. D. Nairn it was agreed that Mr. Byron Snead and Miss Lorretta Veltri be presented an honorarium as in the past.

Report of Common Names Committee: Nil.

Report of the Treasurer - L. D. Nairn:

Financial Statement as of April 16, 1959.

Debits

Bank charges	$ 3.36
Typing of Proceedings	25.00
Receipt book	.35
Chan's Cafe (Banquet deposit)	15.00
	$43.71

Credits

Bank balance December 31, 1958	$ 151.12
Annual dues 1959	20.00
Sale of Proceedings	1.25
	$ 172.37
Bank Balance	$128.66

The Treasurer's report was adopted on a motion by L. D. Nairn and H. R. Wong.

On a motion by L. D. Nairn and R. M. Prentice it was agreed a change in by-laws be made, whereby the annual dues for membership in The Entomological Society of Manitoba be increased from $1.00 to $2.00.

New Business: L. D. Nairn advised members of Mrs. Stansfield's wish that the Entomological Society of Manitoba handle the Stansfield Memorial Fund, to which $183.00 have been contributed to date, and stated that it was felt that the Entomological Society of Manitoba should contribute to this fund. A. G. Robinson stated that A. J. Thorsteinson proposes to buy some instrument for meteorological observations.

It was moved by L. D. Nairn and seconded by W. J. Turnock that the Entomological Society of Manitoba donate a sum of money to the E. J. Stansfield Memorial Fund.

On an amendment by W. A. Reeks and W. Romanow it was agreed that the Entomological Society of Manitoba donate $10.00 to the E. J. Stansfield Memorial Fund.

The meeting adjourned on a motion by H. R. Wong and J. S. Kelleher.

In the evening the members accompanied by their wives and friends met at Chan's Restaurant for dinner and a social evening.

CONSTITUTION AND BY-LAWS OF THE ENTOMOLOGICAL SOCIETY OF MANITOBA

Revision of By-laws: A revision of the following By-laws was approved at the meeting of the Entomological Society of Manitoba on April 17, 1959.

By-law 1. Section a)

to be changed from,

The annual fee for full members shall be $1.00

to,

The annual fee for full members shall be $2.00.

FALL MEETING

Business Session

The fall meeting of the Entomological Society of Manitoba, under the chairmanship of the President, P. H. Westdal was held on November 5-6, 1959, in the Auditorium of the Agriculture Building, University of Manitoba, Winnipeg, Manitoba.

Minutes: The minutes of the spring meeting of April 17, 1959, were read by the Secretary and adopted as read on a motion by W. G. H. Ives and T. V. Cole.

Business arising out of minutes:

1. Honorary membership.

P. H. Westdal reported that nominations, together with supporting documents, for honorary membership had been forwarded to the Entomological Society of Canada on behalf of Professor A. V. Mitchener and Mr. J. B. Wallis.

2. E. J. Stansfield Memorial Fund.

The Secretary read a letter of thanks from Mrs. Stansfield.

Report of the Editor - S. R. Loschiavo: The 1959 Proceedings was ready for distribution shortly after the spring meeting. Fifty-four copies were sent to members, 48 to individuals and institutions on the mailing list and a few were complimentary. Three copies were sent to Dr. Prebble, at his request, for inclusion in the exhibit of Canadian Entomological publications at the joint meetings of Entomological Societies of Ontario, Canada, and America, to be held at Detroit within a few weeks. It is hoped that this exhibit would encourage membership in the various societies.

Publications received during the past year by the Society's library, have been catalogued and are available upon request to the Regional Librarian at the Canada Agriculture Research Station. Since the spring meeting an exchange of publications was arranged with the Agricultural Research Service of the United States Department of Agriculture at Fort Valley, Georgia.

I wish to recommend that the incoming Editor investigate the possibility of having the next Proceedings typed on an electric typewriter prior to processing for publication. It makes a neat job and will greatly improve the appearance of the Proceedings.

The portion of this report concerning the format of the Proceedings and kind of material to be accepted for publication is adequately covered in the Editorial Committee's report presented by Mr. Prentice. I might add that we encourage contributors to submit progress reports or abstracts of their current work even though the full context of their work is to be published in a scientific journal.

The Editor's report was adopted on a motion by S. R. Loschiavo and W. Romanow.

Report of the Common Names Committee - H. R. Wong:

The common name "the hairy mite" was proposed for Glycyphagus destructor (Schrank) (Glycyphagidae: Acarina) by R. N. Sinha.

It was reported that Professor A. V. Mitchener had been succeeded as Chairman of the Committee on Common Names of Insects by F. O. Morrison.

S. R. Loschiavo was appointed the local Common Names Committee's proxy at the Detroit meetings.

H. R. Wong moved adoption of the report as read. Seconded by E. A. R. Liscombe. Carried.

Report of the Treasurer - L. D. Nairn:

Financial statement as at November 5, 1959

Debits

Bank charges	$ 3.00
Chan's banquet 2.00 x 30	60.00
Chan's Cafe staff gratuity	6.00
E. J. Stansfield Memorial Fund	10.00
	$79.00

Credits

Bank balance April 16, 1959	128.66
Annual dues, 1959 (2 x 1.00)	2.00
Chan's Cafe (return of deposit)	15.00
Registration spring meeting (22 x .50)	11.00
Sale of banquet tickets (29 x 2.00)	58.00
	$ 214.00
Bank Balance	$135.66

The Treasurer's report was adopted on a motion by L. D. Nairn and C. H. Buckner.

Tenth Annual Meeting of the Entomological Society of Canada, Saskatoon, 1960:

The membership was asked to express an opinion concerning the date, September 10 to 16, since this date is considerably earlier than usual. The meeting went on record as having no objections to this date.

Proposed Affiliation of the Entomological Society of Canada with the Canadian Federation of Biological Societies:

The Regional Director, R. M. Prentice, outlined the following points in favor and against affiliation:

Pros:

1) Reduction in conference travel - all groups meeting together - convenient meetings.

2) Persons of specific disciplines would be brought together, but from different societies.
3) Unless the Canadian Entomological Society affiliated there was some indication that certain disciplines within the Society would join the federation on their own.
4) If the Society joined now it could help develop by-laws and policies.
5) The Federation would provide a strong national voice for biologists.

Cons:

1) There was an attendance of 350 persons at the last meeting. This represented only four constituents. With the proposed affiliation attendance could be expected to increase to between 1000 to 1500. Only four cities could accommodate such a large group.
2) Fees could not be expected to remain at $3.50. Increased membership would probably increase fees. Eventually a paid manager would likely be required to handle federation business.
3) Unless centralized in Ottawa, committees would find it difficult to function.

R. M. Prentice then outlined the history of the affiliation of regional societies with the national society and pointed out that the proposed affiliation of all biological societies might be the next logical step. National meetings of this federation might facilitate joint regional meetings.

Following a lengthy and spirited discussion, which indicated a lack of information, it was moved by L. D. Nairn and seconded by W. J. Turnock that the Entomological Society of Manitoba do not support affiliation of the Entomological Society of Canada with the Canadian Federation of Biological Societies. Carried.

Report of the Special Library Committee - R. M. Prentice:

Following the 1958 fall meeting a special committee consisting of R. M. Prentice, S. R. Loschiavo, W. R. Allen, A. G. Robinson and P. H. Westdal was appointed to review the policy and some of the problems of processing the Proceedings of the Entomological Society of Manitoba. The Committee met on October 16 and the following proposals have been put fort:

1) It is impractical for the Manitoba Society to consider publishing a separate proceedings at an estimated cost of $400.00 a year. The chairman of the Alberta and Saskatchewan societies were sympathetic to a joint publication from the prairie regions, but felt that the costs were prohibitive. It was generally agreed by the committee that the proceedings in its present form was a satisfactory outlet for papers presented at annual meetings.
2) Material published in the proceedings is indexed by a number of journals. Authors who plan to publish papers presented at our scientific sessions should keep this in mind and to avoid duplication only abstracts should appear in the proceedings.
3) The annual processing of proceedings is the responsibility of two regional research laboratories. Responsibility will alternate between the two laboratories.

The report was adopted as read on a motion by R. M. Prentice and S. R. Loschiavo.

Proposed Publication by Mr. J. B. Wallis:

Discussion led by R. D. Bird regarding assistance by the Society in the publication of an outstanding paper on Tiger Beetles by Mr. J. B. Wallis resulted in a motion by W. R. Allen and Wm. Hanec suggesting that Dr. Bird continue his negotiations between Mr. Wallis and Dr. Ball and bring the matter up at the spring meeting. Seconded by Wm. Hanec. Carried.

W. R. Allen recommended that the executive assist in every way possible in the publication of this paper.

Report of the Nominating Committee - W. R. Allen:

Honorary President	- A. V. Mitchener
Past President	- P. H. Westdal
President	- A. G. Robinson
President-Elect	- R. J. Heron
Secretary	- S. R. Loschiavo
Treasurer	- W. B. Fox
Editor	- Wm. Hanec

In a response to a call for nominations from the floor it was moved by W. A. Reeks, seconded by H. R. Wong that nominations cease. Carried.

P. H. Westdal thanked the executive for their assistance during his term of office as President.

The incoming President, A. G. Robinson, then declared the meeting adjourned.

Scientific Session

The scientific session of the annual meeting was held in the Auditorium of the Agricultural Building, University of Manitoba on November 5-6, 1959. The program covered some aspects of virus transmission by insects food contamination by insects and the effect of insecticides on wildlife. The various papers presented, together with a paper on early Entomology in Manitoba, are reported on the following pages.

SOME FACTORS AFFECTING THE INSECT TRANSMISSION OF PLANT VIRUSES

R. Keith Chapman
Department of Entomology
University of Wisconsin

Most cultivated plants are affected by plant viruses. These plants may be susceptible to only one or a few viruses or with such crops as tobacco and potato to 25-30 or more. By far the greatest majority of plant viruses are transmitted in nature by insect vectors. Many insect-transmitted virus diseases are very destructive to the infected plants and cause a great deal of economic damage. In Wisconsin for instance, aster-yellows virus transmitted by the six-spotted leafhopper is the limiting factor in the production of head lettuce, celery and asters. Infection as high as 100 percent has been observed in these crops with a resulting total loss to the grower. This same virus has infected carrots to the extent of 95 percent and potatoes 75 percent with resulting crop losses of 50 percent or more. Other viruses such as cucumber mosaic, the cabbage mosaics, potato mosaic Y and many others are not as spectacular as far as symptoms are concerned but are often prevalent and take a considerable toll of the crops.

The method of insect transmission of plant viruses varies considerably depending on the viruses and vectors involved. In addition the plant virus-host plant-insect vector relationship frequently is quite complex and involved particularly under the variable ecological conditions encountered in the field. It is the purpose of this paper to discuss some of the factors involved in the process of insect transmission of plant viruses in the field and laboratory.

In order to reduce the amount of misconception that might result otherwise, it is felt that some explanation of terms to be used might be advisable at this time. The following terms describing the relationship between virus, vector and host plant are for the most part similar to those used by Sylvester (1949, 1954).

Acquisition feed: The time that a noninfective vector is fed on a virus source.

Inoculation feed: The time that an infective or viruliferous vector is fed on a healthy recipient. (Sylvester uses the term "test feeding" which is felt to be less descriptive than inoculation feed.)

Acquisition threshold: The minimum time for a vector to feed upon a virus source in order to obtain an infective charge of the virus.

Inoculation threshold: The minimum time necessary for an infective or viruliferous vector to feed upon a healthy plant in order to successfully inoculate the virus into the plant.

Transmission threshold: The minimum time required for a vector to acquire and to inoculate a virus. (In theory this is the sum of the acquisition and inoculation thresholds, but in practice more time is required for transfer of the vector and for penetration to begin.)

Latent period: The time that must elapse before a vector can be demonstrated to be infective after surpassing the acquisition threshold. This has also been called "incubation period".

Retention period: The period of time that a vector, after acquiring the virus, can still be demonstrated to be infective.

Pre-acquisition fast or starvation: The period of time previous to the acquisition feed during which a vector is not allowed access to a food source.

The transmission of plant viruses by insects exhibits a wide range of patterns. For many years the different types of insect transmission were divided into two categories - mechanical transmission and biological transmission. As the name implies, the mechanical transmission was thought to be a mechanical transfer of the virus on the vector's mouthparts from one plant to another. There was thought to be relatively little specificity among viruses and vectors and the latter could quickly acquire and inoculate the virus. The biological transmission was one in which it was felt there was some obligate relationship between the vector and the virus. Between the acquisition and inoculation processes there was an incubation period during which transmission could not take place and it was assumed that the virus was multiplying, undergoing some stage of development or being translocated in the vector's body. In this type of transmission the vector remained infective for long periods of time if not for life.

More recently Watson and Roberts (1939) introduced the idea of using the length of time that the vector retained the ability to transmit the virus as a more reliable characteristic to be used in classifying transmission processes. They used the terms nonpersistent and persistent to indicate respectively a short (less than a day) or lengthy retention of transmissible virus by the vector. Between these two more or less extreme categories lies a group of viruses termed semipersistent by Sylvester (1956) which exhibit some characteristics of both persistent and nonpersistent viruses.

A nonpersistent virus such as cucumber mosaic or potato mosaic can be acquired by the vector (usually from the epidermis) during a very short (5 to 30 seconds) acquisition feed and can be transmitted immediately during a similarly short inoculation feed. The efficiency of transmission is usually increased if the vector is starved prior to acquisition, and prolonged acquisition feeding usually results in reduced transmission. The vector remains infective for only a short time (minutes to hours). Most nonpersistent viruses have several vectors and they usually can be transmitted with ease by mechanical sap-inoculation.

In contrast, a persistent virus such as aster-yellows virus is characterized by somewhat longer acquisition and inoculation thresholds and there is usually a latent period. Acquisition is usually from the mesophyl or phloem tissues and fasting before acquisition or prolonged acquisition feeding has no effect on the transmission efficiency. The vector retains the ability to transmit the virus for long periods, usually for life. The virus can not be mechanically sap-inoculated as a rule and there is often a high degree of vector specificity.

As indicated before, some viruses such as beet mosaic and cauliflower mosaic cannot be grouped readily into the above two categories. These viruses have some characteristics of both persistent and nonpersistent and as previously mentioned have been called semipersistent. These viruses are most efficiently acquired from the mesophyl or phloem tissue. Pre-acquisition starvation has no effect on transmission but prolonged access feeding does increase its efficiency. No latent period is apparent and the virus is retained by the vector for periods intermediate in length (hours to days) to that of persistent and nonpersistent viruses. As with most of the other characteristics of these viruses the specificity of the vectors and viruses is also intermediate to that of the other types.

From these brief descriptions of the various types of transmission it can be readily seen that many factors affect the transmission of plant viruses by insects. In addition to those mentioned above there are numerous other elements which contribute to variations in the transmission process, a few of which are as follows: the number of acquisition feeds; normal or forced termination of feeding; many ecological conditions of which temperature is a prime factor; the life stage of the vector; the use of particular individuals or strains of the vector species; varying the host plant or species of vector; the physiological condition or age of the host; the treatment of the host plant before and after transmission tests; whether the vector is feeding, fasting, molting or held at high or low temperatures during the retention period; and many other items could be listed. Additional factors are operative in the field where the transmission process is affected by many environmental conditions including temperature, light, precipitation, wind currents, location of weed hosts, the arrangement of cultivated plantings, the varieties used, control practices, insect habits including short and long-distance movement, to mention only a few.

It might be well at this point to briefly consider some of the known facts and some of the theories concerning the mechanism of transmission of plant viruses by insect vectors. It is generally conceded that with many persistent viruses, which are transmitted largely by leafhoppers, that the virus is both translocated through the vector's body and multiplies extensively during the latent period. Storey (1933), working with the leafhopper vector of maize streak in South Africa, was able to follow the movement of the virus through the insect's body by means of feeding and injection experiments. He concluded from these tests that the virus entered the alimentary tract by way of the mouth, diffused through the intestinal wall into the blood, from which it passed into the salivary glands and was introduced into the plant from these organs when sufficient quantity had accumulated there. In addition he found certain "inactive" individuals which could not transmit the virus. These could be made "active" by injecting the virus into the blood or by stabbing the insects with a fine needle so that the gut wall was pierced after the insects had fed on a virus source. He concluded from this that the inability of the inactive leafhopper to transmit the virus was caused by the impermeability of its intestinal wall to the virus.

Multiplication of plant viruses in their vectors during the latent period has been demonstrated by many workers in several different ways. Fukushi (1935) was the first to provide evidence of virus multiplication within the insect vector when he showed that the rice stunt virus could pass

through the eggs of infective females to their progeny. The virus from a single female was transmitted transovarially to seven successive generations without replenishments from diseased plants. Considering the extremely small amount of virus that must have been present originally in one egg, it would appear that these experiments strongly indicated the multiplication of the virus in its' vector. In similar tests with the leafhopper vector of clover club leaf virus, Black (1950) found that the virus was passed through the eggs to a high proportion of the progeny. The virus was passed through 21 generations over a five year period without further access to a virus source and without any loss in ability to infect plants. It was calculated that if no multiplication had taken place the dilution would have exceeded 10^{-26}.

More direct evidence of virus multiplication in the vector was obtained by Black (1941) when he measured the aster-yellows virus concentration in the six-spotted leafhopper which was undergoing incubation. He calculated that the virus concentration increased at least 100-fold between the second and 12th day of a 17-day incubation period. Maramorosch (1952) serially injected measured amounts of aster-yellows virus through 10 groups of leafhoppers and showed that there was just as much virus present at the last passage as the first. If no multiplication had taken place the dilution would have reached 10^{-40} while dilutions beyond 10^{-3} have not proved infective.

Additional evidence for aster-yellows virus multiplication in the six-spotted leafhopper was provided by Maramorosch (1953) in tests on the effect of temperature on the length of the latent period. Inoculated but not yet infective leafhoppers were placed at 4°C. from which groups were removed every week from 1 to 6 weeks and tested at 25°C. An average of from 6 to 9 days elapsed before the leafhoppers became infective, irrespective of the time spent at 4°C. It was concluded that the low temperature arrested the multiplication of the virus in the inoculated insects. In temperature tests in Wisconsin the incubation period of aster-yellows virus in the leafhopper was longer at 18°C. and 32°C. than at 24°C. and 28°C., and insects held at 36°C. never became viruliferous. These experiments indicated that low temperatures slow down the virus multiplication and that the high temperatures inhibit the virus. The incubation period of the virus in carrots and asters responded to different temperatures in a manner very similar to that found in the vector. The period became shorter as the temperature increased from 16°C. to 28°C., but longer again at 32°C.

Kunkel (1937) showed that exposure of viruliferous six-spotted leafhoppers to a temperature of 32°C. affected their ability to transmit the virus. After one day's exposure at this temperature they lost the ability to transmit but regained it again within a few hours when returned to 24°C. If kept at the higher temperature for several days it required two days to regain infectivity and if kept for 12 days or longer at 32°C. infectivity was permanently lost. Kunkel felt these results indicated that the longer the insects were kept at the high temperature the more virus was heat inactivated and therefore a longer time was necessary for the virus to multiply to infective levels. Kunkel found more rapid spread of aster-yellows virus late in the season than in mid-summer and believed that the high temperatures of July and August inactivated the virus carried by insects in the field.

In Wisconsin it was found that 36°C. was required to give results comparable to those obtained with 32°C. by Kunkel. In addition, heat treatments at 36°C. or 40°C. for 8 hours each day for 10 days, or at 36°C. for 16 hours per day for 5 days with the remainder of each day at 24°C. did not materially affect transmission by the insects involved. These results indicated that mid-summer temperatures in the field in Wisconsin would not materially affect the transmission of aster-yellows virus.

Additional proof of plant virus multiplication in insects has been obtained with tests on several other leafhopper and aphid vectors. It is generally believed as a result of these experiments that with persistent transmission the virus is ingested by the vector, it passes through the intestinal wall and into the blood where it multiplies many fold during the latent period. The virus then accumulates in the salivary glands until an infective dose is reached and is injected into the host plant through the salivary apparatus.

With nonpersistent viruses the process is very different and there are several theories as to just how the viruses are transmitted by their vectors. Very briefly and simply a few of these theories are as follows:

1. The virus is transmitted in a purely mechanical manner as a contaminant on the exterior of the insect's mouthparts. Although previously held by many workers, this theory has been largely abandoned at least for vectors with sucking mouthparts because of the discrepancies which appear in most transmission processes.

2. Bradley (1952) has suggested that the virus is taken up before the salivary sheath is formed, that the stylet ducts may become clogged with plant material and after the vector moves to a new plant this material is injected while clearing its stylets.

3. Watson (1938) has proposed an inactivator theory in which it is suggested that the ability of the vector to transmit a virus is governed by its appetite and the reaction between the virus and the insect and substances that it produces which might inactivate the virus. The more efficient vectors are more compatable with the virus and less virus-inactivating substances are produced by starving insects while more are produced as feeding time increases.

4. Sylvester (1954) suggests a compatability theory in which the vector efficiency and specificity depends on the compatability of the virus, the insect saliva and the host plant cells being inoculated.

5. Day and Irzykiewicz (1954) have a working hypothesis which incorporates many of the ideas of the above theories and is in accord with the more recent evidence. They suggest that the virus contaminating the stylets is the only part involved in transmission and any that is ingested plays no part in the process. Some of the virus on the stylets is inactivated by salivary juices but some is left for a time which can be inoculated into susceptible host cells. Viruses very susceptible to inactivation cannot be transmitted after the salivary sheath is formed.

A considerable amount of speculation was cleared up when Bradley and Ganong (1955a, 1955b) proved conclusively that with at least some non-

persistent viruses, the transmissible virus was carried exclusively on the tips of the stylets. This was done by ingenious techniques by which they exposed any desirable part of the stylets which were then treated with formalin or ultra-violet light to inactivate the virus on the exposed parts of the mouthparts. They showed in this way that the transmissible part of the virus was carried only on the terminal 5 to 15 microns of the stylets of the aphid vector.

It should be theoretically possible for an insect to transmit a virus in both a persistent and nonpersistent manner. In other words a part of the virus might be transmitted as a contaminant on the tips of the stylets and another part might pass through the insect's body and after a latent period be injected back into a plant by way of the salivary apparatus. This bimodal type of transmission had never been demonstrated until some work at Wisconsin (Chalfant and Chapman, 1959) with some cabbage viruses showed that such was the case. This work showed that cabbage virus A was transmitted by both the green peach aphid and the cabbage aphid in a typically nonpersistent manner. Similar transmission was obtained with the green peach aphid and cabbage virus B but the cabbage aphid transmitted this virus in two different ways depending on the length of acquisition feeding. Following short acquisition feeds (15 secs. - 15 mins.) the transmission was of a nonpersistent type but with longer feeds (1 hr. to 24 hrs.) the transmission was of a semipersistent nature.

This points up the fact that the type of transmission obtained is not a characteristic of the virus itself, as has been intimated in the past, but is a character of the vector-virus relationship. As shown above the same virus had nonpersistent characteristics when transmitted by the green peach aphid but was semipersistent when the cabbage aphid was used as the vector.

Most of the discussion up to this point has had to do with factors affecting transmission under controlled conditions in the laboratory. When virus spread in the field is considered, not only are all of the above factors operative but in addition so many others that only a very small percentage of them can be discussed at this time.

Probably the two most important factors in the transmission of viruses in the field are the movement of the vectors and the source of the virus. If there was no source of virus or the insects did not move from plant to plant or field to field no transmission would take place. There are numerous examples where it has been shown that the close proximity of a virus source in weeds or cultivated crops materially influences the spread of a virus to a susceptible crop. For instance it is unwise to plant peas next to clover which harbors both the viruses which attack the peas and the aphid vector. Seed potatoes cannot be grown successfully in the southern parts of Wisconsin because of the abundant sources of viruses and vectors whereas in the northern part of the state these factors are limited and consequently the seed-potato industry thrives in that area. As indicated the close proximity of the virus source to the susceptible crop is very important and often the difference of only a few yards in distance makes a marked variation in the amount of virus transmitted. This is particularly true with nonpersistent viruses where long distant movement of infective insects would cut down on transmission by the rapid loss of the virus by the vectors. With

this type of transmission there is usually a marked border effect in the susceptible crop. The vectors will tend to feed on the first few rows of a crop as they enter the windward side of a field and rapidly lose their ability to transmit as they move into the crop. In tests on the field spread of potato mosaic Y in southern Wisconsin it has often been very apparent from which direction was the source of virus and the movement of the aphid vectors into the field by the heavy infection in the first few rows on one side or corner of the field and the sharp decline in disease incidence farther into the crop. This pattern is much more evident with nonpersistent than with persistent types of transmission. With aster yellows in New York, however, Linn (1940) found a marked border effect with aster-yellows infection. He also found that by the eradication of perennial weed hosts for 100 feet from lettuce and endive plantings that the percent of aster-yellows infection was appreciably reduced in the plantings. This is very different from the spread of the same virus in Wisconsin where border effects do not occur and weed control has not been effective. It has been estimated that about 75 percent of the infection of aster yellows in Wisconsin is the result of viruliferous six-spotted leafhoppers migrating into the state from a distance of 400-500 miles away. In this instance the proximity of the virus source has little to do with the amount of disease which results.

The movement of insect vectors into and within a crop and many of their other activities are determined by a number of ecological factors. The direction, distance and time of vector movement is largely dependent upon wind and temperature. Temperature often determines whether the insects will fly and the wind direction and velocity is responsible for vector movement of a few rows in a crop or of several hundred miles migration. As for temperature, few six-spotted leafhoppers will fly below a temperature of 60°F. The threshold of flight for the peach aphid is 55°F., while the cabbage aphid is more active at still lower temperatures. Aphids do not fly in darkness but leafhoppers are very active at night providing the temperature is high enough. Young aphids have been found to be more active than older ones. A decrease in humidity has increased aphid flight but they soon adjusted to the change. Similarly aphids increased activity with changes in atmospheric pressure until they became adjusted to the change, and starving increased activity during the first hour or two. (Broadbent, 1949).

The fact that insect movement has been stated to be of prime importance in the amount of virus transmission indirectly indicates the importance of the kind of insect involved. Wingless insects such as leafhopper nymphs or apterous aphids are relatively unimportant in transmission as compared with winged migrants. With many nonpersistent viruses it is believed that the principal agents of virus spread are winged migrants that do not colonize in the field. They fly into a crop, test the plants by inserting their stylets, thus transmitting or acquiring a virus, and then fly off to another plant. Broadbent and Tinsley (1951) found that in one season alatae were responsible for 97 percent of the spread of leaf roll (a persistent virus) and 83 percent of the spread of potato virus Y (a nonpersistent virus. In connection with the importance of winged aphids in transmission, a couple of factors in respect to their build up and movement might be mentioned in addition to the ecological factors which make them move. Before the aphids can fly, conditons of heavy infestation or of

plant host condition must be such that considerable numbers of winged forms are produced. Then a virus-infected crop is a particularly serious threat to surrounding fields, especially when the former is harvested and the infective insects are forced to move out.

Numbers of vectors, which might superficially appear to be most important in transmission, are not nearly as big a factor as the movement and percent of insects which are viruliferous. There ordinarily needs to be at least a moderate number of insects present for very high virus incidence but extremely high vector numbers often results in little or no virus spread. In Wisconsin for instance in 1945 with moderate numbers of leafhoppers the percent of aster-yellows virus infection in carrots was much greater than in 1946 when approximately 10 times as many leafhoppers were present in the fields. The important factor here was the greater percent of viruliferous individuals present in the smaller leafhopper populations in 1945. Similarly in 1957, when there was a tremendous outbreak of aster-yellows disease in the whole midwest, the "infection pressure" (number of vectors multiplied by the percent viruliferous in the population) was approximately 1000 times that in 1958 when relatively minor damage was done by the yellows disease. Just as numbers of vectors are not of prime importance in the spread of the persistent type virus cited, the same is usually true with nonpersistent viruses where numbers of vectors often cannot be correlated with virus incidence. The author has seen beans become infected with virus to the extent of 100 percent when no insects were found to be colonizing the plants and only very few migrants were observed on the plants at any time.

In an intelligent approach to the control of insect-transmitted virus diseases, all of the factors discusses previously must be considered. In some instances the virus spread can be controlled by the reduction of virus source in weeds by means of herbicides. Cultural control can be utilized by planting crops late enough to escape early spread of virus or by harvesting early to escape late infection. Plant breeding has produced many virus-resistant varieties but in many crops such resistance is difficult to find and incorporate into horticulturally satisfactory varieties. As mentioned before, borders or barriers of trap crops, artificial screens or bare ground can minimize virus infection in small plots. Insecticidal control of the insect vectors, however, is probably the most commonly tried method of reducing the spread of insect-transmitted plant viruses. This method of control has often been ineffective for several reasons; the insects that breed in the field are often not the principal vectors; insecticides cannot usually kill viruliferous insects fast enough to prevent transmission; insecticides must be applied before the insects arrive in the field; and in some cases insecticidal applications have actually resulted in increased virus spread.

In general, more satisfactory results have been obtained with insecticide applications for the control of persistent viruses (with their longer acquisition and inoculation thresholds and latent periods) than of nonpersistent viruses (with their lack of latent periods and extremely short transmission thresholds). Of the persistent viruses, such diseases as aster yellows, curly top, potato leaf roll and sugar beet yellows have been reduced considerably by insect control (Smith and Brierley, 1956).

Systemic insecticides with their more uniform protection of the plants throughout the season and their presence in all parts of the plant, particularly in the newly emerged foliage, gives them considerable advantage over the conventional insecticides in the control of viruses spread by insects. A single treatment of such systemic insecticides as Thimet and Disyston at planting time has given 90 percent control of purple top in potatoes, which is far superior to many treatments throughout the season with conventional materials such as DDT. Unfortunately the presently available systemics are not effective in muck soils where many vegetables affected by viruses are grown.

Another relatively new development is that of the viricidal materials have not been shown to be of practical use in the reduction of virus spread at the present time but give considerable promise for the future.

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ASTER YELLOWS - A CHALLENGING PROBLEM IN PLANT PATHOLOGY

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Anyone assigned 45 minutes to talk about any topic, must justify first to himself, then to his audience, such an expenditure of time. Those who arranged the program were obviously convinced that Aster Yellows is an important subject; they devoted a whole day to it. To help you share my conviction that they were right, I shall start by telling you just how wide-

spread the virus disease is, which we call Aster Yellows. Incidentally, the name is misleading. It follows the convention that virus diseases may be called after the host on which they are first described, or on which they are best known. Then, as the causal agent of virus diseases of other plants is found to be a previously known virus, we get such apparent anomalies as aster yellows of flax, sunflowers and carrots.

At the present time, some 300 species of plants are known to be susceptible to this virus. When F. O. Holmes published his Handbook of Phytopathogenic Viruses in 1939 (1), he listed over 170 species in 38 families as hosts of Aster Yellows. Beet curly top virus, which attacked 220 species in 27 families, also have extremely wide host ranges. Possibly they and a few other viruses have now been reported on as many more new hosts as Aster Yellows has collected since 1939. In any case, you can appreciate that it is able to attack a tremendous number of different kinds of plants. The only groups which are still thought to be quite immune to Aster Yellows are the grasses and cereal grains.

Fortunately for us, aster yellows virus does not attack 300 plant species in Manitoba - as far as we know. That host range includes all species known to be attacked in North America. According to reports of the Canadian Plant Disease Survey up to 1957, the virus had been found in Canada on members of 80 genera in about 30 families. Some of those hosts are weeds, some are ornamentals, some are vegetables, and some are field crops. Enough of them are economic crops to make this virus disease important to the Canadian economy, as well as disruptive to the plans and efforts of the home gardener.

Asters were suffering from this virus when the Canadian survey was started in 1920. Although no other hosts were reported until 1930, carrots apparently were attacked in the Maritimes well before 1920. In the 1930's, carrots were seriously injured; infections up to 75% - 90% were reported, and buckwheat also was heavily infected. On potatoes, the aster yellows virus induces a disease called purple top; symptoms very similar to this virus disease may occasionally be induced by other pathogens, although aster yellows seems to be the most frequent cause. Purple top was reported in the Prairies in 1937, and in the Maritimes in 1939. In most years only a small percentage of the plants is affected; in some years, however, the attack has been severe, as it was in 1953 and in 1957. Since 1950, susceptible vegetables have been attacked with light to moderate intensity in Ontario and Quebec; in 1957 the losses in some vegetable areas were disastrous.

Although the virus has been known in the prairies for many years, it was not usually considered important except on asters and occasionally on potatoes and carrots, prior to 1953. In that year it was reported on flax, rapeseed, and sunflowers, all grown on a large scale. In 1954 it was conspicuous, in 1955 even more so; in 1956 there was very little aster yellows on these crops. In 1957, quite unexpectedly, the disease was severe on a very large number of host plants. It practically eliminated some market garden crops of head lettuce and celery in the prairies, and was destructive on carrots and potatoes; it reduced flax yields to a low level, and was injurious on sunflowers (9).

The dramatic outbreak of aster yellows in 1957 posed many interesting scientific problems. It had been shown by Kunkel (7) and others in eastern United States, and Severin and his associates in California (11), that the virus could overwinter in perennial, biennial, and winter annual hosts. It was generally assumed in Western Canada that the insect vectors of the virus, the six-spotted leafhopper Macrosteles fascifrons, picked it up from its overwintering hosts in the spring and proceeded to spread it in all directions. It was not known how the insect overwintered in this area.

This assumption that local foci of virus infection were adequate to account for the disease each year, was not seriously questioned in Manitoba until 1957. In that year the observed facts just would not fit the accepted hypothesis. As there had been relatively little aster yellows in 1956, appreciably less than in 1955, the reservoirs of infection for 1957 should have been correspondingly small. Any infection that occurred should have developed slowly, from discrete foci, and should not have been significant until late in the season - if at all. That is not what happened. Aster yellows was found almost simultaneously across Manitoba, Saskatchewan, and the adjacent States to the south. It was remarkably severe early in the season, in July - and proceeded to get worse as the season wore on. In other words, it followed a pattern that has long been familiar to us here, the pattern of development of the cereal rusts. It seemed to be almost independent of local inoculum early in the summer, although obviously affected by local conditions during the growing season. The explanation for such behaviour in the rusts is that the inoculum arrives in Western Canada, brought here by winds from the south. All that we have to provide, in order to have a major rust outbreak, is a large expanse of susceptible varieties of grain, at a suitable stage of development - and appropriate weather conditions (1).

Having spent most of my professional life in an environment "reeking" of cereal rusts, I should like to draw another parallel between rust and aster yellows. Whenever one of our high quality, rust-resistant cereals loses its resistance and suffers dramatic rust attack, we explain the fact by the occurrence of new strains or physiologic races of rust, which can attack the previously resistant variety. Strains of aster yellows virus, differing in their ability to attack certain plant species have been known for many years. Early work with aster yellows was done in New York, where a wide range of susceptible hosts was reported. When work on the disease was started in California, certain discrepancies were noted. In California, the virus attacked zinnia and celery; in New York, it would not. These discrepancies were finally explained when parallel inoculation studies were made, which proved that the California virus was apparently a distinct strain, able to attack certain hosts resistant or immune to the eastern strain (10). As the California workers pressed their investigations, the list of hosts susceptible to their strain, but not reported for the eastern virus, increased.

Differentiation of strains or physiologic races of pathogenic fungi is hard enough; only in rare cases can they be distinguished by morphological differences. It is almost always necessary to distinguish them by the reactions of carefully chosen host plants, or "differential hosts". The difficulty of distinguishing strains of viruses is obviously even greater, as by

definition the virus is ultramicroscopic. Although serologic reactions can be employed, as well as certain other methods, the most obvious one is the use of appropriate differential hosts.

Hosts which differentiate strains of aster yellows virus have been recorded in the literature. Unfortunately, they have not always been worked out with the precision customary in rust work. To a large extent, the differentials are based on negative evidence. For example, the California workers might report that their virus strain attacked specific hosts, as they did recently for cucumber, squash, and pumpkin (3). No records exist of the eastern strain attacking these crops. It will therefore be assumed that these cucurbits may differentiate the two strains. This may be the case - but until and unless careful, parallel investigations are made by the same workers, under the same conditions, with all the strains available, the value of specific hosts as differentials may be questioned.

It has long been accepted that the eastern strain of aster yellows does not attack celery, onion, and zinnia, whereas the western strain attacks all three. Holmes (6) refers to celery and zinnia as "refractory" hosts for the eastern strain, insinuating that under special conditions they may be affected. One of the difficulties involved in host differentiation is the fact that the virus has to be transmitted by leafhopper vectors. It is well established that the vectors can feed and breed on some plant species, such as cereal grains, immune to the virus; and that they can transmit the virus to other, susceptible plant species on which they cannot survive more than a few hours. Freedom from virus infection in nature may thus indicate that a given plant species is immune or resistant to the virus (grasses), or that infection can only take place if large numbers of viruliferous insects feed on the same plant (potatoes). A further complication is introduced by the fact that, to prove conclusively that the symptoms on a given plant species are in fact those of aster yellows, the virus must be transmitted from that plant to a suitable diagnostic host, such as asters or celery. Some hosts have been found, such as potatoes and flax, from which the leafhoppers seem unable to pick up the virus. (It can be transmitted from potato to tomato by grafting, however, and can be reisolated from the tomato by insects.) These difficulties and complications are cited merely to indicate that work with aster yellows virus is not always straightforward and easy.

Identification of virus infection is made on the basis of host symptoms. The symptoms induced by aster yellows virus vary with the host, but do have some features in common. The virus belongs to the "yellows" group. This indicates that one of the conspicuous symptoms which it induces in most hosts is loss of green color (chlorosis), or yellowing. A first symptom in many hosts is clearing of the veins, which become relatively translucent. Young tissues become chlorotic; the pale green or yellowish appearance is often most conspicuous at the apex of the stem and of individual branches. In many plants dormant buds start to grow, giving rise to dense clusters of foliage. Stems and leaves in many cases become twisted or otherwise distorted. The early chlorosis in some plants is followed by color changes varying from yellow to reddish or purplish. The most characteristic symptoms of aster yellows are observed in the flower parts. Many plants respond to early infection by complete failure to produce flowers, or the normal flowers may be replaced by a rosette of pale green leaves. Later infection often results in the production of abnormal

flowers. Sepals, petals, stamens and pistils may be variously malformed, or replaced by leaf-like structures (phyllody). Phyllody may affect all or only some of the flowers on a branch. In composite flowers, the whole head may be affected, or phyllody may be restricted to a sector of the inflorescence. The leaf-like structures are usually green; virescence, phyllody, and proliferation of floral parts, are the commonest symptoms - but in some species they may vary from green through yellow to red or purple. In some cases affected flowers may give rise to secondary stems bearing secondary inflorescences.

Many plant species respond to aster yellows infection by assuming an abnormally erect habit of growth. Effect on plant height appears to be a function of the stage at which infection occurred. Some affected plants grow taller than normal, while other individuals growing nearby may be stunted. Kunkel (7) reported in his early work that affected asters usually lived as long as healthy ones, unless they succumbed to secondary infection by fungi. This does not seem to hold true for all plants. In some hosts at least (e. g. flax) the growing point dies if infection occurs early. Sunflowers also may respond by a characteristic sectorial necrosis. Death of the tissues seems to start from the phylloid, virescent sector of the head, and progress downward along a sector of the stem, which breaks down and turns dark brown to black. Secondary organisms certainly invade the necrotic area, but necrosis seems to be a direct result of virus infection (8).

Plants affected early by aster yellows, with consequent death or malformation of the flower parts, fail to produce seeds. Plants attacked later, which may have some apparently healthy flowers among the diseased ones, produce much less seed than normal. The seeds that are produced may be small, light, and in many cases will not germinate. Losses caused by aster yellows infection in vegetable crops usually result from the distortion, reduction in size, or other injury to vegetative parts, which characterize the disease. In the major susceptible field crops loss is attributable to reductions in the quantity, size, and quality of the seed.

The means by which the various symptoms and other effects of aster yellows infection are produced are not yet known. There is an apparent disturbance in the kinds or proportions of growth substances produced in the plants; as with other diseases, certain symptoms resemble some of the effects of various plant hormones. They also resemble the disturbances induced by some fungus pathogens. The effects of infection by aster yellows virus on rape are remarkably similar to those induced by the "white rust" fungus.

Internal effects of virus infection on diseased plants have received some study. Katherine Esau (2) has pointed out, in her own work and in review articles, that the yellows viruses are carried in the phloem, and cause injury to phloem tissues. Halisky et al (5) found that legumes affected by aster yellows showed phloem degeneration, proliferation followed by necrosis. Girolami (4) demonstrated similar proliferation and necrosis of phloem elements in flax plants infected with aster yellows virus.

Movement of the virus in the phloem is rapid, at about the same rate calculated for movement of food substances in the phloem. The virus moves rapidly in the direction of food transport, downward in normal plants,

but upward if the plant has been defoliated and food consequently has to be transported up to newly developing leaves.

Aster yellows is not transmitted by seed produced on diseased plants. As there is no vascular connection between the "mother" plant and embryo, yellows viruses, which are carried in the phloem, are unlikely to be transmitted through the seed. Esau (2) found that sugar beet seed, which would not transmit the disease, contained a high concentration of curly top virus; however, the embryos of such seed were quite free of virus.

Although aster yellows can be transmitted by the propagation of infected vegetative tissues (potato tubers, etc.), and by grafting, the only significant means of transmitting it is the aster or six-spotted leafhopper. In California some 20 or more other species of leafhoppers can act as vectors, but are much less important than M. fascifrons.

The dependence of the virus on its insect vector affects the epidemiology and the control of the disease. Dr. Chapman and associates at the University of Wisconsin have shown by brilliant studies that the vectors migrate northward in the spring, borne by southerly winds. As indicated above, this resembles the method by which cereal rust spores are blown into Western Canada from the south. The usual pattern of rust dispersal by wind as worked out by Craigie and others, takes in the Red River Valley, western Manitoba, and eastern Saskatchewan. Cereal rusts also occur in Alberta, although in most years infection starts too late in the growing season to do much damage. The most interesting feature of rust development in Alberta, in connection with aster yellows, is that the physiologic races that occur in the southwest of the province, at Lethbridge, sometimes are different from those that occur in Manitoba, Saskatchewan, and even in the Edmonton area. They are, however, often the same as the races that occur in the Creston area of southeastern British Columbia.

Apparently, then wind-borne spores from the Mississippi and Red River valleys do not always provide the initial rust inoculum in the Lethbridge area. It seems probable, from observations made in 1957 and 1958, that the wind-borne leafhoppers which initiate major aster-yellows outbreaks in Manitoba and Saskatchewan, also do not always provide the original inoculum of aster yellows in the Lethbridge area.

The observations made in 1957 are based on apparent differences between the strains of virus in Manitoba and Saskatchewan, and the strain near Lethbridge. Aster yellows in Manitoba, although severe on celery, and present on onions and rape, did not affect zinnias. Almost every known host of aster yellows was reported injured in Manitoba in 1957 - but zinnias growing beside marigolds and other ornamentals which were severely attacked, remained perfectly healthy, or at most showed slight symptoms on one or two plants. This corresponded to the situation at Madison, Wisconsin, where zinnias were not infected by leafhoppers taken from diseased celery. At Lethbridge, however, according to information from Dr. R. Hawn, the zinnias were devastated by aster yellows. The virus in Manitoba and Saskatchewan behaved like a variant of the California strain; the one near Lethbridge seemed to be the regular California strain, which attacks zinnias.

The pertinent observations in 1958 were made by Mr. P. H. Westdal, who made a survey with Chapman and his group in the United States. He was able to trace wind-borne migrant leafhoppers through the northern United States and Canadian prairies, through to Edmonton. He found none in the Lethbridge area - but between Lethbridge and Calgary, encountered a locally-developing population.

Our information is still very limited. On that information, however, we can conclude tentatively that, as in the wind-borne cereal rusts, the wind-borne migrant leafhoppers from the south determine not only the occurrence and severity of aster yellows outbreaks, but may also determine the strain or strains of the virus which occur in the region which they invade. Epidemiology of the disease in Ontario, Quebec, and the Atlantic provinces may be entirely different. The source of virus, the origin of possible migrants, and the biology of the vectors in those regions, may have no relationship to those in Western Canada. One thing that is fairly certain, based on reports in the Canadian Plant Disease Survey, is that the California or Western strain of aster yellows has been present in Eastern Canada, at least in New Brunswick, for many years.

Just as the fact that aster yellows is transmitted by leafhoppers determines the severity and distribution of the disease, and occurrence of virus strains in a given region, so also it determines the control measures which can be used against the disease. Plant viruses have not been controlled by the protectant and eradicant sprays which are effective against certain fungus and bacterial pathogens. Some cultural practices, such as date of seeding, control of weeds, etc., may be helpful in reducing injury, but most are aimed at the insect vector, rather than at the virus itself.

Two main methods of control, other than growing only nonsusceptible crops, are: control of the insect by any means available; and the breeding of resistant varieties of plants. Resistant varieties may be actually resistant to the virus, or they may be unattractive to the insect vector. Control of the vector is a problem for the entomologists, and the production of resistant varieties, a problem for the plant breeders. Fortunately, representatives of each of these disciplines are taking part in this discussion, so their points of view will be put forward by people qualified to do so.

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BREEDING FLAX FOR ASTER YELLOWS RESISTANCE

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The serious epidemic of aster yellows on flax in 1957 prompted the initiation of a breeding program at the Canada Agriculture Research Laboratory, aimed at breeding a variety of flax resistant to the disease. It was apparent, from our experience and from that of other research workers, that there was no known source of resistance although some varieties appeared to be more tolerant to infection than others under field conditions.

Mr. Fredericksen, a pathologist working at the University of Minnesota, suggested a list of 20 varieties growing in the World Collection of Flax that appeared to carry less infection than others under field conditions. Accordingly, seed of these 20 varieties was obtained with the intention of using them as a starting point in a search for resistance.

Our original intent was to construct four large cages to fit over a group of 20 to 24 pots. The cages would be of the size which would allow four to be used in one growth cabinet at the same time. On discussing this type of cage vs. individual pot cages with authorities in the field of breeding for insect resistance it was decided to adopt the smaller cage, constructed to fit over a six-inch pot and tall enough to allow room for the plants to

grow. Growth cabinets would be used when more careful control of growth conditions for both plants and leafhoppers is possible.

The program was divided into three stages:

1) Search for a source of resistance which may be an entire variety or even one plant in a variety whose progeny would breed true for resistance.

2) Study the inheritance pattern of resistance.

3) Cross the source of resistance with a standard acceptable variety in order to introduce the germplasm necessary to produce a variety acceptable in all respects to our conditions.

The first problem to be overcome was the assurance of a steady supply of viruliferous leafhoppers. The Entomology Section of the Canada Agriculture Research Laboratory gave excellent co-operation in this regard, although unforseen complications made their task more difficult.

Our first test utilized four pots of each variety and 10 kernels were planted in each pot. When the plants were from four to six inches high, cages were placed over the pots and 15 to 20 leafhoppers were released into each cage. Although the proportion of viruliferous leafhoppers was obviously quite high, there was no way of being certain of their potency at the time they were released into the cages.

The leafhoppers were allowed to feed for about five days, then released and after about 10 days to two weeks symptoms of aster yellows were quite noticeable on almost all plants. Occasionally a plant was observed that showed no symptoms of aster yellows, although the other seven or eight plants in the pot were infected. These plants were grown to maturity, and the harvested seed planted and exposed to viruliferous leafhoppers in the same manner. After five generations of such treatment it became obvious that this continued selection had resulted in a gradual change in the disease tolerance of the population. Where previously it was possible to find only one or two plants not infected, it was now difficult to find plants showing aster yellows symptoms. The leafhoppers were viruliferous because check pots of Redwood, which is quite susceptible to aster yellows, were scattered throughout the growth cabinet, and in most cases all plants in these pots showed typical aster yellows symptoms. It was felt advisable to plant entire pots to a check variety rather than plant a few seeds of the check in each pot along with the material to be tested because there was always the possibility of differential feeding, which could result in the insects preferring only Redwood, to the exclusion of the plants to be tested. In this regard all pots were kept free of weeds for the same reason.

This procedure will be continued for a few more generations or until no plants with aster yellows can be found. When this stage is reached, the seed of the apparently resistant plants will be grown in the field under larger cages and again exposed to viruliferous leafhoppers. It will be necessary to test this resistance under field conditions.

It is too soon, at this stage, to be certain that we have found resistant plants, but results so far indicate that some measure of success has been

achieved by following the method which has been outlined. When stage three, or the actual crossing and the selection of resistant progeny, is reached, larger cages may have to be utilized on a greater scale or perhaps under field conditions in order to screen the large F_2 population necessary in a breeding program. If the resistance is simply inherited, then the breeding problems will be simplified and the backcross method can be used, making it possible to work with smaller populations.

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THE SIX-SPOTTED LEAFHOPPER, MACROSTELES FASCIFRONS (STAL.) AND ASTER YELLOWS CHLOROGENUS CALLISTEPHI H. IN MANITOBA

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The following is an abstract of a report on work conducted at Winnipeg, Manitoba in 1958 and 1959 on the biology of the six-spotted leafhopper, Macrosteles fascifrons (Stal.) and on the occurrence of the aster yellows virus, Chlorogenus Callistephi H.

The six-spotted leafhopper overwintered in Manitoba in the egg stage only. Adults migrated into Manitoba in substantial numbers, in spring, beginning about mid May. The migrant population reached a peak of about 80 leafhoppers per 100 sweeps in mid June on favored foods such as cereals. This peak was due partly to movement of leafhoppers to preferred foods and probably partly to continued migration. There was a high mortality of migrants in late June and early July. The non-migrant population arose partly from overwintered eggs but mostly from eggs laid by migrants. Nymphs began to appear in late May and first generation adults in late June. Distinct broods were not apparent in the field because of the overlapping of generations. The peak of population of about 450 leafhoppers per 100 sweeps was reached about mid August. Four generations were reared in a year. A species of Dryinid is a parasite and a predator of the six-spotted leafhopper. The leafhopper is also parasitized by a Pipunculid. In general field collections the percentage of leafhoppers transmitting the aster yellows virus did not exceed one percent. The percentage of transmission was highest in the migrant population but dropped in July and August with the rapid increase in local population. Weeds are a source of aster yellows virus in Manitoba. The rate of virus transmission was low in June and July and reached a peak in August in conjunction with the peak in population. In Manitoba, early maturing crops generally escape severe aster yellows infection but it is often a problem on late crops.

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THE EFFECTS OF INSECTICIDES UPON WILDLIFE

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I once heard a prominent wildlife biologist claim, in a moment of discouragement, that our task is to maintain wildlife resources on an ever-decreasing level. Certainly he would have preferred to use the word "increasing" and actually had that direction as his personal goal, but he was disheartened by a decision from the United States' Capitol that constituted a major setback for wildlife.

My colleague's statement has often been recalled in the intervening years as I witnessed one force after another make inroads on wildlife habitat and populations. The effect of these recurring reversals on the professional conservationist is to make him conscious of other land-use agencies and extremely sensitive to their every action that may alter productive wildlife environment.

It is not surprising then that fish and game biologists became concerned about insecticides and their possible effects on wildlife back in the period when these toxicants were undergoing initial development. Since that time there has been a steady flow of popular and technical writing on the subject as well as a great amount of controversy regarding the true role of insecticides in nature. Although most authors take a more conservative outlook, certain writers (J. H. Baker, 1958, and Wallace, 1959, for example) have claimed that the ever-expanding pesticide program in North America poses the greatest threat that wildlife has ever faced.

Three revolutions in growth already have been recorded in the relatively short history of the use of insecticides. The first of these was the adoption of aerial application in the 1920's, some 35 years after insect control by poisons came into practice. Economic entomologists quickly saw the potentialities of aircraft in their work and conservationists soon thereafter took notice of the dangers inherent in this less-precise method of spreading poisons on the land. Several accounts of game and songbird loss, that resulted from widespread aerial dusting of forests, appeared in the 1930's and 1940's but, generally speaking, neither loss nor concern appear to have been high (Rudd and Genelly, 1956).

The second revolution in the insecticidal field came with the dramatic appearance and wholesale acceptance of DDT early in World War II. The Armed Forces, almost unrestrained by program costs and with abundant personnel and aircraft, introduced DDT to the world and brought the new chlorinated hydrocarbon insecticides into the limelight. The probable hazards associated with widespread and indiscriminate use of this new poison were quickly sounded by conservation groups but they had only meager factual information for their assessments. In retrospect, Rudd and Genelly

(1956) point out that neither the sensational claims for the effectiveness of DDT nor the alarmist predictions on the undesirable consequences of its use proved to be correct.

The tremendous expansion in the use of insecticides and the outburst of new chemical poisons during the past 13 years, constitute the third major revolution in this field. Millions of acres of forest and croplands are now treated annually and a fourfold increase in the use of insecticides is expected in the next ten or fifteen years (Cottam, 1959). Choice of toxicants is no longer restricted to DDT and its predecessors, chief of which were the arsenicals; several new chlorinated hydrocarbons and the organic phosphorous poisons have been introduced since World War II and now are widely used. Of additional concern to wildlife students is the currently changing philosophy of agriculturists and foresters in their anti-insect campaigns that substitutes the word "eradication" and all that it implies for the gentler word "control".

Opposition from conservation organizations to certain aspects of insecticidal programs has kept pace with the evolution of chemical control. The basic cause for concern always has been that materials poisonous to insects are also poisonous to other animal life. At first, alert naturalists suspected the presence of potential dangers and made cursory investigations. This stage is exemplified by our present casual interest in the possible undesirable affects of the Greater Winnipeg mosquito abatement program (Anon. 1959) and of the grasshopper control program in Manitoba agricultural areas. Anxiety over pesticidal programs in the United States naturally grew as the programs expanded, new chemicals appeared, and reports of wildlife loss from many widely-scattered regions increased in number. Mass application of insecticides by aerial methods for the control of many pests, in particular, spruce budworm, gypsy moth, Mediterranean fruit fly, grasshopper and Mormon cricket precipitated much new concern over insecticidal programs (Cope and Springer, 1958).

Nothing in the history of insecticides aroused the indignation of wildlife interests more than the fire ant eradication program in southeastern United States. This all-out attack on an insect was started in 1957 and has as an eventual goal the chemical treatment of some 20 million acres of land. In respect to this program, Cottam (1958), stated: "It appears that the control procedure is so drastic and destructive that it is analogous to scalping the patient to cure dandruff! The cure seems to be far worse than the disease." Repercussions to the fire ant program were heard internationally and the entire question of insect control measures and their side effects was opened to closer scrutiny. It may help to bring the overall problem's significance into better perspective by noting that the U. S. Government budgeted $280,000 in 1958 and $2,565,000 in 1959 for research into the effects of pesticidal chemicals upon fish and wildlife (National Wildlife Federation, 1959).

Canada had neither the need nor apparently the strong encouragement from special-interest groups to develop its insect control programs since World War II at the rapid and sometimes unruly rates experienced in the United States. Examples of the adverse effects of insecticides upon wildlife under field conditions are available from Canada, but more abundant and more varied illustrations come from south of our border. Recorded and

widely known instances of wildlife losses in Canada that resulted from chemical treatment for insects are restricted to forest spraying operations.

Blanket aerial coverage, the type most injurious to beneficial fauna, with DDT-oil formulations has occurred over Canadian forests between 1945 and 1958 in British Columbia, Ontario, Quebec and New Brunswick. Treatment in most instances was for control of spruce budworm (Webb, 1959). The dosages, except in one instance, did not exceed one pound of technical DDT per acre. This amount is not likely to have serious adverse effects directly or indirectly on warm-blooded animals (Rudd and Genelly, 1956, and Hoffman, et al. 1958).

Detrimental effects of DDT when used as a forest spray are usually restricted to fish which as a group are much more susceptible than birds and mammals to this poison. In New Brunswick on the Miramichi River system young salmon, especially the fry, were drastically reduced in numbers along with food chain organisms as a result of forest spraying with DDT since 1952 (Keenleyside, 1959). The extreme hazard of DDT to fish and fish-food organisms was shown again in 1957 in British Columbia during aerial forest treatment for black-headed budworm; certain trout, salmon, and fish-food populations underwent large reductions (Crouter and Vernon, 1959).

DDT has been more thoroughly studied in the laboratory and in the field by both economic entomologists and wildlife biologists than any other insecticide. Its potential hazards to beneficial biota are known and recommendations for safe application have been widely circulated. Nevertheless, new situations with the use of DDT still arise and the findings are sometimes revealing. An example of this is the study by Barker (1958) wherein he calls attention to the possibility that moderate applications of DDT, in this instance for the control of American elm diseases in Illinois, under certain conditions can be concentrated in the bodies of earthworms to produce lethal effects on robins nearly one year later.

The most noteworthy adverse consequences of insecticides upon either fish or game in Canada have been the fish losses in forest streams in New Brunswick and British Columbia. New types of wildlife injury may eventually be recorded in Canada if programs now operating in the United States are adopted on a large scale in this country. In particular, wildlife students are concerned with future developments in the fight against insects in our agricultural regions where valuable game populations are found.

The grasshopper problem in the Canadian West will likely be responsible for a major share of the anticipated expansion in the fight against agricultural insect pests. Brown (1951) points out that aircraft sprays have been used in Canada against grasshoppers since 1945. In the United States in 1956, 1.7 million acres of rangeland and more than 4.5 million acres of cropland were treated for grasshopper control. Minor outbreaks of this insect are handled from the ground, but major infestations over rough terrain in the United States are being poisoned more each year from the air. Aldrin, heptachlor, chlordane, and toxaphene are used chiefly against grasshoppers, but dieldrin, although not recommended by the U.S. Department of Agriculture, is receiving increasing use in many states (Cope and Springer,

1958). These toxicants have also proven valuable in work with other insects, and an array of newer chemicals are being commercialized to meet continuing demands for more effective control agents.

It has been found that as a general rule toxaphene and chlordane are similar to DDT in their effect on birds and mammals. More lethal than DDT are heptachlor, aldrin, and dieldrin. In respect to fish, chlordane and DDT have approximately the same toxicity. Fish are more severely affected by dieldrin, toxaphene, and aldrin than by DDT. In broad terms, the chlorinated hydrocarbon insecticides, of which all those above are examples, are a greater cause for concern than the organic phosphates. This is because members of the chlorinated group are extremely toxic at low concentrations, have long-time stability, and have received wide promotion for insect control. Their toxicity may be equalled or exceeded by some of the organic phosphates, but these chemicals lose potency relatively soon (Stickel and Springer, 1957).

Damaging effects on wildlife have resulted in several instances from the use of these newer insecticides in the United States. Hanson (1952) in North Dakota reported that toxaphene and oil at two pounds of toxicant per acre aerially broadcasted over a marsh proved harmful to all animal life studied in the area except adult birds and some small crustaceans. In the same series of field experiments on marsh areas it was found that chlordane aerially applied at the rate of one pound per acre, besides causing mortality among juvenile waterfowl, apparently interfered with bird reproduction. Wildlife mortality was heavy during a rice leaf miner outbreak in 1953 in California that was treated with dieldrin at the rate of eight ounces to the acre. This program caused large losses of fish and of birds, including egrets and mourning doves (Rudd and Genelly, 1956). A substantially complete fish kill occurred in 1955 on a tidal marsh area in Florida following treatment for sandfly larvae with dieldrin pellets at the rate of one pound of active ingredient per acre (Harrington and Bidlingmayer, 1958). Tarzwell and Henderson (1957) conclude from their studies that run-off from an extensive area treated with dieldrin would adversely affect fish life.

The fire ant eradication project in southeastern United States is described fully by George (1958a). He states that in this program quail have been practically eliminated from areas treated with the recommended dosage of two pounds of either technical dieldrin or heptachlor in dry-granular form per acre. M. F. Baker (1958) found that a total kill of quail and an extensive kill of other vertebrate animals resulted from the fire ant program on a study area in Alabama.

Early reports that covered wildlife damage from insecticidal programs stressed mortality, sometimes in an alarming way. Possibly the accounts of wildlife losses mentioned in this paper have given the impression of being sensational. This was not intended because sounder reasoning has come to prevail in the conservation field in recent years and insecticidal damage now is being assessed in a more realistic manner. The immense benefits to society of insect control programs are recognized by wildlife students who also realize that many wildlife losses are ecologically insignificant and usually quickly recoverable by the process of repopulation. It is when the losses become significant either because of their relative

immensity or because the recovery rate is slow due to the animal's nature or distribution that wildlife students question the propriety of the program. Insect control programs run partially by unwarranted fears and emotions and not completely by sound principles are also opposed.

Wildlife students recently have grown more cognizant of the indirect, long-term, and delayed effects of insecticides and their residues on the biota. These subtler consequences are now rated as more important than immediate mortality. A significant factor here is that the chlorinated hydrocarbons are stored to varying extents in animal fat. In the animal body, aldrin converts to dieldrin, is stored as such and quite naturally appears in the milk of lactating animals as dieldrin. Heptachlor is stored in animal fat as heptachlor epoxide. DDT and endrin are stored as such (Gannon and Decker, 1959).

The many and complex effects associated with this storage are not thoroughly understood, but some preliminary findings have been published. DeWitt (1958) showed that egg production, fertility, and hatchability were significantly reduced by inclusion of DDT in diets fed breeding quail, and that chicks from these matings showed high crippling and mortality rates even when reared on insecticide-free diets. He states further that: "All of the chlorinated compounds tested appeared cumulative in action, and produced adverse effects upon survival, growth and reproduction. In all cases, inclusion of the insecticides in diets of breeding birds resulted in increased percentages of crippled and defective chicks, and in lowered chick survival."

Rudd (1958) remarks that we have only the crudest knowledge of the actions of pesticidal chemicals on nature. He offers three major categories of indirect effects as follows: (1) interference with the food chain; (2) faunal displacements, that include the disruption of biological controls by the simultaneous poisoning of arthropod parasites and predators of pest insects; and (3) chemical alterations, that range from increased insect resistance to the chemicals, to sublethal effects on wildlife that may cause, in addition to injuries already mentioned, shortened life span, reduced vigor, and possibly adverse genetical effects.

Many measures designed to reduce the deleterious effects of insecticidal programs on beneficial fauna are described in the literature. Consultation with fishery and game workers during the organizational stages of large-scale insect control programs usually results in minor adjustments being made in the plans and specifications that bring about major wildlife savings. Of great importance too is the need for conscientious operators who do their utmost to apply the chemicals in the way prescribed; careless application is frequently the main cause of damage to wildlife.

George (1958b) outlines long-range approaches to this overall problem that would provide solutions of more benefit to society as a whole. He advocates more specific chemicals that would do the job intended with a minimum of side effects. Along with this he encourages more emphasis on biological methods of control, on cultural methods of control in managing forests and croplands, and on the development of plant varieties that are resistant to insects and disease. These are commendable suggestions

but, as he indicates, they will not ease the immediate problem which basically is the need for closer cooperation between interested parties and better understanding of the true effects of insecticidal programs upon environment.

The current relationship of pesticidal programs to wildlife in Manitoba does not to my knowledge require urgent attention. There is no evidence that insect poisoning in this province has at any time seriously affected benefical fauna. Mass application of toxicants to protect flora from insect damage has not occurred in our forested or agricultural areas. Primarily our problem has been grasshopper control on croplands and so far chemicals, formulations, and application methods have shown considerable respect for wildlife. Most grasshopper control in Manitoba today is spot-type treatment, done by the land operator (with some government subsidy for the toxicant), using ground applicators, usually low pressure boom-type weed sprayers. Treatment is confined almost entirely to cultivated lands; wild lands are not subjected to appreciable poisoning. Recommended dosages of one ounce of dieldrin or three ounces of heptachlor per acre are within limits presently prescribed for safeguarding wildlife.

Wildlife biologists believe it is their duty to study and point out the adverse effects of insecticidal programs so that these effects receive objective consideration and are not overlooked or minimized. The programs in Manitoba will be watched closely in the years ahead for new developments. Wildlife interests will be on lookout especially for danger signals, such as mass aerial application of insecticides to forests, rangeland, wetland, or the use of heavier dosages if resistant populations appear, and programs that seem to be misguided or poorly organized. We believe that this is what you as well as general society expect from the wildlife profession.

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CONTAMINATION OF GRAIN AND GRAIN PRODUCTS

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In the process of evolution insects became fully entrenched on this planet long before the appearance of man and they have challenged with considerable success man's every effort to displace them. They are man's formidable competitors for food, they attack and often destroy his garments, his livestock and even his dwellings. We have learned from the Bible, the hieroglyphics of the Egyptians and the writings of the Greeks that ancient civilizations were beset by many insect problems. It is interesting to note that in the past 200 years the number of insect species known to exist have increased from 2,000 to 700,000 with 6,000 species in North America considered important enough to be called pests.

In 1868 an editorial in an Entomological magazine stated: "Few persons are aware of the enormous amount of wealth annually extracted from the pockets of the cultivators of the soil by those insignificant little creatures which in popular parlance are called 'bugs' but which the scientific world chooses to call insects". From time to time estimates have been made as to actual economic losses due to insects. The most recent figures I could find are:

Canada	$ 300,000,000 per year
U. S.	$4,000,000,000 per year

We are all aware of the fact that insects are important from an economic point of view but we sometimes fail to realize their importance as contaminants of human food and the possible health hazards attributable to them.

The discussion today deals only with the small group of insects that attack stored grain and grain products. It might be advisable to briefly outline the habits of several of the more important stored product insects for the benefit of those who are not engaged in this field.

For the sake of convenience the stored product insects can be broken into four general categories.

Insects that feed on the sound, entire kernel can be extremely destructive and are known as primary feeders. These insects also prepare the way for those pests that can attack the damaged kernels but are unable to penetrate the whole, sound grain. The primary feeder group includes whole, sound grain. The primary feeder group includes the rice weevil, granary weevil, lesser grain borer and Angoumois grain moth. All of these spend the greater part of their life cycle within the grain kernel.

The germ feeders, namely the Indian meal moth, cadelle, rusty grain beetle and flat grain beetle feed primarily on the germ. The seed coat of the kernel must be broken before these insects can gain entrance to the interior of the kernel.

The majority of our insects are considered ground cereal feeders and generally infest a multitude of products. This group includes the Indian meal moth, saw-toothed grain beetle, Mediterranean flour moth, cadelle, flour beetles, spider beetle, carpet beetle and mites.

The balance fall into the category of insects which feed on out-of-condition material and this group includes the foreign grain beetle, meal moth, flat grain beetle, fungus beetles and mealworms.

In the grain and milling industries, economic losses from insect attack occur at all stages between the producer and the consumer; on the farms, in the country elevators, in railroad cars, at terminal elevators and in food processing plants. Insects may go out with the finished product to the wholesaler, then to the retailer and finally to the home.

So far we have only mentioned the losses resulting from insect depredations. We must also include rodents, birds, chemicals and fungi for a more complete picture of possible contamination and economic loss. It has been stated that insects, rodents and moulds annually deprive man of about 10 percent of the cereal foods produced. This is calculated as sufficient food to feed 150 million people. Although the greatest loss occurs in warmer parts of the world where pests can thrive throughout the year and proper storage facilities are often lacking, we in North America still suffer heavy losses. In the United States the loss resulting from attack by stored food insects exceeds 300 million dollars per year. In Canada the severe winters restrict the period of insect activity in unheated storage and help to reduce the losses caused by insects.

The losses suffered through contamination of foodstuffs are much more obscure and most people are not even aware that they exist.

By dictionary definition the words "to contaminate" mean to render

unfit for a specified use. As most of the grain that is grown and most of the products manufactured from such grain are destined for human food we should ask ourselves several questions:

1. Can food manufactured from grain or grain products be contaminated other than by human hands?

2. If so, how does such contamination take place and why are such contaminants important?

3. What can we do about them?

The answer to the first question is yes. Insects, birds, rodents, chemicals and moulds can cause a great deal of trouble as far as product contamination is concerned.

I am sure we all realize the importance which must be attached to any form of food contamination. To protect the public, legislation was required to make certain that contaminated food products do not reach the market. I would like to quote a few sentences from the Canadian Pure Food and Drug Act:

"1. No person shall manufacture, prepare, preserve, package or store for sale any food under conditions or circumstances as might contaminate a food, drug or cosmetic with dirt or filth or render the same injurious to health.

2. No person shall sell an article of food that

a) has in or upon it any poisonous or harmful substances.
b) is unfit for human consumption.
c) consists in whole or in part of any filthy, putrid, disgusting, rotten, decomposed, or diseased animal or vegetable substance.
d) is adulterated.
e) was manufactured, prepared, preserved, packaged or stored under unsanitary conditions."

It is quite evident from the above exerpts that everyone connected with the handling of grain and grain products has a definite responsibility to see that all conditions of this act are met.

Four major sources of contamination are involved. These sources are insects, rodents, birds, chemicals and fungi, and each group will be dealt with separately to clarify the situation as much as possible.

I. INSECTS

Insect contamination of whole grain in the form of insect bodies or fragments and insect droppings can occur at each and every stage between the farmers' bins and the processing plants. Contamination of the finished product can occur from the manufacturing plants to the housewives' cupboards.

At the present time the milling industry does not possess machinery capable of removing all internally infested kernels that might be present in a wheat lot. Also, it is primarily the internal insect infestation which is responsible for fragments in flour and other cereal products and not the insect infestation which might be present in the manufacturing plant itself.

It has been shown that a single dehydrated weevil adult can fracture into 3000 pieces, many of which are small enough to pass through the finest seives present in a flour mill and which will ultimately end up in the finished product.

Several years ago I carried out some experimental work to determine the losses suffered from milling insect infested wheat. We started with two 60 bushel lots of identical wheat. One was held as a control and one was artificially infested. This was repeated several times so that we were able to obtain several different levels of internal insect infestation.

The wheat lots were milled on a large experimental mill and hourly samples of each mill stream were secured and analyzed for ash, moisture content and insect fragments.

Tests on the whole grain gave the following results:

1. Test weight per bushel decreased during storage in both the control lot and the infested lot due to loss in moisture content, but the infested lot decreased in weight still further due to insect feeding.

2. Moisture content decreased in both lots during storage but the loss was less in the insect infested lot due to insect activity.

3. Protein content increased in both lots but the increase was highest in the control lot.

4. The entoleter scourer aspirator was very effective in removing internal infestation.

To clarify the results of these experiments I would like to mention several facts concerning the milling process.

There are a number of machines involved in the milling process, each machine having a definite job to do. The flow of materials through the various machines is called mill streams, e.g. when the grain goes through the first set of rolls or grinders the material coming out below the rolls is referred to as the first break stream.

All finished flour may appear to be the same to the untrained individual, but every mill run has definite standards which the finished flour must meet. One of the more important characteristics of a finished flour is the ash content. During the milling process the miller diverts the mill streams to the various grades of flour largely on the basis of their ash content (which incidentally is determined several times throughout the run). In this manner he can produce a finished product of a certain ash content.

One other word of explanation - the term per cent Hungarian refers to the number of pounds of flour obtained from 100 pounds of wheat.

In order to manufacture flour on an economically sound basis the miller must get a good return of flour for the amount of grain ground. The per cent Hungarian, therefore, is a numerical expression of the efficiency level of the manufacturing process. This percentage usually runs in the region of 70-75 per cent, meaning for every 100 pounds of grain ground, 70-75 pounds of flour are obtained.

The following table shows how the insect fragments are distributed in the three grades of flour and the percent of wheat each stream represents in the total flour.

Table I shows that there are five streams denoted by a star. These are the only streams that do not go into the top grade flour. Of the remainder of the streams, 7M1, 6M and CD add a great many fragments to the overall total and also make up a considerable portion of the per cent of total wheat. It would mean a large economic loss if the three streams just mentioned were removed from the patent flour to reduce the fragment count of the finished product.

As was previously mentioned the ash content of the various streams is a determining factor in its grade allocation.

Our results showed that the ash content of the infested streams ran consistently higher than that of the control. As insect fragments add to the ash content of the mill streams it is logical to assume that if a low ash flour is required some of the high ash streams would have to be diverted to the lower grades of flour resulting in a loss of patent flour.

If the cumulative per cent Hungarian is plotted against percentage of ash for both infested and control, a much clearer picture of the final result of milling infested grain is obtained. If a standard .390% ash flour is used as a basis for comparison and the lines from the curves are dropped to the base line there is a difference of 1.5% in patent flour production. In actual practice this would mean that a mill grinding 15,000 bushels of wheat per day infested at a level of 12 internal forms per 100 grams would lose 135 cwt. of patent flour with an increase in the lower grades of flour. This would certainly be a significant economic loss.

So far we have been concerned only with the economics of milling infested grain. The magnitude of the fragment counts of the finished flour was such that a product from this flour would be violative of the Food and Drug laws and would be subject to seizure. This will be discussed in more detail shortly.

II. RODENTS

The people closely associated with the handling, processing or storing of grain and grain products are cognizant of the fact that rodents can be a real problem. I am sure that we are aware of the losses attributable to rodents through damage to building and damage to bags, packages,

Table I - Fragmentation Results of Flour Streams

Stream	Fragments	% of Total Wheat
1B	102	.95
2B	17	1.76
3B	21	1.08
*4B	220	.95
*5B	52	.72
1M1	19	1.90
1M2	8	4.38
2M1	6	3.43
2M2	26	8.86
3M1	52	.90
3M2	38	9.45
4M1	62	1.71
4M2	56	3.84
5M1	44	.90
5M2	92	3.84
6M	130	7.60
7M1	214	6.60
*7M2	256	2.89
1 Siz	20	.81
2 Siz	228	.76
*1T	500	1.71
*2T	876	3.84
RD1	152	.45
RD2	102	2.80
GD	26	.27
CD	588	3.10

etc., but do we realize the magnitude of the contamination aspect of the problem? Rats are known to carry 10 diseases including Bubonic plague, tularemia, murine typhus, rabies and bacterial food poisoning.

Sources of rodent contamination can be split up into three sections.

1. Contamination by rodent pellets.
2. Contamination by rodent hairs.
3. Contamination by rodent urine.

At the present time the milling industry does not possess machinery capable of removing all the rodent pellets that might be present in wheat as received at the mill. Because rodents have the habit of licking their fur they are constantly ingesting hairs with the result that their pellets are charged with hair fragments. If it is impossible to remove all of the rodent pellets from a wheat mix it is logical to assume that some of the hair fragments will end up in the finished product.

Rodent hairs are capable of travelling considerable distances by means of air currents. I personally have collected rodent hairs from the filters of an air conditioning unit located on the 13th floor of an office build-

ing in the heart of a large city as well as from each floor and the roof of a large flour mill presumed to be free of rodent infestation. Much of the mill machinery is not a completely closed system and it is easy to visualize rodent hairs being added to the mill stream even though the wheat being ground might be entirely free of contamination by rodent pellets.

The third source of contamination, rodent urine, is also extremely important and applies mainly to warehouses or buildings where the finished products are stored. The biology of the mouse is such that the elimination of urine is a more or less continuing process. A mouse in the course of his daily living may contaminate a number of bags each with only several drops of urine. The contamination however slight is still present and of course violative of Food and Drug regulations.

III. BIRDS

Birds are usually a source of contamination only in the case of whole grains and such contamination would in the letter of the law render such grain unfit for human consumption.

IV. CHEMICALS

Possible contamination of grain and grain products by various chemicals such as insecticides is common knowledge but there are two other possible sources of contamination that fall in this category which might not be so evident namely organic seed treatments and the use of rodenticides.

V. FUNGI AND MOULDS

Contamination from this source can be important in grain storage in that it enhances the deterioration of stored grain. It is important in the mill, where certain areas of the mill machinery can be polluted with these organisms resulting in a tainted or discolored product. It is important to the shipper, especially in Southern markets, where whole shipments of flour can be ruined through rapid growth of these organisms on the exterior of the bags. Last but not least it is important to the bakery specialty manufacturers where spore counts are a necessary part of production standards and high counts can result in exploding packages, among other damages.

So far we have dealt briefly with the sources of contamination and why we must consider them important. Just as important are the methods by which the specialists in the various fields check for contamination.

Each of the five major sources of contamination are fields in themself, but I will attempt to describe briefly some of the methods employed and the results obtained. Generally speaking, all contaminants are microscopic in size, difficult to separate from cereal foods and impossible to identify without some degree of special training.

I. INSECTS

Internal insect infestation can be much more important than free living insects from the standpoint of finished product contamination. Free living insects are usually removed during wheat cleaning and milling operations. Internal infestation is for the most part not discernible to the naked eye because the greater portion of the life cycle of insects in this group is spent within the shell of the kernel and cannot be seen.

Over the years a number of methods have been used to locate this hidden infestation, the three used commonly are:

a) Staining techniques to color the egg plugs.

b) Cracking floatation; the grain sample is coarsely ground followed by digestion of the starchy portions and the floatation of insect material by means of mineral solvents. The material so removed is then examined under the microscope.

c) Radiography; by means of an X-Ray the internal insect infestation is rendered visible to the naked eye. This is the most recent development in the "detection" field and is by far the most accurate because the internal infestation can be easily counted by this method.

The method used to detect insect fragments in flour and other cereal products depends on the product in question. The method for flour is basically the digestion of the starch and the floatation of insect material by means of mineral solvents. The material so recovered is placed on ruled filter papers which can be examined under the microscope. The identification of such material required considerable skill and practice.

II. RODENTS

The detection of rodent contamination in whole grain or cereal products is usually based on the identification of rodent hairs. Whether the hairs come from pellets in the grain or are air borne in the mills make no difference to the end result. The method used to separate insect fragments from flour is also used for the separation of rodent hairs.

The method used for the detection of rodent urine stains on flour bags is based on the premise that the urine stain will fluoresce when examined under black or ultra-violet light. The technician must exercise caution in such an examination as other substances such as some bag sizings will also fluoresce. To absolutely identify the presence of rodent urine a chemical solution known as Frehling's solution may be "painted on" the suspected area. A positive result is evidenced by the treated area turning chrome yellow in color.

III. BIRDS

The detection of bird contamination in finished flour is extremely difficult unless feather fragments are present. Feather fragments could be the result of contaminated grain or from an air borne source within the mill.

IV. CHEMICALS, FUNGI AND MOULDS

The contaminants included in this group are generally the most difficult to detect. Complex chemical tests are available for the detection of certain chemicals and spore counts can be run for the determination of mould and fungi contamination, but it is not the purpose of this paper to discuss the methods in current use for the detection of the various organisms.

Contamination of food is important and it is hoped that this presentation has helped to make us aware of some of the problems that can exist.

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EARLY COLLECTORS AND COLLECTIONS OF INSECTS IN MANITOBA

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"The state of society in which the works of creation are duly investigated is not in its state of infancy or boyhood, but that of its maturity and confirmed manhood; for, in its earlier and rude stages, the sciences in general are looked upon with indifference, and not seldom with contempt, but, in proportion as civilization advances, they acquire daily more and more importance. The last, probably, that is raised to its proper rank in the public estimation, is the study which is distinguished by the name Natural History." - Rev. Wm. Kirby, 1837.

INTRODUCTION

Faunal surveys attempt to show the distribution of species and their ecological relationships. When surveys are of a continuing nature they show changes in distribution and abundance. Changes in the distribution of insect species are especially apparent in Canada, where many species have been introduced. Some have been deliberately introduced in attempts to control outbreaks of pests by biological methods. Many other species have been introduced accidentally, and it has been speculated (4) that some of these reached the shores of Canada in earth ballast during the era of sailing vessels. Insect populations are by no means static. Noxious species appear periodically in outbreak numbers, and it is becoming increasingly important to collect data that will permit the forecasting of outbreaks in advance. This assures timely action designed to prevent losses from insect attack and to study the role of factors that eventually will reduce

outbreaks to a status of low populations. An important requisite to forecasting is a knowledge of earlier outbreak patterns, their periodicity and duration. This points to the need for long-term infestation records and museum material dating as far back as history can provide. Unfortunately, early collections of insects in Manitoba have been inadequately recorded and most of them have been lost or buried in distant museums. Wallis (15) gave an account of the early collectors and collections of the present century, featuring the work of resident entomologists. The present contribution attempts to augment Wallis' account by covering an earlier period. It became readily apparent at the start of this compilation that some degree of selection would be necessary. Accordingly, only those persons who actually collected insects, or who made unusual contributions to our knowledge of insects, are included in the brief biographical notes presented herein. Where possible, the scope of their interest in insects and general nature study is indicated. Considering the period under review, it is not surprising that most of the naturalists discussed were transients.

It is recognized that this account fails to do justice to some of the early naturalists who made only casual reference to insects, especially biting insects. Notable among these naturalists are Forster, Hearne, Isham, Kelsey, and Thompson. Possibly the most interesting of this group was Thompson (Tyrrell, 14) who obviously was a keen observer and not without wit. He described the life history of the mosquito, the structure of its "bill", and he even mentioned a method of protection from these pests. He related, "A sailor finding swearing of no use tried what tar could do, and covered his face with it..." Kelsey (6) also found biting insects troublesome, but he will be best remembered for his power of description and unique style which are well illustrated by his account of a bear, encountered on his trip up the Nelson:

> ". . . Thus it (the Nelson) continues till you leave y woods
> and then you have beast of severall kind
> The one is black a Buffilo great
> Another is an outgrown Bear w, is good meat
> His skin to gett I have used all y, means I can
> He is man's food and he makes food of man. . ."

Many of the early naturalists were specialists in geology, medicine, or botany with a passing interest in insects. One of the most interesting of this group was James Barnston, a boy from Norway House, later becoming a well known botanist who, according to Maycock (7), was the first to catalogue the herbarium of McGill University.

Interest in natural history during the eighteenth and early nineteenth centuries was largely confined to observations on mammals, birds, fish, and fossils. Accounts of these were written by officers of the Hudson's Bay Company and Arctic expeditions engaged in the search for trade routes to the Pacific. Interest in insects received little attention until about the second quarter of the nineteenth century. By this time feuds between the Hudson's Bay Company and the North West Company had ended, and more travellers were using the southern trade routes. Not only were these more amenable to travel, but offered to the collector more variety in plant and animal life than did the northern states. About the middle of the nineteenth century both the Imperial Government and Canada were showing increasing interest

in the exploitation of the Territories, and most of the insect collections at this time were made by members of government-sponsored expeditions. Later in the nineteenth century most of the known insect collections were made by officers of the Geological and Natural History Surveys of Canada and by private collectors. However, the scope of collecting at all times was exceedingly small and most of the captured insects were beetles. The greatest contribution of the Hudson's Bay Company to our knowledge of insects was their physical aid to expeditions that travelled through the Province. This kind of assistance was especially acknowledged by Preble (9) after his expedition to the Mackenzie.

BIOGRAPHICAL NOTES

John Richardson (1797 - 1865)

Richardson was the surgeon and naturalist of the Sir John Franklin expeditions. The second expedition (1825 to 1827) followed the same route as the first and took the party through Manitoba, travelling via Albany, N. Y., Niagara, Sault Ste. Marie, Fort William, Lake of the Woods, Winnipeg River, Lake Winnipeg, Cumberland Lake (then called Pine Island Lake), and hence to Fort Resolution.

Richardson probably made a greater contribution to our knowledge of insects, birds, mammals and fish than any other naturalist to the beginning of the present century. His insect collection (10) was named and classified by Rev. Wm. Kirby. Kirby also listed the few insects collected during the expeditions of Parry, Ross, and Back.

Some of Richardson's insect material was collected enroute from Albany to Cumberland House. Approximately 30 species fall into this category. Nearly an additional 100 species are shown as having been collected at Latitude 54° and Cumberland House. The location frequently shown as "Lat. 54°" probably was Norway House, which was built on its present site in 1826.

Richardson obviously was most interested in beetles, as indicated by the following synopsis of numbers of species by families: Coleoptera - 345; Hymenoptera - 32; Lepidoptera - 32; Hemiptera - 17; Diptera - 14; Orthoptera - 3; Neuroptera - 2; Trichoptera - 2; Homoptera - 1; Others - 1. It is presumed this material was lodged in the British Museum of Natural History, but confirmation is lacking.

Richard King

Richard King was the surgeon and naturalist of the Capt. George Back expedition of 1833, 1834, and 1835. This expedition was sponsored by the Imperial Government and almost 1000 private contributors. The purpose of the expedition was to find Sir John Ross, who had been reported lost in the Arctic. Back followed much the same route as Richardson, and hence King collected on the Winnipeg River, Lake Winnipeg and York Factory, as well as Cumberland House and other points enroute.

M. E. Bourgeau

Mr. Bourgeau was with the Palliser expedition to Manitoba and other parts of the Territories from 1857 to 1859. Being primarily a botanist, he collected several hundred species of plants, but also collected 157 specimens of insects. The species of the latter are not recorded by Palliser (8), but Dr. R. B. Benson stated in personal correspondence that the material was lodged in the British Museum of Natural History in 1859. The composition of the collection cannot be ascertained without going through the entire species catalogue of the museum.

Henry Youle Hind (1823 - 1908)

According to Thomas (13) the Canadian Government commissioned George Gladman to head an exploratory expedition to the Territories. Gladman planned the expedition and started it on its way in 1857, but illness apparently prevented his further participation in the work. Consequently, two of Gladman's lieutenants, H. Y. Hind and S. J. Dawson continued the expedition in 1858 and 1859, but they worked independently. Both had similar terms of reference, but Hind was especially charged with making observations on geology and natural history. These expeditions perhaps lacked the prestige of the Palliser expedition, but both Hind and Dawson made important contributions to Canada. However, the two leaders disagreed in their interpretation of the usefulness of the land, the temperament of Indians and Metis, and best means of communication over the vast area. Dawson generally showed better judgment, but Hind will be remembered for his detail of observation.

Hind was a professor of chemistry and geology at Trinity College. His account of the country is notable for his descriptions of plant and animal life and quality of his illustrations.

Hind made observations on birds and trees, describing forest types encountered during his travels. He observed phenomena such as frost injury to aspen (5, p. 404), plagues of grasshoppers, and the nuisance of mosquitoes and "bull dogs". Apparently Hind's description of insects, mammals and birds were made from field notes, because there is nothing to indicate that he collected specimens for future study.

The Hind expedition is especially noteworthy because one of its members, H. L. Hime, was the first photographer to visit the Canadian prairies (13). His photographs were not reproduced directly in the Hind report, but were used as a guide in the preparation of wood cuts. Consequently, Hind's illustrations were extremely clear and accurate.

Archdeacon W. W. Kirkby (? - 1908)

Archdeacon Kirkby was referred to by Wallis (15), as "Kirby", and the letter "k" has inadvertently been dropped in other documents or letters that pertain to Kirkby. Consequently, there is a risk of confusing him with Wm. Kirby, author of "Chien d'Or" and Rev. Wm. Kirby, the English cleric and entomologist.

I have not been able to determine the movements or interests of this naturalist very precisely. His knowledge of this country undoubtedly was recognized, because he was mentioned by Hine (5) during his visit to the Red River Settlement in 1858. Kirkby was then stationed at the old St. Andrews church which was nine years old at that time. According to Rev. C. B. Boon, (personal communication) Kirkby served at Island Lake and York Factory, and he went to Fort Simpson in 1859. Also, he was the first Anglican missionary to the Yukon, having made two trips there prior to 1861.

Kirkby was interested in the Chipewyan Indians, and as an entomologist he was mainly interested in Lepidoptera. What became of Kirkby's main collection is unknown, but he gave Bell (2) 29 species of Lepidoptera in 1879 during Bell's visit to Island Lake and God's Lake. These were identified by Herr Geffcken of Switzerland (2).

Frank Russel

Frank Russel, a staff member of the University of Iowa, made a collecting trip to Grand Rapids and Cedar Lake, Manitoba, in 1891 (11). Finding these rather poor collecting areas, his explorations took him further northwest in 1892, 1893, and 1894. His primary interest was in birds, mammals, and fossils, but he also collected 35 species of insects, all members of the Coleoptera. Nine of these species were collected at Grand Rapids, Manitoba. Undoubtedly Russel's collections were deposited in the museum of the University of Iowa.

S. H. Scudder (1837 - 1911)

This entomologist was born in Boston. After graduating from Harvard, he became well known as a student of Orthoptera, and he published a catalogue of this family in 1901. At the age of 23, in 1860, he visited Manitoba where he travelled between Winnipeg and The Pas (12). His collection of Orthoptera captured on this expedition consisted of 15 species, three of which were described as new. Scudder does not name the collection in which these specimens were lodged.

Robert Bell (1841 - 1917)

This distinguished scientist was born in Toronto and he graduated from McGill University in Medicine. From 1863 to 1867 he was professor of chemistry and natural science at Queen's University. He served over 50 years with the Geological Survey of Canada, part of this period as its Director. The high costs of railway transportation that existed in the west in 1882 prompted the Government of Canada to explore alternative transportation outlets from Manitoba. Consequently, the Government dispatched an expedition by sea to Hudson's Bay in 1884, 1885, and 1886, the object being to determine the length of the season of navigation in the Bay. The expedition was commanded by Capt. A. R. Gordon, with Prof. Bell in charge of the scientific investigations. Bell again visited Hudson's Bay in 1897, and conducted other surveys to northern Manitoba, Alberta, and the North West Territories. Bell retired to his farm at Rathwell, Manitoba, where he died in 1917.

Bell collected both plants and animals. His collections from God's and Island Lakes (2) consisted of 237 species of plants, 55 species of birds, 20 species of fresh water mollusks, and 38 species of insects (Coleoptera). Some of the latter were given to Bell by Kirkby. Another list of insects was published in 1883 (3). This fairly extensive list of beetles included 69 species collected at Oxford House and between Lake Winnipeg and Hudson's Bay; 51 species from Nelson House; and 19 species collected between Cross Lake and Cumberland House. All of Bell's insect collections were identified by J. L. Le Conte. It is presumed that his material was lodged in the National Museum in Ottawa.

During his first visit to northern Manitoba Bell (2) made observations on the distribution of forest trees, including tamarack, spruce, balsam fir, birch and poplars. At God's Lake Bell reported tamarack approaching 20" d. b. h. Unfortunately such stands don't exist in this area today because of past devastating forest fires.

DISCUSSION

It is clear that much of the insect material collected during the past century has been lost or lodged in collections outside of Manitoba. The number of classified collections in this Province is small. Among the best of these are the collections of the University of Manitoba, Canada Agriculture Research Branch in Winnipeg, Manitoba Museum Association, and the Riding Mountain National Park. Most of the material in these collections is recent, with the oldest material having been collected by well known names such as Wallis, Criddle, Mitchener, Roberts, May, Brooks (G. S.), and Bird. The value of these collections will increase with time, so every attempt should be made to preserve and enlarge existing collections for the benefit of future students of insect epidemiology.

Although most of the nineteenth century insect collections in Manitoba were taken in forested areas, it is surprising how few are now recognized as forest insects of importance. Exceptions to this observation are: Monochammus scutellatus (Say) (10, 3); M. marmorator (Kby.), (= H. congener) (10); and Hylobius pinicola (Couper) (3).

Among the presently recognized forest insects of economic importance not recorded in Manitoba during the last century are Pristiphora erichsonii (Htg.), Choristoneura fumiferana (Clem.), Acleris variana (Fern), and Malacosoma disstria Hbn.

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APPENDIX

ADDITIONS TO THE LIBRARY OF THE ENTOMOLOGICAL SOCIETY OF MANITOBA

The following list contains the names of authors and/or titles of publications received in exchange for the Proceedings since the publication of the list appended to Volume 14.

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