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PROCEEDINGS OF THE
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ENTOMOLOGICAL SOCIETY OF MANITOBA

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

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INTRODUCTION

Although the Society was not a host to meetings of other related organizations in 1965 it had a successful year. Interest remained high among the members and the Proceedings are recognized and in demand by libraries and workers in entomology.

The spring meeting, after the presentation of 2 papers on soil insects and a short business session, featured a tour of the Grain Research Laboratory, Winnipeg.

The Annual Meeting was held at the C. D. A. Research Station, Winnipeg and featured the theme of integrated control. Dr. H. E. Welch, Head, Department of Zoology, University of Manitoba and formerly of the Research Institute for Biological Control, Belleville, Ontario gave the opening address. It was followed by a series of papers on various aspects of control. The Society was especially favored by a timely visit from Dr. S. Pradhan, President of the Entomological Society of India, and Director of the Division of Entomology, Indian Agricultural Research Station, New Delhi. Dr. Pradhan was gracious enough to address the Society on some aspects of his work as well as to outline a few of the entomological problems of India. A banquet was held in the Montcalm Motor Hotel with Professor G. L. Rowland of the Department of Psychology, University of Manitoba, as guest speaker. He discussed his work on primate behavior and illustrated infant behavior with movies.

After association with the Society from its beginning I appreciate the opportunity to serve as its President. With the active support of the executive it has been a pleasure. As this is my final year before retirement I wish to express my gratitude to the membership for their friendship and extend my best wishes for the continued success and growth of the Society.

R. D. Bird,
President.

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ENTOMOLOGICAL PROBLEMS AND RESEARCH IN INDIA

S. Pradhan

Mr. President and authorities and members of the
Entomological Society of Manitoba

I am sincerely grateful for the honour of your very kind invitation extended to me to address this distinguished gathering. As President of the Entomological Society of India I convey the greetings of that Society to the Entomological Society of Manitoba.

As regards my address I must crave your indulgence if I am not able to treat you with a well prepared speech. During my whirlwind tour of the world I have had no time to prepare a speech and I have scribbled something this morning.

I am supposed to speak on the entomological problems and research in India. Let me therefore start with the statement that the entomological problems in India are far more complex, far more difficult and far more pressing than the entomological problems in Canada, atleast as far as I have been able to visualize them. As this Session is scheduled to be for one hour and as I must leave sufficient time for questions and clarifications I propose to be as brief as possible, but I also request the President to use his Presidential prerogative to stop me as soon as I am going beyond the limit. Therefore I propose to confine most of my remarks to agricultural entomology with which I have been more intimately connected.

As regards the magnitude of the entomological problems in India, more than 40,000 insect species have been described from India. Of these 40,000, more than 1,000 species have been observed to feed on plants of economic importance. Of these 1,000 species about 500 species have been recognized as pests and out of these 500, more than 250 have been listed in all-India lists of crop pests and out of the 250, about six dozen have been considered to be serious pests.

As examples of the entomological problems facing individual crops the rice crop has about three dozen pests; the wheat crop is practically free from serious insect pests in the field except termites in unirrigated areas but it has very serious pests in storage. Of the two major crops of rice and wheat, rice faces more serious problems in the field and wheat faces more serious problems in storage. Practically all fruit crops and all important cash crops like sugarcane and cotton are subject to serious pests.

As regards the nature of the entomological problems, the whole field of agricultural pests can be divided into two broad categories, viz., the internal feeders and the external feeders. Insecticides have made it possible to control a majority of the external feeders and the problems to be solved remain in the field of economics and organization. As regards internal feeders the problems remain entomologically unsolved. Hence entomological investigations are mostly concentrated on the internal feeders which generally do not yield to the insecticidal approach. The problem of insect resistance to insecticides has not yet been acute, mainly because the selection pressure has not been great. The residue problem has begun to cause serious concern.

The organizational set-up for agricultural entomology follows the organizational set-up of the agricultural department. At the central or federal level there is the Indian Agricultural Research Institute which is responsible for carrying out investigations of fundamental nature. At this Institute we entomologists carry out investigations on what we call fundamentals of agricultural entomology. Then there is a central institute for forests where work is in progress in forest entomology. Problems of veterinary entomology are being tackled at the Indian Veterinary Institute about 150 miles from Delhi. Again there are central commodity institutes like Sugarcane Research Institute, Rice Research Institute, Potato Research Institute, Tobacco Research Institute, Coconut Research Institute, Central Drug Research Institute and others. Entomological problems are being tackled in each of these institutes. Besides these central institutes, there are State departments and in each State department there is an entomological staff for tackling local problems. There are a large number of universities where mostly morphological, physiological and some taxonomic work is in progress.

Nature of Entomological Contributions

The next question of this august gathering will likely be how the entomological problems are being tackled at the research and extension levels. Hence I will try to present a few examples from this field. In doing so I propose to pick out examples from my own work. I am doing so not because others have not done as good as or even better work than what I am going to present but because with these examples I can more confidently answer the research questions which might be raised.

First of all I would like to draw your attention to some of the research which has been undertaken with a view to evolving practical techniques for what is now being much discussed all over the world as integrated control and which formed the theme of the first talk delivered yesterday. I did not draw attention to it yesterday because at that time attention was being concentrated mostly on the philosophy of integrated control and what I am going to say is on the technique of integrated control.

From the very beginning I have felt, rightly or wrongly, that for rational solution of insect problems we must carry out intensive work on the ecology and population dynamics of each important pest species. And in the ecological complex, the most dominant factor, according to my conception, has been temperature. Hence I started to study the effect of temperature on the life economy of insects as early as 1940. As a result of these studies the following new equation was evolved:

$$Y = Y_o e^{-ax^2}$$

wherein Y_o = highest value of the developmental index; Y = developmental index at temperature t; $x = T-t$; T = temperature corresponding to Y_o, and e = constant = 2.718282. Not only is this equation based on rational biological reasoning, but with its help calculations are simplified since it is the normal equation of statisticians, who have published tables of calculations for ready reference. Moreover, this equation has made it possible to evolve another equation for calculating developmental periods corresponding to any range of variable temperature. This equation is:

$$Y_{(t_1 - t_2)} = \frac{Y_0 \int_{x_1}^{x_2} e^{-ax^2} \, dx}{t_1 - t_2}$$

wherein $Y\,(t_1 - t_2) =$ average value of the developmental index corresponding to a temperature fluctuation between t_1 (max.) and t_2 (min.), at which the corresponding values of x are x_1 and x_2. With the help of these two equations it is possible to calculate both the accelerative and retardative effects of fluctuating temperatures on insect development.

Biometer

An advance in this line is in the evolution of a ready reckoner for reading off the rate of insect development at any temperature and for estimating the amount of development or number of generations in any given period and under any age range of temperature fluctuation by counting the number of certain cells. This device has been named Biometer (Pradhan 1945). A biometer consists of a thermograph chart which is transparent and in which the horizontal lines instead of showing temperature indicate the calculated rate of development corresponding to different temperatures. When this transparent chart is superimposed over a thermograph tracing, one can read directly the rate of development at different points of the time scale. Further, as the ordinate of this chart represents the rate of development and the abscissa the time, the area below the temperature tracing gives directly the amount of development. The different portions of the area are not equal in value because the relation between temperature and development is not linear, but this difficulty is avoided by estimating the area not by a planimeter but by counting the cells formed by horizontal and vertical lines; these cells differ in area but are equivalent in developmental value. This device reminds one of the old method of thermal summation, with the advantage that it is not based on the assumption of a straight line relationship between temperature and rate of development. It can be based on any kind of relationship found experimentally, and takes into consideration even the upper descending part of the curve. Thus the area above the line showing maximum value of developmental index has a minus value, and in case the temperature rises above this line the area enclosed by temperature above this line is to be subtracted from the area below this line. This method also takes into account all the irregularities of temperature fluctuations.

Use of Biometer in Integrated Control

Now the biometer is proving very useful for suggesting integrated control particularly in the case of internal feeders whose rate of development cannot be observed from outside. Thus the integrated control suggested for the internal feeders like lepidopterous stem borers of sugarcane is as follows: moths of these pests lay their eggs on the plant surface and the larvae hatching from these eggs crawl on the plant surface for a specified period which can be determined by actual observation for each species. Thereafter, these larvae enter the plant tissue and get out of the reach of ordinary insecticidal dusts and sprays. Hence it is suggested that the insecticidal sprays against these first stage larvae should be made to coincide with the hatching period of these eggs which can be easily determined with the help of the biometer. The spraying should be carried out just when the early hatching is expected and the variation in the hatching period should determine the persistence of the insecticide which has to be selected. The strength of the insecticide has also to be determined so as to ensure that the first stage larvae will pick up the lethal dose of insecticide during the few minutes when they crawl over the plant surface. By taking care of these specifications it is expected that a large majority of the newly hatched larvae will be killed before they are able to do any appreciable damage. Also by means of these precautions the persistence of the insecticide will last only for the specified period needed to kill the first stage larvae and no more. Thereafter parasites parasitizing different stages of the larvae and pupae can be released in such a manner that the release of a particular parasite coincides with the peak of the stage against which they are to work and this peak can be determined with the help of the biometer. These biological control operations carried out in the larval and pupal periods can thus be integrated with the chemical control directed against the first stage larvae. Last of all, the peak emergence of the moths can also be determined with the help of the biometer and at that stage one can resort to the latest technique of controlling the development of the next progeny with the help of the sterile adult technique. Integration of this latest technique with the chemical and biological control operations mentioned earlier is highly rational because the efficiency of the sterile adult technique is maximum at the lowest population density of the pest. Hence it is quite rational to reduce the population of the pest from its highest peak at the egg stage to the lowest level at the adult stage by means of chemical control and biological control, the efficiency of which is higher at higher population density of the pest, and then to use the sterile adult technique at the low population level of the pest.

Effect of temperature on insect susceptibility to insecticides

Our earlier studies on this aspect have led to the conclusion that for studies on insect resistance, temperature has to be differentiated into three separate components: (a) temperature during insecticidal application (Treatment temperature) which increases the uptake of the insecticide, (b) temperature after the insecticidal application (Post-treatment temperature) which increases up to a certain degree the physiological resistance of the insect to the insecticide and (c) temperature before the insecticidal application (Pre-treatment temperature) which increases both the physiological resistance and the uptake of insecticide (Pradhan 1960). It has been further shown that at least in some cases the change in insects' resistance to insecticides with change in temperature follows essentially the same curve as is obtained in cases of temperature-effects on any other physiological activity, implying thereby a similarity between the insect resistance to insecticides on the one hand and its other physiological activities on the other hand. Our views on this subject have been constantly undergoing evolution and according to our present tentative view it is possible that the post-treatment temperature instead of always increasing the physiological resistance of the insect up to a certain degree as stated above, may probably be increasing the metabolism of the insecticides inside the insect's system and that if this metabolism leads to non-toxic or less toxic metabolites the insect's resistance may increase with temperature as stated earlier, but if the metabolites happen to be more toxic than the original chemical the temperature effect can be reversed. Experimental evidence in favour of or against this possibility is under investigation.

A physiological theory of the mode of action of DDT

We have propounded this theory only recently. According to this theory the negative temperature co-efficient of DDT action is partially due to the negative temperature co-efficient of the viscosity of the matrix of the nerve membrane. It has been experimentally established by us that the application of DDT increases the frequency of the automatic impulses in the insect nerve. The low temperature on the other hand, increases the viscosity of liquid and semi-liquid material like the matrix of the nerve membrane and thus hinders the ionic exchange across the nerve membrane which generates the electrical impulse in the nerve. The result of these two opposite actions leads to a physical breakdown in the functioning of the nerve. The details of these experiments are yet to be published. All the same, it provides an example of the extent of the intensive probe we are trying to make into the depth of the entomological problems.

A new biotic theory of the periodicity of locust cycles

Now I may turn from the above stage of a sort of molecular biology to an example of an extensive global approach. For this, I wish to make a reference to what is called a new Biotic Theory in the Periodicity of Locust Cycles. According to this theory the population explosion of the Desert Locust in India takes place not where and when the climatic conditions are optimum for the development of this species as is ordinarily expected but where and when the climatic conditions are too inhospitable for the enemies of the Desert Locust but are tolerable to the Desert Locust. It is visualized that vertebrate predators, particularly the cold-blooded ones, are comparatively more effective in delimiting the breeding of the Desert Locust both in time and space (Pradhan 1962, 1965).

Some recent practical results

Now I refer briefly to our work between the above two extremes. In this connection, I would draw your attention to the following two practical results:

(a) Neem repellent against the Desert Locust

A few years ago we found that the kernel of the seed of *Azadirachta indica*, which is a popular local tree called *neem*, can be used as a very effective anti-feeding material against the Desert Locust. If a 0.1% suspension of the kernel of the seed of this plant is sprayed on any crop, that crop remains safe against locust damage for about three weeks. This discovery has put a very potent weapon in the hands of the individual cultivators who used to feel helpless when locust swarms invaded the area. Now with the help of this anti-feeding material they can save individual field crops if they so desire, irrespective of what their neighbours may like to do (Pradhan *et al.* 1962, 1963).

(b) An improved storage structure

Bags of polythene film and polythene film linings have been used quite extensively for safe storage of grains and other food material. However, the defect in this existing use has been that the polythene film gets damaged due to mechanical abrasion and handling stress and strain. Hence we have tried the idea of embedding this polythene film in the walls of the storage structures made of other materials like earth, cement and brick. In this way, the mechanical strength of the earth, cement or other material saves the polythene film from mechanical injury and the polythene film adds to the imperviousness of the other materials. We have found that the storage structures made on the above principle have been maintaining their efficacy for the last several years during which they have been tried (Pradhan *et al.* 1965).

Finally I must thank you again for the excellent opportunity provided to me for talking to you in a group. I also take this opportunity to express my sincere appreciation and gratitude for the hospitality I have received at Winnipeg. I am particulary grateful to Dr. Bird and Dr. Sinha who kindly took the initiative of writing to me and inviting me to this centre of learning and research and who have been treating me more as a personal guest than merely as an official visitor.

REFERENCES

Pradhan, S., 1945. Idea of biograph and biometer. *Proc. Nat. Inst. Sci. India,* 12 (6): 301-314.

Pradhan, S., 1960. Investigations on problems of insect resistance to insecticides carried out at the Indian Agricultural Research Institute, New Delhi- *Proc. Haffkine Inst. Diamond Jubilee Symp. Bombay:* 115-127.

Pradhan, S., 1962. Probable role of biotic factors in the periodicity of locust cycles - *Indian J. Entomol.* 23 (1): 1-6.

Pradhan, S., 1965. A new biotic theory of the periodicity of locust cycles - *Indian J. Entomol.* 27 (1): 95-101.

Pradhan, S., Jotwani, M. G. and Rai, B. K., 1962. The neem seed deterrent to locusts. *Indian Fmg.* 12 (8): 7, 11.

Pradhan, S., Jotwani, M. G. and Rai, B. K., 1963. The repellent properties of some neem products. *Bull. Reg. Res. Lab. Jammu,* 1 (2): 149-151.

Pradhan, S., Mookherjee, P. B. and Sharma, G. C., 1965. Pusa bin for grain storage. *Indian Fmg.* 15 (1): 14-16.

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PROBLEMS WITH PESTICIDES: THE POSSIBLE UTILIZATION OF FEEDING BEHAVIOR IN AN INTEGRATED APPROACH TO INSECT CONTROL[1]

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Abstract

The advantages and disadvantages of chemical and biological methods of control are discussed. No short-term or single approach to insect control is considered entirely effective. The desirability of an integrated multiple-approach program utilizing the best features of chemical and natural control is emphasized. Included in this approach is the search for compounds that influence insect feeding behavior, for example, attractants, repellents, arrestants or feeding stimulants. The feeding behavior of many species of insects has a chemotactic basis. Studies on the feeding behavior of flour beetles and rusty grain beetles have shown that these species respond to chemotactic stimuli. The use of traps baited with substances that elicit different feeding responses is discussed as a possible control method and as a survey tool.

Introduction

Francis Bacon once said "You cannot command nature except by obeying her". That quotation contains the essence of the necessity for maintaining what is frequently referred to as the balance of nature. It also implies that management without knowledge could be disastrous. What is this balance of nature we hear so much about? It means simply that all living organisms in an ecosystem are functionally related to one another in a rather delicate and dynamic balance (Doutt 1964). It can be defined more accurately by analogy with a spider web (Egler 1964). The concept of a spider web is superior to that of the food chain with which to visualize the interacting system of living things in a given habitat. You cannot disrupt one strand of the web without affecting other strands.

Unfortunately, and perhaps unthinkingly, modern man disrupted this delicate balance in many instances where he relied almost exclusively on pesticides to eradicate or control undesirable insects that infest our food and fiber.

Pesticide Dilemma

Because of our rapidly expanding world population which is increasing faster than our rate of productivity we face a great socio-economic problem. The long-term solution lies with statesmen, sociologists, and religionists. But we are concerned with the present, and it is our job to protect our fields, and harvests from insects, microorganisms and other contaminants, by all the means at our disposal. Until now we have relied almost entirely on pesticides. The main consideration in the use of an insecticide is to obtain immediate practical results. But as we now know the regular and intensive use of insecticides since the end of World War II has created a number of other problems

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[1] Contribution No. 207 from Canada Department of Agriculture, Research Station, 25 Dafoe Road, Winnipeg 19, Manitoba.

familiar to all of us -- insect resistance to insecticides; effect on parasites and predators; residues in soil, plants, and animals, of the persistent chlorinated hydrocarbons; and the presence of pesticides in areas far removed from points of application. Here lies our dilemma. The use of these materials creates problems but we must use them to maintain and ensure a continued high rate of productivity.

Today in North America we have probably the highest agricultural productivity in the world through the application of the fruits of research of many disciplines in the biological sciences. A large share of the credit belongs to the producers and users of agricultural chemicals. In the area of public health we owe a debt of gratitude to pesticides which have reduced the incidence of malaria, typhus, and many other insect-borne diseases in different parts of the world. On the debit side of the ledger we see signs of short-term thinking by some of the proponents of chemical control. These fail to realize, or choose to ignore the effects on the ecosystem, of repeated spraying in a given area, or the persistence and spread of residues.

The level-headed ecologist is interested in a thoughtful re-examination of the pesticide problem, a pooling of knowledge concerning our ecosystem, and an application of basic ecological rules in pest control. He stresses what he is for, not what he is against. The responsible biologist will not mislead the public by suggesting that we have satisfactory substitutes for pesticides. Rather, he will encourage meetings of representatives from government, industry, and other interested areas to explore ways of solving their problems. Not all ecologists are level-headed. Some are adamant, uncompromising, and most voluble in denouncing their opposition to pesticides. They often magnify and distort a given situation beyond all proportion.

Unfortunately the extremist element in both groups makes the task of bringing the two together for sensible discussion extremely difficult. What those who condemn Rachel Carson's "Silent Spring" really mean is that some of her statements are offensive to them. Those who praise the book in its entirety close their minds to the fact that some of her conclusions are not backed by sufficient evidence. Also her style of writing is such that it may alarm the non-scientific reader and this could do considerable harm.

New Approach to Insect Control

Obviously there are objections to, and problems associated with, some chemical control programs. Presently biological control by itself is not entirely adequate. No method by itself can cure all our insect problems. New approaches to insect control that can complement current practice should be investigated. Thus attractants, arrestants and feeding stimulants (Dethier et al. 1960), may be used as lures in baits or traps with or without toxicants. Instead of spreading insecticide over a given area to kill insects we would lure the insects to the baited traps. Similarly compounds that repel insects or deter them from feeding may be exploited for possible use in control programs. The advantages of this approach are obvious. If it is successful in field use it can be considered as a truly selective means of control since only those insects that are stimulated by particular substances in the trap would be affected.

The use of compounds that affect insect behavior as a means of control is increasing. In 1956-57 highly effective attractants were used to eradicate the Mediterranean fruit fly in Hawaii and Florida (Steiner et al. 1961). Plastic traps were baited with angelica seed oil as the attractant and DDVP a toxicant, to give a quick kill. Later, isopropyl and sec-butyl esters of cyclohexene carboxylic acid (siglure) were substituted for the angelica oil. Bait spray containing a protein hydrolysate and an organo-phosphorus insecticide proved to be highly effective in Hawaii. The hydrolysates were enzymatic preparations of soy or yeast and the insecticides were metacide, parathion, or malathion. Tannic acid was used as a repellent and toxicant to alfalfa weevil larvae (Bennett 1965). Male gypsy moths were lured to traps baited with gyplure, acetoxy-1-hydroxy-9-octadecene (Jacobson and Beroza 1964). This sex attractant was very useful in recognizing areas of infestation and is currently being investigated as a control measure. There is presently a lively interest in the sex attractants of several insect species.

Attractants, arrestants, or feeding stimulants from host plants have been studied for many insects for example: Papilio ajax larvae (Dethier 1941), diamond-back moth (Verschaffelt 1910, Thorsteinson 1953), European corn borer (Beck 1965), tobacco hornworm (Yamamoto and Fraenkel 1960), yellow mealworm larvae (Murray 1960), prairie grain wireworm larvae (Davis 1961), spruce budworm larvae (Heron 1965), boll weevil adults (Keller et al. 1962), silkworm larvae (Horie 1962), Mexican bean beetle (Nayar and Fraenkel 1963, Augustine et al. 1964), yellow-fever mosquito (Galun et al. 1963), large milkweed bug (Feir and Beck 1963), smaller European elm bark beetle (Loschiavo et al. 1963), western and eastern corn rootworm adults (Derr et al. 1964), squash bug adults, monarch butterfly larvae, elm leaf beetle larvae (Keller and Davich 1965), the coccinellid beetles Epilachna spp. (Stride 1965), female house fly adults (Robbins et al. 1965), khapra beetles and Trogoderma parabile Beal (Spangler 1965).

It would appear that the utilization in suitable baits and traps, of food-derived or host-derived chemicals that affect insect behavior may offer some promise in future integrated control programs. I have undertaken study of insect behavioral responses to chemotactic stimuli in the hope that this approach may offer a complementary method of control that would be free of the objections to the more conventional methods.

Feeding Behavior of the Confused Flour Beetle,
Tribolium confusum Jacquelin duVal

In 1962 I began to work on the feeding behavior of some species of stored products insects. There was some basis for initiating such a program. It had been noted on many occasions that in mills, flour beetles were more numerous in the dead stock around machinery carrying "germy" stocks, than in stock of endosperm origin (Smallman and Loschiavo 1952). This could be the result of faster development and higher reproduction in the germy stocks, but another factor might be the presence of arrestants or feeding stimulants which would induce greater uptake of food. Preferential feeding by the rusty grain beetle, Cryptolestes ferrugineus (Stephens), was noted in our laboratory and by others (Rilett 1949). The germ end of a wheat kernel was always eaten first.

Preferential feeding was also observed in larvae of the dermestid beetle, Trogoderma parabile Beal. These and other observations suggest a chemotactic basis for feeding by stored products insects (Shepard 1940, Birch 1947, Magis 1954, Murray 1960).

Fraenkel and Blewett (1943) considered that, in general, the failure of stored products insects to accept certain diets is due to the absence of adequate sensory stimuli. But in later work Fraenkel et al. (1950) attributed failure to grow to a nutritional deficiency in the diet. Most of the literature on host selection by phytophagous insects indicates that sensory stimuli play an important role in feeding behavior and that poor growth can occur if one of the deficient components in a diet is a stimulant whose omission leads to a reduction in feeding (Murray 1960, Dadd 1960).

A prerequisite to studying feeding behavior was the development of a suitable method of measuring feeding responses (Loschiavo 1965a). The experimental design was of the 2-choice type whereby insects could choose between test and control substrates in a circular arena. Aggregation of insects and amount of feeding within known time intervals were the criteria of response. By these two criteria, responses to stimuli associated with orientation, biting, and swallowing could be measured.

In preliminary experiments it was noted that flour beetles failed to respond to substances presented in a moist state. Apparently the presence of moisture inhibited the response to chemotactic stimuli in the active substance. These results showed the importance of testing extracts in dry form when using flour beetles as test animals. The preference for the drier of two humidities by unstarved, undessicated flour beetles has been demonstrated by Willis and Roth (1950, 1951).

In my experiments the initial responses were usually the strongest. The intensity of response declined with time. Apparently there are two phases in the response pattern: 1. locomotion of randomly-wandering beetles and 2. arrest of locomotion upon gustatory stimulation. The initially intense response is probably due to a low threshold of response to gustatory stimuli. This is not surprising considering that the insects have been deprived of food for 24 hours prior to a test. The less intense response with time probably reflected a rising threshold of response for feeding.

Threshold is a measure of sensitivity of the chemoreceptors at the time they are initially stimulated. When the threshold has reached its highest level sensory adaptation of the chemoreceptors occurs and there is no longer any sensory input (Dethier and Bodenstein 1958). Kennedy (1958) applied the concept of falling and rising thresholds to the behavior of aphids. He explained that during locomotion thresholds of response to stimuli from the host are lowered to the point where the aphid becomes sensitive to host stimuli. At the same time thresholds of response to stimuli that excite locomotion are rising. Ultimately host stimuli become dominant and the aphid responds. These threshold concepts seem to adequately explain the feeding behavior of flour beetles in our experiments.

Loschiavo (1965b) investigated the chemotactic properties of fractions extracted from brewers' yeast, flour, bran, and germ. In addition, amino acids, sugars, fatty acids and some proteins known to occur in wheat or wheat products were tested for their ability to elicit feeding responses in flour beetles.

Unidentified sugars and polypeptides in yeast were highly stimulative. An ether-soluble component of an ethanol extract of yeast repelled beetles. Results of tests with wheat fractions showed that various solvent extracts of wheat germ elicited the most intense aggregating and feeding responses. These results suggest that the size of an infestation in a mill depend not only on the favorability of a certain millstock for growth and reproduction, but also on its initial ability to attract or arrest insects, to stimulate feeding, or both (Loschiavo 1965b, Smallman and Loschiavo 1952).

Feeding Behavior of the Rusty Grain Beetle
Cryptolestes ferrugineus (Stephens)

Presently under investigation is the chemotactic effect of fungi associated with stored grain on the feeding behavior of flour beetles and rusty grain beetles. Griffiths *et al.* (1959) showed that some grain-infesting mites feed preferentially on certain fungi. Rilett (1949) observed that the presence of molds in a cereal diet greatly improved its suitability as a larval food for the rusty grain beetle. Perhaps fungi contribute to the increase in numbers of insects by providing feeding stimuli that favor the uptake of nutrients essential for growth and reproduction. Loschiavo and Sinha (in press) showed that rusty grain beetles aggregated in large numbers and fed extensively on kernels infected with the mycelia and spores of the fungus, *Nigrospora sphaerica.* The strongest responses were evoked by damp, infected kernels with exposed germs. The chemotactic effect of stimuli from the fungus was the most important single factor influencing response. In the absence of *Nigrospora* chemotactic stimuli from the exposed germ elicited powerful responses.

Many fungi grow in stored grain if temperature and moisture are suitable. Damaged kernels with exposed germs also occur in stored grain. It is reasonable to suggest that chemotactic stimuli from certain microflora and from exposed germs of kernels may influence the abundance and distribution of insects in grain storage facilities.

Possible Applications of Chemotactic Compounds

As the foregoing paragraphs show, there is ample evidence that some stored-products insects respond to stimuli from components in their natural food and from fungi. The next logical step in these investigations is to test biologically-active substances under field conditions by utilizing them in suitable traps in granaries and grain elevators. Crude field traps allowing free access of insects are presently being tested. A more sophisticated trap which will allow the entry, but not the escape, of insects is presently being devised. If these function effectively on an experimental basis we may be able to use them in control programs by incorporating insecticides with the attractants, arrestants, or feeding stimulants. Another possible application of the baited-trap technique is as a survey tool to help detect hidden infestations of insects in stored grain, mills, or warehouses.

The study of insect feeding responses may be an important prerequisite to new approaches to insect control. As was pointed out earlier, no single approach to insect control will solve all our problems. It is only by the concerted efforts of scientists approaching the problem from different directions that we may hope to keep ahead of the insect competitors for our agricultural and forest products.

REFERENCES CITED

Augustine, M. G., F. W. Fisk, R. H. Davidson, J. B. Lapidus, and R. W. Cleary. 1964. Host plant selection by the Mexican bean beetle, Epilachna varivestis. Ann. Entomol. Soc. Amer. 57: 127-37.

Beck, S. D. 1965. Resistance of plants to insects. Annu. Rev. Entomol. 10: 207-302.

Bennett, S. E. 1965. Tannic acid as a repellent and toxicant to alfalfa weevil larvae. J. Econ. Entomol. 58: 372-3.

Birch, L. C. 1947. The ability of flour beetles to breed in wheat. Ecology 28: 322-4.

Dadd, R. H. 1960. Observations on the palatability and utilization of food by locusts, with particular reference to the interpretation of performance in growth trials using synthetic diet. Entomol. Exp. et Appl. 3: 283-304.

Davis, G. R. F. 1961. The biting response of larvae of the prairie grain wireworm, Ctenicera aeripennis destructor (Brown) (Coleoptera: Elateridae), to various extracts of germinating rye seed. Can. J. Zool. 39: 299-303.

Derr, R. F., D. D. Randall, and R. W. Kieckhefer. 1964. Feeding stimulant for western and northern corn rootworm adults. J. Econ. Entomol. 57: 963-5.

Dethier, V. G. 1941. Chemical factors determining choice of food plants by Papilio larvae. Amer. Natur. 75: 61-75.

Dethier, V. G., and D. Bodenstein. 1958. Hunger in the blowfly. Z. Tierpsychol. 15: 129-40.

Dethier, V. G., L. Barton Browne, and C. N. Smith. 1960. The designation of chemicals in terms of the responses they elicit from insects. J. Econ. Entomol. 53: 134-6.

Doutt, R. L. 1964. Ecological considerations in chemical control. Implications to non target invertebrates. Bull. Entomol. Soc. Amer. 10: 83-8.

Egler, F. E. 1964. Pesticides in our ecosystem: communication II. Bioscience 14: 29-36.

Feir, D. and S. D. Beck. 1963. Feeding behavior of the large milkweed bug, Oncopeltus fasciatus. Ann. Entomol. Soc. Amer. 56: 224-9.

Fraenkel, G. S., and M. Blewett. 1943. The natural foods and the food requirements of several species of stored products insects. Trans. Roy. Entomol. Soc. London 93: 457-90.

Fraenkel, G., M. Blewett, and M. Coles. 1950. The nutrition of the mealworm, Tenebrio molitor L. Physiol. Zool. 23: 92-108.

Galun, R., Y. Avi-Dor, and M. Bar-Zeev. 1963. Feeding responses in Aedes aegypti. Stimulation by adenosine triphosphate. Science 142: 1674-75, December 27.

Griffiths, D. A., A. C. Hodson, and C. M. Christensen. 1959. Grain storage fungi associated with mites. J. Econ. Entomol. 52: 514-8.

Heron, R. J. 1965. The role of chemotactic stimuli in the feeding behavior of spruce budworm larvae on white spruce. Can. J. Zool. 43: 247-69.

Horie, Y. 1962. Effects of various fractions of mulberry leaves on the feeding of the silkworm, Bombyx mori L. J. Sericult. Sci. Japan 31: 258-64.

Jacobson, M. and M. Beroza. 1964. Insect attractants. Sci. Amer. 21: 20-7, August.

Keller, J. C., F. G. Maxwell, and J. N. Jenkins. 1962. Cotton extracts as arrestants and feeding stimulants for the boll weevil. J. Econ. Entomol. 55: 800-1.

Keller, J. C. and T. B. Davich. 1965. Response of five species of insects to water extracts of their host plants. J. Econ. Entomol. 58: 164-5.

Kennedy, J. S. 1958. The experimental analysis of aphid behavior and its bearing on current theories of instinct. Proc. 10th Int. Congr. Entomol., Montreal 1956, 2: 397-404.

Loschiavo, S. R. 1965a. Methods for studying the feeding behavior of the confused flour beetle, *Tribolium confusum* (Coleoptera: Tenebrionidae), Ann. Entomol. Soc. Amer. 58: 383-8.

Loschiavo, S. R. 1965b. The chemosensory influence of some extracts of brewers' yeast and cereal products on the feeding behavior of the confused flour beetle, *Tribolium confusum* (Coleoptera: Tenebrionidae). Ann. Entomol. Soc. Amer. 58: 576-88.

Loschiavo, S. R. and R. N. Sinha. 1966. Feeding, oviposition, and aggregation by the rusty grain beetle, *Cryptolestes ferrugineus* (Coleoptera: Cucujidae) on seed-borne fungi. Ann. Entomol. Soc. Amer. (in press).

Loschiavo, S. R., S. D. Beck, and D. M. Norris. 1963. Behavioral responses of the smaller European elm bark beetle, *Scolytus multistriatus* (Coleoptera: Scolytidae) to extracts of elm bark. Ann. Entomol. Soc. Amer. 56: 764-8.

Magis, N. 1954. Mise en évidence de préférences alimentaires chez *Tribolium castaneum* Herbst (Coléoptère Tenebrionidae). Arch. Int. Physiol. 62: 22-32.

Murray, D. R. P. 1960. The stimulus to feeding in larvae of *Tenebrio molitor* L. J. Insect Physiol. 4: 80-91.

Nayar, J. K., and G. Fraenkel. 1963. The chemical basis of the host selection in the Mexican bean beetle, *Epilachna varivestis* (Coleoptera: Coccinellidae). Ann. Entomol. Soc. Amer. 56: 174-8.

Rilett, R. O. 1949. The biology of *Laemophloeus ferrugineus* (Steph.). Can. J. Res. D. 27: 112-48.

Robbins, W. E., M. J. Thompson, R. T. Yamamoto, and T. J. Shortino. 1965. Feeding stimulants for the female house fly, *Musca domestica* Linnaeus. Science 147: 628-30. February 5.

Shepard, H. H. 1940. Insects infesting stored foods. Univ. Minnesota Agr. Exp. Sta. Bull. 341.

Smallman, B. N., and S. R. Loschiavo. 1952. Mill sanitation studies. I. Relative susceptibilities of mill stocks to infestation by the confused flour beetle. Cereal Chem. 29: 431-40.

Spangler, H. G. 1965. Reactions of the larvae of the Khapra beetle and *Trogoderma parabile* to certain food substances and organic compounds. J. Econ. Entomol. 58: 212-18.

Steiner, L. F., G. G. Rohwer, E. L. Ayers, and L. D. Christenson. 1961. The role of attractants in the recent Mediterranean fruit fly eradication program in Florida. J. Econ. Entomol. 54: 30-5.

Stride, G. O. 1965. Studies on the chemical basis of host plant selection in the genus *Epilachna* (Coleoptera: Coccinellidae). I. A volatile phagostimulant in *Solanum campylacanthum* for *Epilachna fulvosignata*. J. Insect. Physiol. 11: 21-32.

Thorsteinson, A. J. 1953. The chemotactic responses that determine host specificity in an oligophagous insect, (Plutella maculipennis (Curt.) Lepidoptera). Can. J. Zool. 31: 52-72.

Verschaffelt, E. 1910. The cause determining the selection of food in some herbivorous insects. Proc. Acad. Sci., Amsterdam 13: 536-42.

Willis, E. R., and L. M. Roth. 1950. Humidity reactions of Tribolium castaneum (Herbst.). J. Exp. Zool. 115: 561-88.

Willis, E. R., and L. M. Roth. 1951. The attraction of Tribolium castaneum to flour. J. Econ. Entomol. 43: 927-32.

Yamamoto, R. T. and G. Fraenkel. 1960. Assay of the principal gustatory stimulant for the tobacco hornworm, Protoparce sexta (Johan.), from solanaceous plants. Ann. Entomol. Soc. Amer. 53: 499-503.

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PHYSICAL METHODS OF INSECT CONTROL[1]

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The use of physical agents for controlling insects likely outdates other means of control. Undoubtedly the material and natural forces of the universe were recognized and employed by man against insect pests long before he turned to chemicals. But the scientific use of mechanics, light, sound, electricity, temperature and radiation for controlling the behaviour, and life and death of insects are comparatively recent developments. Twenty years ago they were regarded as possible adjuncts or alternatives to the powerful new chemical insecticides that were then beginning to flood research laboratories; now, many are looked upon as promising substitutes for chemical means of control. For today the wide use of agricultural chemicals for controlling insect pests is being critically examined on all fronts. Not only are scientists concerned about the long-term effects on humans and animals of minute traces of chemicals in soils, plants, and in foods; they are equally, if not more concerned with the development, through selection, of insect strains that have become resistant to one or several chemical insecticides. This development of resistant strains of insects poses a threat to our entire food supply, since agricultural efficiency and the production and quality of foods are so heavily dependent on the use of agricultural chemicals. Thus, developments in the use of other methods of controlling insect pests are assuming increasing importance.

Investigators of physical methods are optimistic that the new advances in space research, and radiation technology may provide basic knowledge that can be used against insects. In this regard they are mindful of the classical success achieved in the eradication of the screw-worm fly on the island of Curacao in the Caribbean (Lindquist 1955) by the release of males sterilized by irradiation. This exemplifies the combined approach of physics and biology for the solution of a serious insect pest problem. At the same time, however, this spectacular achievement may lead us to expect too much from non-chemical means of control.

This paper reviews some of these developments and indicates, where applicable, their possible role in Canadian agriculture. Some of these applications have hardly progressed beyond the laboratory stage; others are widely used and may gain further acceptance as their technology improves.

Electromagnetic Radiation

The application of electromagnetic radiation for the control of insects has been of interest to us at the Winnipeg laboratory for several years (Watters 1962b). We were primarily interested in it as a means of controlling insects in stored products. At its present stage of development, however, it is un-economical and less efficient than other means of insect control.

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There seems to be general agreement that insects are killed in a high-frequency electric field by the heat generated within their bodies as a result of molecular agitation. The amount of heating that occurs is a function of the dielectric properties of the material, the frequency of the electric field and the field strength. D'Arsonval (1893) was one of the first to report the heating of laboratory animals exposed in a high-frequency electric field. Headlee (1931) pioneered the work with insects and suggested that adults of holometabolous insects were more susceptible to heat injury than larvae. He noted that nymphs and adults of hemimetabolous insects were equally susceptible. Frings (1952) reported that adult flies were more susceptible than larvae and attributed this to the orientation angles of the appendages in the electric field since objects that lie parallel with the field absorb more electrical energy than those that are vertical to the field. Whitney et al. (1961) have reported that adults of Sitophilus granarius (L.), Tribolium confusum Jacquelin du Val, Tribolium castaneum (Herbst) and Rhyzopertha dominica (Fabricius), that had been killed by exposure in a high-frequency electric field had broken appendages. It is possible to attribute this to the induction of localized heating in appendages that have become orientated parallel to the electric field.

The advantage of dielectric heating over other forms of heating for the destruction of insects in food products is that the heat can be generated uniformly within the entire product. Generally, temperatures ranging from 140° to 160° F are sufficient to kill all insect stages present. Despite uniform heating within the material, however, there is a non-uniform heat loss, whereby the periphery tends to lose heat more rapidly than the centre. Van den Bruel et al. (1960) have reported that insects on the outside of bags of flour survived dielectric heat treatments while insects at the centre were killed. Heat losses caused by low ambient temperatures may be prevented by insulating the electrodes.

A comparison of the values of the dielectric properties of insects and cereal products suggests that insects may be expected to absorb more electrical energy and thus may become heated at a faster rate than the surrounding cereal. Theoretically, therefore, the product could be heated to a temperature of 120° F, while insects, being capable of absorbing more electrical energy, would be heated to 160° F. Whitney et al. (1961) investigated the possibilities of selective heating and concluded that although insects heated faster than the products initially, as the product increased in temperature there was less difference in the heating rates of insects and cereals. Likewise, Thomas and White (1959) reported that although woodworm beetles, Lyctus brunneus, Stephens in oak sapwood were probably selectively heated in a high-frequency electric field, this was not relied upon to control them.

As electronics technology advances we may expect some of the problems encountered with the use of high-frequency electric fields for control of insects to be overcome. Developments in techniques to control the concentration and output of electromagnetic energy appear promising. Bletchly (1965) has reported the use of very high frequencies (2450 mc/s.) to control woodboring insects in locations where control with chemical insecticides and fumigants is ineffective. Other laboratories in Europe and Canada are investigating the use of centimeter wavelengths for applying penetrating beams of energy into infested materials. Thus, some difficulties associated with present techniques for using high-frequency electric fields for insect control may be overcome by extending investigations to the lower wavelengths in the electromagnetic spectrum.

Light is another form of radiant energy that has been used to reduce insect populations or to control their behaviour to our advantage. Light traps that exploit the ability of flying insects to react to colours, odours, shapes and movement have been developed for many different species. Although the actual reduction of insect populations by trapping is generally considered to be inferior to other forms of control, nevertheless, traps have proven to be useful for surveys and in studies of insect behaviour. The use of light to protect stored products has also been investigated since many insect pests tend to avoid well illuminated areas. Insects seem to be more sensitive to the wavelengths near the ultraviolet region of the visible spectrum and this has been utilized in so-called "black-light" traps that have been used for the control of insects around hot dog stands.

Electric grids used in conjunction with an ultra-violet light source have been used to kill houseflies and blowflies (Green et al. 1963). Although there was evidence that flies were killed as a result of contacting the electrically-charged grid, there was no indication of the proportion of the population that was eliminated.

Ionizing Radiation

Ionizing radiation such as that produced by x-rays, a gamma source, or accelerated electrons may be used to control insects. At present there are two ways in which this can be done. The first involves the well-known male sterility technique in which male insects are treated in an attempt to inactivate or damage sperm cells without interfering with their sexual instincts. The second method is the treatment of insects in a confined mass of material. This obviously has an application in stored-products and possibly also in locations where wood-boring insects are a problem.

In referring first to the treatment of male insects to control a pest population, the familiar account of the eradication of screw-worm on Curacao needs no elaboration (Lindquist 1955). Despite this initial success, similar control with other species of insects has not been achieved for various reasons. The main requirements of the technique appear to be the ability to treat and release large numbers of male insects periodically, which will compete with and ultimately swamp the indigenous male population. The treated males must possess dominant lethal mutations in the genes which will not influence their longevity nor their ability or their willingness to mate.

Gamma irradiations of infested foodstuffs is a promising new approach in the use of penetrating radiation to kill insect stages within food products. The technique is similar in many respects to the high-frequency (H. F.) electric fields dealt with previously since infested products are exposed for brief periods to high energy sources. Unlike the H. F. method, however, which relies solely on heat to achieve control of insects, irradiation achieves its effects by penetrating radiations produced by the nuclear disintegration of radioactive substances such as cobalt-60. The symptoms of radiation damage on insects and animals are more apparent than the mechanisms that cause the damage. It is known that the interaction of radiation with molecules of water leads to the formation of H and OH free radicals which are chemically reactive and are powerful reducing and oxidizing agents (Anonymous 1964). However, O'Brien and Wolfe (1964) indicate that there is doubt as to the actual processes involved. There seems to be general agreement that the main damage is caused to the cell nucleus rather than the cytoplasm. Cornwell and Bull (1960) have listed molecular rearrangement on chromosomes, chromosome breakage, and retardation of nuclear or cell division as three possible causes of radiation damage to the germ cells primarily, while high doses damage both the germ cells and somatic cells.

The main effects of radiation on insects that have been measured to date are mortality and the shortening of life (O'Brien and Wolfe 1964), although Cork (1957) has reported that adult Tribolium that survived a single dose of 11,000 roentgens outlived the controls. Thus, it seems that with Tribolium, low doses may protect all the insects while high doses protect the strongest (O'Brien and Wolfe 1964). Melville (1958) reported that at 5,000 to 10,000 rads. the grain mite, Acarus siro Linnaeus (reported as Tyroglyphus farinae Linnaeus), laid more eggs than the controls, more of which hatched, but the opposite results were obtained at 20,000 rads.

Although the use of radiation devices for controlling insects in stored products seems attractive in that the method would obviate the need for using chemical controls, the technique as developed at present has several formidable disadvantages which may preclude wide acceptance. The major disadvantages are high installation expense and the limited amounts that can be treated in unit time. For example, with existing conveyor facilities, most grain terminal operations are geared to a maximum handling capacity of 200 to 300 tons per hour past a given point. Other limitations are listed by Cornwell and Bull (1960). To operate on an economic basis, the unit should be used continuously for most of the year. Since Canadian stored grain does not presently require treatment for the eradication of insects on a continuous basis, it is doubtful whether irradiation equipment would have a place in Canadian grain handling operations in the foreseeable future. It is possible that the technique may have a use in the processed food industry where specialty food products may be irradiated prior to consigning them for long-term storage.

There is no evidence that irradiation of seeds and foods leads to detectable physical or chemical changes that might result in hazards to man or animals (Anonymous 1964). It has been shown that radiation can destroy vitamins, the extent of the damage varying with the dose and the foodstuff (Read 1960). Experiments are presently in progress at the Winnipeg Research Station to evaluate the possible damage to wheat and barley resulting from exposure to gamma irradiation in a mobile cobalt-60 source.

Temperature

Insects develop, reproduce and live within a wide range of temperatures but specific temperatures above or below these biological ranges may impede growth, inhibit oviposition or cause changes leading to death. The heat of the sun has been used by primitive people to dry foods and thus make them less liable to attack by insects; these practices are still used to drive away insects since temperatures above 95°F are generally unfavourable for insect reproduction although live insects may occasionally be found in foodstuffs that are heating at temperatures above 120°F. Flour mills and other types of food processing plants have been superheated by infrared heaters to control insect infestations in machinery. Generally, temperatures of 130° to 140°F maintained for about 12 hours controlled infestations (Cotton 1964). Heat treatments of buildings are obviously restricted to the summer months. The main disadvantages of the use of heat to control insects in buildings are that it dries out wooden equipment, and causes it to warp and crack. Machinery belts may soften and stretch, and grease may escape from grease cups. Insects in the walls of the building may survive the treatment if the heat is lost too quickly. Also, unless the entire building is heated, it may become quickly reinfested from adjoining unheated areas.

The use of low temperatures has been exploited to some extent in the Prairie Provinces to control insects in stored grain and in flour mills. Grain stored in 1,000-bushel granaries cools to well below freezing, but larger bulks retain the heat of summer longer and the central areas of these bulks remain above freezing. Insect infestations often develop in patches of grain that have not cooled sufficiently to arrest insect and mould growth. Heating grain may be cooled by transferring it to other granaries or by turning it in a grain elevator. However, the main factor involved in cooling grain is the mixing of cool and warm grain rather than the momentary exposure of heating grain to low air temperatures (Watters 1962a). In England, where grain may be stored at a moisture content near 20 per cent, the use of refrigeration equipment has been investigated for reducing the temperature from 68° to 41°F; at this temperature, insect growth is stopped and the slow rates of increase of mites are unlikely to cause serious trouble (Burrell 1965). Possibly the use of low temperatures to control insects in stored grain could be exploited to a greater extent in Canada through the use of aeration systems whereby near-uniform low temperatures could be attained during winter. This would be particularly valuable during years when grain is put into storage at a high moisture content.

In Western Canada, "freeze-outs" are used to control insects in flour mills during winter. Close collaboration with Government meteorological offices is maintained so that mill operations may be suspended during prolonged cold spells. Water lines are drained, milling machinery opened, and heat turned off to allow mill temperatures to fall to near outdoor temperatures. The most successful "freeze-outs" are obtained when mill temperatures remain below 0°F for 3 days. Although "freeze-outs" are not used widely, they are superior to general fumigations for the control of insect pests. Furthermore, flour mills that have had successful "freeze-outs" remain free of insects for a longer period than mills that have been fumigated since the freeze-out is applied to the entire premises in contrast to fumigation which is generally applied only to the milling sections.

Sound

Sound has been used to control insect behaviour with the object of making insects do what we want them to do instead of what they want to do. Frings and Frings (1965) believe that the most promising way to use sounds is to broadcast insect communication signals in order to control their responses. Belton (1963) has suggested ways of attracting mosquitoes to point sources of sound where they can be lured to their own destruction. But the signal must compete with the natural one not only in frequency but also in intensity. Another way of using sounds is to broadcast certain frequencies that can confuse insects especially those that depend on sound signals for locating sexual partners. This is an extension of the signal "jamming" technique which was practised widely in radio communications during World War II.

Certain moths which have well developed tympanal organs react to ultrasonic frequencies such as those produced by bats. Belton (1963) has used this as a means of reducing damage to corn in fields. Kirkpatrick and Harein (1965) have observed that Indian-meal moths laid fewer eggs in food in a room containing an audio oscillator and amplifier operating at 120 to 2,000 cycles per second at less than 5 mw power output. Moreover, adults that developed from eggs laid during sound treatments lived for a shorter period than the corresponding control adults. It is possible that this form of energy may be used to obtain continuous control of those moths that infest the surface of grain stored in flat storages where it is presently necessary to rely on repeated applications of chemicals of low-mammalian toxicity to obtain control.

Frings and Frings (1965) have listed the advantages of sounds over chemicals for controlling insects. Among these advantages are: no risk of allergies, no risk of drift, easily controlled, easily produced, no application hazards, no soiling hazards, can be used to control behaviour, no residues.

Mechanical Force

Mechanical forces to control insects were probably the first forms of insect control and although the flyswatter is still used throughout the world in one form or another, other means of mechanical control have superceded it. The entoleter, for example, is an impact machine that employs centrifugal force to destroy insects and to fracture grain kernels that have been structurally weakened by insect attack. Wheat or flour is fed into the centre of a rotor which has a speed up to 3,500 r.p.m., and is then thrown outwards by centrifugal force through apertures formed by round steel impactors. It is possible to adjust the speed of the rotor to avoid damage to sound kernels and yet fracture insect-damaged kernels. Intact and broken kernels are separated by sifters. Flour is often fed through an entoleter before it goes into the packing bins to ensure destruction of eggs and other insect stages. Entoleters handling flour operate at reduced speeds near 1,200 r.p.m.

Bailey (1962) has used a compressed air gun to investigate the effects of various forces of impact on insects. Although some larvae within kernels survived a single impact force of 150 ft. per second, none survived a daily treatment of 21 ft. per second (Waterhouse 1965). Thus, it seems that a single force of impact that causes no apparent damage to insects living within kernels causes lethal effects if repeated at intervals during development. At the Winnipeg Station, we have observed that infestations of grain insects can be controlled by transferring infested grain to another location. Although this measure is more effective in winter than in summer, nevertheless, a high degree of control has been achieved in warm weather.

Air Movement

The effect of forced air movement in bulks of grain has served to eliminate stratification of layers of damp grain which is often caused by translocation of moisture due to temperature differences. Various types of air ducts are used at the bottom of grain storages, and outside air may be circulated throughout the grain mass during dry, cool weather. Since insects depend on the presence of damp patches in grain to establish large populations, air circulation is an effective form of insect control. The total exclusion of outside air has been utilized in hermetic storage of grain which has been developed in England (Oxley and Hyde 1955) and Australia (Bailey 1957). The cause of death has been shown to be a lack of oxygen, the accumulation of carbon dioxide being relatively unimportant (Bailey 1955, 1956, 1957).

Hocking (1960) has employed air currents to prevent flying insects from entering doorways. Provided the air flow exceeded the maximum flight speed of the insect it was possible to prevent bees and flies from flying through a specially designed doorway. Illuminated edges at the opening, smooth shiny walls without a pattern visible to insects and an underlying screening treated with a long-lasting residual insecticide were effective supplementary measures in excluding insects from doorways.

Atmospheric Ions

Maw (1963) has investigated the role of air ions on insect behaviour. Exposure of blow flies to positively and negatively charged air ions showed that the insects reacted to positive ions by flying at greater speed; negative ions produced a more sustained flight. Much remains to be discovered concerning the influence of atmospheric electricity upon insects. Artificial potential gradients of electricity may prove to be a useful means of controlling swarms of flying insects.

"Insect-proof" containers

A problem encountered by the food industry is how to protect processed foods from becoming infested after they leave the food processing plants. Various types of insect-resistant sacks have been developed. Polycarbonate, a promising new type of plastic, has a high tensile strength and is highly resistant to penetration by stored products insects (Highland and Jay 1965). At the Winnipeg Station, we have found sacks manufactured from polyethylene to be highly effective as well. Kraft paper bags are widely used and will give protection against many species of insects except boring insects which can readily drill holes in paper and provide openings for other insects. A new type of valve closure has been developed in the United States which should prove useful since most bag penetrations are made through poorly constructed closures. Plastic sacks may be used in the tropics for local food storage but the continued use of grappling hooks for loading ships militates against their use for export purposes. Jute sacks are relied upon mainly as food containers (Davey et al. 1962).

Southgate (1965) has investigated the use of plastics and other synthetic materials to construct portable, long-term storage buildings capable of holding 500 to 5,000 tons of bagged produce. The materials consisted of polyvinyl chloride-coated nylon or terylene, and neoprene-on-nylon. Airwarehouses have been constructed recently which are not only insect-proof but also may serve as efficient fumigation chambers. Provision is made for the circulation of outside air within the building. One of the limitations in the use of plastics for storing cereals and cereal products is that they form a barrier to the escape of water. Foods that have been insufficiently dried may become mouldy if enclosed in plastic containers.

Sanitation

A discussion of physical methods for controlling insects would be incomplete without references to hygiene and sanitation. Although these procedures are simple and well known they are commonly ignored in preference to more sophisticated measures. The use of screening for excluding insects from houses and industrial premises is common practice in North America but less so in Europe. Vacuum cleaners are frequently used to remove infested floor sweepings in flour mills and warehouses. Such measures reduce the spread of infestations from the floor to milling machinery and packaged foods. Removal of unused equipment or other items not essential to food processing or storage will deprive insects of harbourages and facilitate the cleaning and treatment of premises. Food machinery is designed now to eliminate corners where stock may accumulate and provide breeding niches for insects. Improved techniques for the movement and storage of foods have greatly reduced the need for excessive quantities of insecticides to control insects. In future greater emphasis will be placed on these various forms of physical control.

Conclusion

This has been a brief review of the major physical agents for the control of insects that are either presently being used or are at various stages of development. Some may be integrated effectively with other forms of control; others may be used by themselves. As our knowledge of new forms of insect control and management grows together with knowledge of their immediate and long term influence on insects, so our ability to control insect pest populations will improve. The lessons of the past have taught us that it is more important to understand the biological implications of an insect control measure, rather than to strive for spectacular eradication.

REFERENCES

Anonymous, 1964. Report of the working party on irradiation of food. pp. 1-85. Ministry of Health. Her Majesty's Stationery Office, London.

Bailey, S. W. 1955. Air-tight storage of grain; its effects on insect pests. I. Calandra granaria L. (Coleoptera, Curculionidae) Australian Jour. Agr. Res. 6 (1): 33-51.

Bailey, S. W. 1956. Air-tight storage of grain; its effects on insect pests. II. Calandra oryzae (small strain). Australian J. Agr. Res. 7 (1): 7-19.

Bailey, S. W. 1957. Air-tight storage of grain; its effects on insect pests. III. Calandra oryzae (large strain). Australian J. Agr. Res. 8 (6): 595-603.

Bailey, S. W. 1962. The effects of percussion on insect pests of grain. Jour. Econ. Entomol. 55 (3): 301-304.

Belton, P. 1963. Effects of sound on insect behaviour. Proc. Entomol. Soc. Manitoba 18 (1962): 22-30.

Bletchley, J. D. 1965. Very high frequencies and wood-boring insect control. Proceedings XIIth Int. Congr. Entomol. London (1964): 689.

Burrell, N. J. 1965. Refrigeration of damp grain. Farm and Country.

Cork, J. M. 1957. Gamma-radiation and longevity of the flour beetle. Radiation Res. 7 (6): 551-557.

Cornwell, P. B. and Bull, J. O. 1960. Insect control by gamma-irradiation: an appraisal of the potentialities and problems involved. J. Sci. Food & Agr. 11 (12): 754-768.

Cotton, R. T. 1964. High temperatures — how they affect insect pests. The Northwestern Miller. 270 (6): 30-32.

D'Arsonval, A. 1893. Influence de la fréquence sur les effets physiologiques des courants alternatifs. Compt. Rend. Acad. Sci. (Paris) 116: 630-632.

Davey, P. M., D. L. Proctor, S. Elcoate, and F. J. E. Ashwell. 1962. Sacks for overseas investigation. Pest Infestation Research. Her Majesty's Stationery Office. London. p 74.

Frings, H. 1952. Factors determining the effects of radio-frequency electromagnetic fields on insects and materials they infest. Jour. Econ. Entomol. 45 (3): 396-408.

Frings, H. and Frings, M. 1965. Sound against insect. New Sci. 26 (446): 634-637.

Green, A. A., P. S. Tyler, and J. R. Rider. 1963. Mechanical measures of control. Pest Infestation Research. Her Majesty's Stationery Office. London. p. 34.

Headlee, T. J. 1931. The differential between the effect of radio waves on insects and on plants. Jour. Econ. Entomol. 24 (2): 427-437.

Highland, H. A. and E. G. Jay. 1965. An insect-resistant film; further research at U. S. D. A. Savannah Laboratories identifies polycarbonate as the plastic film offering greatest resistance to insect penetration. Modern Packaging 38 (7): 205-206, 282.

Hocking, B. 1960. An insect-proof doorway. Bull. Entomol. Res. 51: 135-144.

Kirkpatrick, R. L. and Harein, P. K. 1965. Inhibition of reproduction of Indian-meal moths, Plodia interpunctella, by exposure to amplified sound. Jour. Econ. Entomol. 58 (5): 920-921.

Lindquist, A. W. 1955. The use of gamma radiation for control or eradication of the screw-worm. Jour. Econ. Entomol. 48 (4): 467-469.

Maw, M. G. 1963. Physics in entomology: Sound and electricity in insect behaviour. Proc. 18th Annu. Meeting North Centr. Branch. Entomol. Soc. Amer. 18: 6-10.

Melville, C. 1958. An apparent beneficial effect of gamma-radiation on the flour mite. Nature 181 (4620): 1403-1404.

O'Brien, R. D. and Wolfe, L. S. 1964. Radiation, radioactivity, and insects. Academic Press, New York and London.

Oxley, T. A. and M. B. Hyde. 1955. Recent experiments on hermetic storage of wheat. Proc. 3rd Int. Bread Congress, Hamburg pp. 179-182.

Read, M. S. 1960. Current aspects of the wholesomeness of irradiated food. J. Agr. & Food Chem. 8 (5): 342-349.

Southgate, B. J. 1965. Plastics films for the bulk storage of food. Plast. Inst. Trans. & J. 33 (103): 11-15.

Thomas, A. M. and White, M. C. 1959. The sterilization of insect-infested wood by high-frequency heating. Wood 24: 407-410.

Van den Bruel, W. E., Bollaerts, D., Pietermaat, F., and Van Dijck, W. 1960. Etude des facteurs déterminant les possibilités d'utilisation du chauffage diélectrique à haute fréquence pour la destruction des insects et des acariens dissimulés en profondeur dan les denrées alimentaires empaquetées. Parasitica 16 (2): 29-61.

Waterhouse, D. F. 1965. Some aspects of Australian entomological research. Proc. 12th Int. Congr. Entomol. London (1964): 46-51.

Watters, F. L. 1962a. The cooling of heating grain by transfer during cold weather. Jour. Econ. Entomol. 56 (2): 215-219.

Watters, F. L. 1962b. Control of insects in foodstuffs by high-frequency electric fields. Proc. Entomol. Soc. Ont. 92 (1961): 26-32.

Whitney, W. K., S. O. Nelson, and H. H. Walkden. 1961. Effects of high-frequency electric fields on certain species of stored-grain insects. U. S. Dep. Agr. Marketing Res. Rep. No. 455, 52 pp.

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THE PESTICIDE MANUFACTURER'S VIEWS ON INTEGRATED CONTROL OF PESTS

G. R. Fraser

Integrated control of pests is essentially the application of natural, biological or artificial control methods at a time when each particular method is most effective. The pests may be insects, mites, rodents, weeds, or any other class of life which interferes with or reduces man's efforts to produce food. In a program of integrated control designed to produce the maximum amount of good food with a minimum amount of labour and expense, there will still be a place for insecticides, herbicides, or other pesticides. However, in integrated control there must be precise use of insecticides in combination with other agents of control. This will undoubtedly mean a more judicious choice of pesticide, and certainly, closer attention to the rate and timing of its application.

There has been some practice of integrated control despite the tremendous increase in the use of chemical pesticides that came after World War II. One relatively simple example of integrated control has been the long standing recommendation to use press drills or packers, at seeding, to decrease the mobility of wireworms combined with a chemical seed treatment. The resultant control of wireworms is better than when either treatment is used alone.

Another example of integrated control is the preparation of fallow fields in such a manner as to leave an undesirable environment for oviposition by cutworm moths, with a subsequent application of insecticide if necessary. The summerfallow method alone is frequently inadequate for cutworm control. However, when the summerfallow method is followed by an application of insecticide the control of cutworms is more successful than when either method is used by itself.

Problems of Integrated Control

Provincial and Federal government pest control recommendations include a wide variety of cultural practices or techniques designed to reduce the abundance of alternate host plants at any particular site, to reduce the mobility or oviposition of pest insects, or to preserve pollinating or predacious insects. This tendency to cling to accepted and effective measures is more apparent in weed control bulletins than in insect control bulletins. This is to be expected since cultural techniques and practices are less likely to change for non-mobile pests such as plants. Some bulletins and handbooks outline chemical controls only and leave the integration of these controls to the grower. The grower has tried to integrate the chemicals of the present age with cultural practices and rotations handed down from the previous century. Too many of our bulletins and handbooks ignore aspects of control other than chemical.

Integrated control programs may mean that closer attention will have to be paid to the timing and the rate of application of pesticides. This point has been stressed strongly for many years in the extension work done by pesticide manufacturers. Growers in the Prairie Provinces will certainly confirm this to be true of our herbicide recommendations, and similarly orchardists will say the same of our insecticide and miticide recommendations. Perhaps closer integration of all methods of pest control will provide the extension workers in industry with their best reason for insisting on close attention to timing and rate of application of a pesticide. Certainly, pesticide manufacturers are being called on more and more each year to provide extension or technical advice on the application of pesticides.

Although an integrated control program may introduce a reduction in the rate of application of a pesticide, it may mean that more growers will have to use pesticides and use them over a wider area than at present. This may force people who are not using pesticides presently, or who use them only periodically to use them regularly. The more complicated the integrated control program becomes, the more difficult will be the task of the agricultural extension worker. To achieve the greatest degree of success for the integrated control program may require a thorough program of education.

Current Practices in Insecticide Use

Insecticides are not used as widely on agricultural crops as some people might think. In 1964, the total expenditure for insecticides and fungicides for use on agricultural crops was $10, 250, 000. At the present time, the Dominion Bureau of Statistics does not break this figure down any further. The value of pesticides for treating livestock was $2, 369, 000 of which $500, 000 was spent on preparations known as "wormers". The point is that the cost of protecting the millions of acres of cereals, vegetables, vines, tree fruits, root crops was only $10, 250, 000, and the cost for 1965 is likely to be considerably less. The insecticide business in Western Canada is known to be opportunistic. The question facing the manufacturer every year is whether or not there will be an outbreak and if so, will it be serious enough to require the use of pesticides.

Frankly, pesticide manufacturers do not encourage the person who uses pesticides in large quantities sporadically, one who may be said to follow the "drown 'em" philosophy. Such a grower is frequently one of the worst growers. He is a proponent of the "desperation technique", and consequently is seldom satisfied with the results he obtains. Because of this he is not a good prospect for continuing sales. There is an old axiom in selling: "The first sale makes little money; it is the repeat orders that count". Therefore, time and patience are wasted in trying to sell proponents of the "desperation technique". Such growers are less frequently found in the Prairie Provinces because the insect complex and their ecology are simpler than those which confront the orchardist or the market gardener. There is less scope for integrated control programs on the Prairie Provinces and therefore, chemical methods of control are less likely to interfere with other methods of control.

Integrated Control in Orchards

The fruit growing industry illustrates the interesting progress that is being made in integrating various pest control methods. Improvements in the integration of control methods are a result of a rapidly expanding knowledge of the ecology of fruit insects. Such knowledge is essential to achieve optimum results in pest control. Dr. Madsen of the Summerland Research Station in British Columbia recently outlined a study started in 1960 on a block of apple trees in the Okanagan Valley. No pesticides were applied to these trees but normal fertilization, pruning and irrigation procedures were followed. After 4 years he found that 100% of the fruit was infested by codling moth, 8% by leaf roller, 5% by budmoth. Scab was abundant and leafhoppers were so numerous that the foliage was grey in colour. Nevertheless, mite populations were reduced; European and McDaniel mites were abundant for two years but fell to non-economic population levels at the end of 4 years. Predacious mites were abundant showing that natural control is sufficient to control mite populations in orchards. Dr. Madsen emphasizes that the mite populations remained at economically high levels for two years which means that the grower must have some means of controlling these populations until the natural control by predators is sufficiently effective. The Summerland laboratory has found that a more accurate timing of the population of improved oil sprays can control the economic species of mites without seriously affecting the predator species. Another answer is to have highly specific miticides which would kill only the pest species. Several new miticides are being tested and most of them show promise of having properties of specific miticides.

Another interesting field of research at Summerland is the control of codling moth by the sterile male technique.

The attitude of the pesticide manufacturer to an integrated program of pest control as outlined by Dr. Madsen can be summarized as follows: The increase in the use of specific miticides could easily offset the decrease in use of insecticide to control codling moth, if the latter species is controlled by other means; the manufacturer will be required to produce miticides and insecticides of greater specificity which will gradually lead to widespread use of these products and increased attention to proper timing of their application; such products will undoubtedly remain on the market longer and enable the manufacturers to ammortize their costs over a longer period of time.

The cost of pesticides is made up largely from the need to pay for the research required to develop the product within a period of 8 or 10 years before the product becomes obsolete. Emphasis is being placed on the development of more specific products. An example of this is found in the development of products to control orchard pests. Not more than 5 years ago, my company developed a product that turned out to be systemic insecticide highly specific for aphid control. It was virtually ineffective against codling moths, leaf rollers, budmoths, pear psyllas, or mites. Because it was so specific it was relegated to the files. Last year this product was brought out again for extensive testing because of its potential use in a program of integrated control. We are very interested in this product and feel that if it is satisfactory, it could yield as much revenue as the products we currently sell for control of the codling moth. Undoubtedly it would remain on the market longer than products used for control of codling moth or pear psylla since, of all the orchard pests, these insects are second only to the mites in the rate with which they develop resistance.

The development of an integrated program of pest control frequently raises many associated problems. For example, a few years ago, we started selling chelated zinc and iron to correct serious deficiencies in the soil and the horticulturalists informed us that the general health and vigor of the trees was markedly improved. Nevertheless, they noted at the same time that aphid populations began to increase greatly. This was easily understood when one compared the soft lush foliage of trees on treated soil with the foliage of trees on soil deficient in these minerals.

Ecology in Integrated Control

The entire ecology of the plant, the pest species and the predacious species must be considered in relation to the cultural, biological and chemical controls for a specific insect. For instance, weeds or native plants serve as alternate hosts for pests of cultivated plants and recommendations are made that these species should be eliminated as far as possible. Nevertheless, insects such as the scale insects in the Okanagan can never be eliminated because their alternate hosts extend miles from the cultivated areas. Fortunately, no one has suggested that the mountain sides be denuded but a few years ago in California a campaign to exterminate the wild blackberry was carried out because it was an alternate host for some diseases of agricultural importance. It was not known at the time that the plant was a host plant of an insect predator of alfalfa pests.

Nevertheless, we do see prospects in the future for the use of selective herbicides to remove alternate host plants. It is hoped that this will not become a common practice until we are sure other aspects of the environment are not going to be radically upset at the same time.

The control of several economic pests in any given environment could enable a relatively non-economic species to reach economic population levels. The program of integrated pest control would have to be modified to prevent this. A problem of this kind has arisen in connection with the use of herbicides at the present time. The widespread elimination of annual weeds has changed the relative abundance of weed species and as a result new herbicides are being introduced to control species which were not of economic importance a few years ago. It is significant to note that these new herbicides are more specific in their action and more expensive than the well-known compound, 2,4-D. Disruptions of a natural environment whether by chemical or biological means can have costly repercussions which can usually be controlled adequately by the application of chemicals until a more permanent integrated program of control is found.

Biological Control

Biological control of pests is one alternative to chemical control. The classic examples of successful biological control have been employed mainly in situations where population interrelationships have been relatively simple. Two plants that have been successfully controlled by the introduction of insects are Klamath weed and Opuntia cactus. Other examples of biological control are myxamitosis for the control of rabbits and the selection of a solid stemmed variety of wheat for the control of wheat stem sawfly. Nevertheless, the list of such successful control methods is not a long one.

Some of the disadvantages of biological control are: the techniques require a long time to be developed; the cost of making the technique economically feasible is probably as high as for chemical methods of control; and if any side effects develop that have not been investigated previously, they could be embarrassing at best, or disastrous at worst. There is no guarantee that resistance to certain biological preparations such as *Bacillus thuringensis* cannot occur. It is now thought that rabbits in Australia are resistant to myxamitosis. A product such as *B. thuringensis* has taken many years to develop but no one can predict its market life.

Future Objectives of Insect and Disease Control

In the near future, I would suggest that one of the objectives of pest control in agriculture will be to produce the greatest tonnage of food. This will mean that less emphasis will be placed on aspects of quality such as shape, colour, uniformity and so forth that are now demanded by North American housewives. A certain number of pests may have to be tolerated in any program of integrated pest control. Some techniques such as the sterile male technique may eliminate a pest but this technique cannot be applied to all species. Nonetheless, we think that chemicals will be a part of any program of integrated control for a long time no matter how many control techniques are included in the integrated program of control.

The increasing demand for food may mean that some characteristics presently included in plant breeding programs will have to be sacrificed in favour of other characteristics. This autumn, the Seed Growers Association warned growers of the new high yielding variety of wheat, Manitou, that they should treat their seed for bunt as it is more susceptible to this disease. Undoubtedly, other compromises will have to be made as the various disciplines concerned with research on agricultural production expand and work more closely together. We in the pesticide manufacturing industry hope to be ready with the chemicals needed in these new programs as they are developed.

While we are interested in the welfare of the grower, we are also interested in making profits because without them we cannot continue to serve agriculture as fully as we have in the past. In a recent issue of "Croplife", leading manufacturers made predictions concerning the future markets for insecticides. Without exception, they predicted increases in the volume of sales and many of them pointed out the challenges and opportunities afforded by the integration of chemical methods of pest control with other methods of control.

Pesticide manufacturers think that the success of integrated control of pests depends on having a suitable pesticide available at the right time rather than on having biological techniques of control. Unless such a pesticide is available, any program of integrated control will fail because the grower cannot be left without some means of controlling pests until a new technique of non-chemical control is developed.

Finally, we predict an increase in the use of pesticides in urban areas. Since an integrated program of control is less readily instituted for homes, gardens, or industrial premises, we feel the amount of $6,696,000 spent in this market last year in Canada can only be exceeded in the future. This revenue is nearly 66% of the total income for the protection of large acreage crops. In both sales areas, we foresee a future that will continue to be brighter and we hope, somewhat less encumbered with unknown aspects of the ecology of both crops and pests.

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FIELD KEY TO ADULT JUNE BEETLES (Phyllophaga spp.) ATTACKING CONIFEROUS PLANTATIONS IN MANITOBA

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Abstract

A field key for identification of the males and females of four species of June beetles attacking coniferous plantations in Manitoba is presented.

Four species of *Phyllophaga* have caused serious damage to agricultural crops (Criddle 1918) and coniferous plantations (Prentice and Hildahl 1957, 1959) in Manitoba. These are: *nitida* (LeConte), *anxia* (LeConte), *drakii* (Kirby), and *rugosa* (Melsheimer). The first three have been reported by Ives and Warren (1965) to be the principal species damaging pine seedlings. *P. rugosa* has been reported to be very destructive in coniferous nurseries at Cass Lake, Minnesota (Craighead 1950), but is uncommon in plantations in Manitoba. Criddle (1918) reported that this species was the most abundant one in sandy soils. Since most of the coniferous plantations in Manitoba have been or will be established on this type of soil, *P. rugosa* could become a serious pest.

Luginbill and Painter's (1953) key to the nearctic species of *Phyllophaga* was used to identify over 5,000 adults. A study of these specimens reveals that certain external characters of the VII and VIII sterna of the male and female abdomen can be used to separate the four Manitoba species. The specimens shown in Figures 1 to 8 were coated with ammonium chloride sublimate to enhance these morphological features in the photographs (Jackson 1962). The following key based on these characters provides a rapid method of identifying the species without injuring live specimens in biological and population studies:

Key to *Phyllophaga* adults attacking coniferous plantations in Manitoba

1. Ventral surface of abdomen broadly flattened and slightly depressed; males (Figs. 1-4) 2
   Ventral surface of abdomen rounded; females (Figs. 5-8) 5
2. Sternum VII with ridge near middle (Fig. 4) 3
   Sternum VII with ridge at the anterior margin (Fig. 1).............. .... *P. rugosa* (Melsheimer)
3. Sternum VII with narrow ridge (Figs. 2, 4); sternum VIII with depressed area not roughened 4
   Sternum VII with broad ridge (Fig. 3); sternum VIII with depressed area roughened .... *P. drakii* (Kirby)
4. Ridge on sternum VII not prominent, represented by two widely separated humps (Fig. 2) .... *P. nitida* (LeConte)
   Ridge on sternum VII prominent and continuous, lateral areas forming a ledge (Fig. 4) .... *P. anxia* (LeConte)

5. Posterior border of sternum VII deeply concave (Fig. 5, 6) 6
   Posterior border of sternum VII shallowly concave (Figs. 7, 8) 7
6. Posterior border of sternum VIII with indentation truncate (Fig. 5)
   .... _P. rugosa_ (Melsheimer)
   Posterior border of sternum VIII with indentation not truncate
   but shallowly concave (Fig. 6) .... _P. nitida_ (LeConte)
7. Posterior border of sternum VIII with indentation deeply and
   narrowly concave (Fig. 8) .... _P. anxia_ (LeConte)
   Posterior border of sternum VIII with indentation shallowly and
   widely concave (Fig. 7) .... _P. drakii_ (Kirby)

REFERENCES

Craighead, F. C. 1949. Insect enemies of eastern forests. U. S. Dep. Agri. mis. pub. 657. 679 pp.

Criddle, H. 1918. The habits and control of white grubs in Manitoba. Agri. Gaz. Can. 5: 449-454.

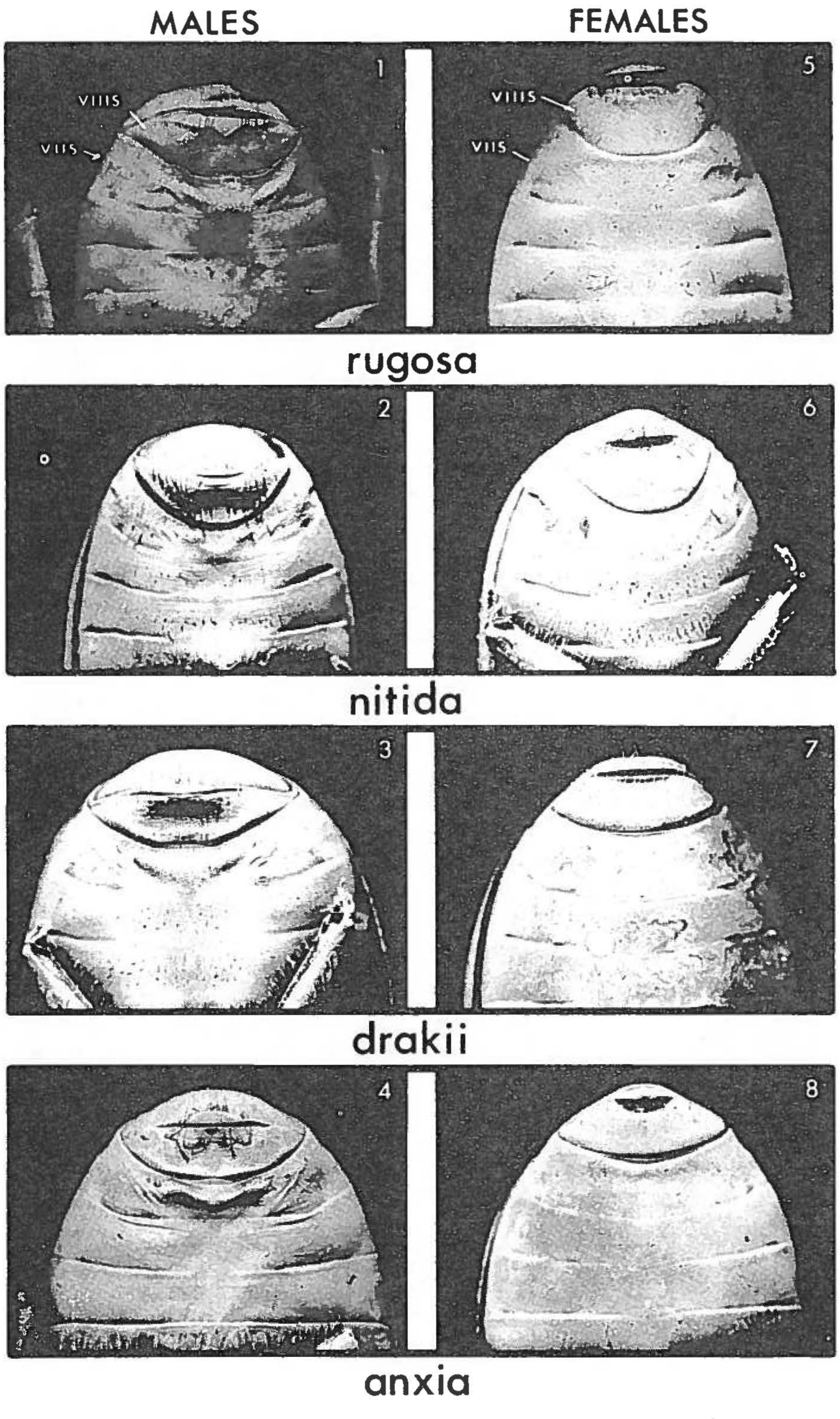
Ives, W. G. H. and G. L. Warren. 1965. Sequential sampling for white grubs. Can. Entomol. 97: 596-604.

Jackson, R. 1962. Use of sublimated ammonium chloride for photographing dried biological material. J. Biol. Photogr. Assoc. 30: 137-140.

Luginbill, P. and H. R. Painter. 1953. May beetles of the United States and Canada. U.S. Dep. Agr. Tech. Bull. 1060: 102 pp.

Prentice, R. M. and V. Hildahl. 1957. Provinces of Manitoba and Saskatchewan, Forest Insect Survey, pp. 53-64. In Annu. Rep. Forest Insect and Disease Surv., Forest Biol. Div; Can. Dep. Agr. 94 pp.

Prentice, R. M. and V. Hildahl. 1959. Provinces of Manitoba and Saskatchewan, Forest Insect Survey, pp. 68-78. In Annu. Rep. Forest Insect and Disease Surv., Forest Biol. Div. Can. Dep. Agr. 121 pp.



Figs. 1 - 8. Venters of adult Phyllophaga. Abbreviation S, sternum.

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DISTRIBUTION OF THE NATIVE ELM BARK BEETLE Hylurgopinus rufipes (Eichhoff), IN MANITOBA AND SASKATCHEWAN

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Abstract

Surveys to determine the distribution of elm bark beetles in Manitoba and Saskatchewan were initiated in 1962, after the appearance of the Dutch elm disease in Minnesota. The native elm bark beetle, Hylurgopinus rufipes (Eichhoff), was found throughout the natural range of white, elm, Ulmus americana L., and at one location outside the range in Saskatchewan. The smaller European elm bark beetle, Scolytus multistriatus (Marsham), was not found in either province.

Introduction

The Dutch elm disease, Ceratocystis ulmi (Buism.) C. Moreau, was introduced into the United States about 1930 (May and Gravatt 1931) and Canada prior to 1944 (Pomerleau 1945) and has caused widespread damage to white elm, Ulmus americana L. in northeastern United States and eastern Canada (Davidson 1964). The occurrence of the disease in the Minneapolis-St. Paul area of Minnesota (Anonymous 1961), and the spread of the smaller European elm bark beetle, Scolytus multistriatus (Marsham), from Massachusetts (Chapman 1910) to Minnesota (Schroeder and French 1961) and southern Ontario (Watson 1948) caused concern for the survival of white elm in Manitoba and Saskatchewan.

A survey was initiated in 1962 by the Manitoba-Saskatchewan Region of the Forest Insect and Disease Survey, Department of Forestry of Canada, to ascertain the distribution of the native elm bark beetle, Hylurgopinus rufipes (Eichhoff), in relation to the occurrence of white elm, and to determine if S. multistriatus was present in the region.

Methods

Bark beetles were collected from early spring to late fall principally by examining all dying or dead parts of healthy, unhealthy, and dead elm trees including calluses formed around old wounds. Attempts were made to collect the migrating adults during May and June by beating the branches and foliar parts of living trees. Sixty-nine trap-logs, measuring 4 feet long by 3 to 8 inches diameter and cut from living white elm trees in late October 1962, were also used in an attempt to determine the distribution of bark beetles in 1963. These were supported 18 inches above the ground amongst healthy elm trees at Winnipeg, Emerson and Souris, Manitoba. Trap-logs in the Riding Mountain National Park were supported at one end only. Each log was periodically inspected for entrance holes from mid-May to late September, and then the bark was carefully removed to determine if bark beetles were present.

Results

The native elm bark beetle was commonly collected in southern Manitoba, and less frequently towards the northern and western limits of native elm in Manitoba and Saskatchewan (Fig. 1). Its scattered distribution in the latter areas may be due to the sporadic occurrence of the native host. Although white elm is used extensively in shelterbelts and as shade trees throughout the Aspen Grove and Prairie sections of these two provinces, the native elm bark beetle was collected at only one location outside the natural range of its host. This sample was taken from a planted white elm tree in a farm shelterbelt near Milden some 25 miles west of Outlook, Saskatchewan. It was also not detected on Chinese or Siberian elm, *Ulmus pumila* L. *S. multistriatus* was not collected during the four-year survey from 1962 to 1965. The abundance of the native elm bark beetle in relation to the number of elm samples taken each year in both provinces is shown in Table I. Bark beetles were collected only by the examination of living, dying or dead trees.

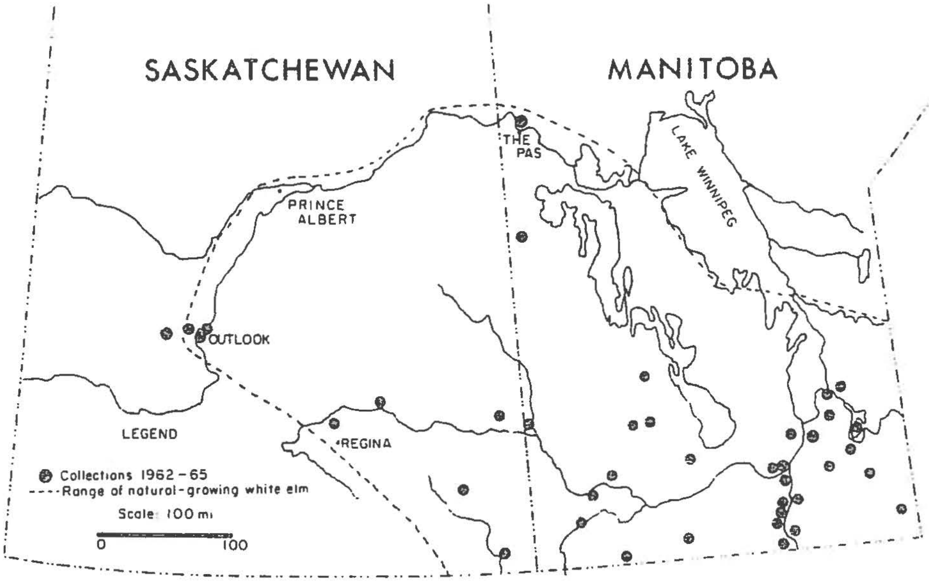

Fig. 1. The distribution of the native elm bark beetle, *Hylurgopinus rufipes* (Eichh.)

TABLE I

Native elm bark beetles collected from white elm in Manitoba and Saskatchewan, 1962-1965

Year	No. of elm samples	Percentage of samples with adult beetles
1962	66	27.3
1963	86	7.0
1964	159	8.2
1965	117	20.5

Although the trap-logs became readily infested with the elm borer, Saperda tridentata Olivier, and the red elm bark weevil, Magdalis armicollis (Say), they generally failed to attract bark beetles. Only one entrance hole and egg gallery were recorded and they were found in a log at Souris. Poor results were also noted by Watson and Sippell (1961) in the use of trap-logs in determining the distribution of elm bark beetles in Ontario. The sampling of the foliar parts of living trees failed to produce any bark beetles.

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REFERENCES

Anonymous. 1961. The Dutch elm disease. Coop. Economic Insect Report. U. S. Dep. Agr. Vol. II, No. 39: 917.

Chapman, J. W. 1910. The introduction of a European scolytid, the smaller elm bark beetle, Scolytus multistriatus (Marsh.), into Massachusetts. Psyche 7: 63-68.

Davidson, A. G. (Compiler). 1964. A review of the Dutch elm disease. Bi-monthly Prog. Rep. Can. Dep. Forest. 20 (4): 1-8.

May, C. and G. F. Gravatt. 1931. The Dutch elm disease. U. S. Dep. Agr. Circ. 170.

Pomerleau, R. 1945. La maladie hollandaise de l'orme au Canada. Rev. Can. de Biol. 4: 116-118.

Schroeder, D. B. and D. W. French. 1961. Dutch elm disease found in Minnesota. The Plant Disease Recorder. U. S. Dep. Agr. Vol. 45, No. 9: 749.

Watson, E. B. 1948. The European elm bark beetle. Forest Insect Invest. Bi-monthly Prog. Rep., Can. Dep. Agr., 4 (5) 2.

Watson, W. Y. and W. L. Sippell. 1961. Scolytid vectors of the Dutch elm disease in Ontario. Can. Entomol. 93: 403-405.

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A PRELIMINARY LIST OF THE APHIDS OF MANITOBA

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Abstract

A preliminary list of 211 species of aphids, with their host plants, is presented for Manitoba.

INTRODUCTION

The Province of Manitoba covers an area of 246,512 square miles near the centre of the land-mass of North America. The climate is continental, with severe cold in winter and hot, dry summers (Kendrew and Currie 1955).

The central and northern parts of the Province are covered with coniferous forest, in which black spruce, Picea mariana (Mill.) B. S. P., is the principal tree. Close to the northern boundary the trees are small, scattered, and interspersed with tundra. Aspen parkland and open plains on which wheat and other cereal grains are grown comprise most of the southern and western portions of Manitoba. Groves of trembling aspen, Populus tremuloides Michx., and in some areas, bur oak, Quercus macrocarpa Michx., are characteristic of the parkland. Manitoba maple, Acer negundo var. interius (Britt.) Sarg., green ash, Fraxinus pennsylvanica Marsh var. subintegerrima (Vahl) Fern, and white elm, Ulmus americana L., are the principal trees on the flood plains of the rivers. Along the southeastern boundary a western extension of the Great Lakes Forest occurs, in which the eastern white pine, Pinus strobus L., and the red pine, Pinus resinosa Ait., reach the western limits of their ranges (Rowe 1959, Bird 1961).

Both authors have collected aphids in the southern part of the region for several years, and the second author has received a large number of aphid specimens from all parts of the Province through the help of the Canadian Forest Insect and Disease Survey.

No list of the aphids that occur in Manitoba has been published to date. In answer to requests for such a list, the following is offered, though there is still much unworked material in the aphid collections already assembled, and many more species yet to be found. The list contains 211 species arranged alphabetically by genera, followed by the names of the host plants on which they occur.

Acyrthosiphon brevis Richards. Spiraea sp.

Acyrthosiphon caraganae (Cholodkovsky). Caragana arborescens.

Acyrthosiphon dirhodum (Walker). Avena sativa, Festuca pratensis, Hordeum vulgare, Lolium perenne, Phalaris arundinacea, Rosa spp. Triticum aestivum.

Acyrthosiphon pisum (Harris). Lathyrus odoratus, Medicago sativa, Melilotus alba, Melilotus officinalis, Pisum sativum.

Acyrthosiphon sibiricum (Mordwilko). Urtica dioica.

Acyrthosiphon solani (Kaltenbach). Pelargonium sp. (Geranium house plant). Salvia sp.

Acyrthosiphon scariolae (Nevsky). Lactuca scariola.

Amphorophora crataegi (Monell). Crataegus sp.

Amphorophora laingi Mason. Matteuccia struthiopteris.

Amphorophora nabali (Oestlund). Prenanthes alba.

Amphorophora ribiella (Davis). Ribes aureum.

Amphorophora rubi (Kaltenbach). Rubus spp.

Anoecia graminis Gillette and Palmer. Hordeum jubatum (roots).

Anoecia oenotherae Wilson. Oenothera biennis (roots).

Anoecia querci (Fitch). Suction trap.

Anoecia setariae Gillette and Palmer. Equisetum laevigatum (roots).

Aphis armoraciae Cowen. Achillea millefolium, Artemisia frigida, Artemisia sp., Taraxacum officinale (all on roots).

Aphis asclepiadis Fitch. Asclepias sp.

Aphis ceanothi Clarke. Ceanothus ovatus.

Aphis corniella Hille Ris Lambers. Cornus stolonifera.

Aphis fabae Scopoli. Arctium minus, Aster sp., Cirsium arvense, Dahlia sp., Gladiolus sp., Lilium sp., Philadelphus sp., Rhubarb, Tropaeolum majus, Viburnum spp., Zinnia sp.

Aphis farinosa Gmelin. Salix spp.

Aphis gossypii Glover. Cucumis sp.

Aphis helianthi Monell. Cornus stolonifera, Helianthus sp.

Aphis heraclella Davis. Cicuta maculata, Heracleum lanatum, Sium sp.

Aphis knowltoni Hottes and Frison. Taraxacum officinale (roots).

Aphis maculatae Oestlund. Populus spp., Populus tremuloides.

Aphis monardae Oestlund. Monarda fistulosa.

Aphis nasturtii Kaltenbach. Alisma sp., Polygonum sp., Rhamnus cathartica, Rumex sp., Sagittaria sp.

Aphis neogillettei Palmer. Cornus stolonifera.

Aphis neomexicana (Cockerell). Ribes sp.

Aphis oenotherae Oestlund. Epilobium angustifolium, Oenothera biennis.

Aphis oestlundi Gillette. Oenothera spp.

Aphis pomi DeGeer. Malus spp. Sorbus sp.

Aphis ribiensis Gillette and Palmer. Ribes sp.

Aphis rubifolii Thomas. Rubus spp.

Aphis spiraecola Patch. Cosmos sp., Cotoneaster acutifolia, Spiraea sp., Zinnia sp.

Aphis spiraephila Patch. Spiraea spp.

Aphis varians Patch. Ribes alpinum.

Aphis viburniphila Patch. Viburnum spp.

Aphthargelia symphoricarpi (Thomas). Symphoricarpos albus.
Asiphonaphis pruni Wilson and Davis. Prunus virginiana.
Asiphum rosettei Maxson, Populus tremuloides.
Aspidaphis adjuvans (Walker). Polygonum aviculare.

Betulaphis quadrituberculata (Kaltenbach). Betula papyrifera.
Brachycaudus helichrysi (Kaltenbach). Chrysanthemum, Gloxinia, Gynura, Matricaria (house plants).
Brachycaudus rociadae (Cockerell). Delphinium sp.
Brachycolus atriplicis (Linnaeus). Chenopodium album.
Brachycolus tritici Gillette. (in yellow pan trap).
Brevicoryne brassicae (Linnaeus). Cabbage, cauliflower, turnip.

Calaphis betulaecolens (Fitch). Betula papyrifera.
Calaphis granovskyi-viridipallida grp. Betula papyrifera.
Capitophorus elaeagni (Del Guercio). Cirsium arvense, Elaeagnus commutata. Shepherdia argentea.
Capitophorus hippophaes (Walker). Elaeagnus commutata, Polygonum sp., Shepherdia argentea.
Capitophorus pseudoglandulosus Palmer. Artemisia frigida.
Capitophorus xanthii (Oestlund). Xanthium strumarium.
Cavariella aegopodii (Scopoli). Anethum graveolens, Apium graveolens, Salix spp., Sium suave.
Cepegillettea betulifoliae Granovsky. Betula gladulosa.
Chaetosiphon fragaefolii (Cockerell). Rosa spp.
Chaetosiphon scalaris Richards. Potentilla sp.
Chaitophorus nigrae (Oestlund). Salix spp.
Chaitophorus populicola (Thomas). Populus spp., Populus tremuloides.
Chaitophorus populifolii (Essig.). Populus spp.
Chaitophorus stevensis Sanborn. Populus spp.
Chaitophorus viminalis Monell. Salix spp.
Cinara abieticola (Cholodkovsky). Abies balsamea.
Cinara banksiana Pepper and Tissot. Pinus banksiana.
Cinara bogdanowi (Mordvilko). Picea glauca.
Cinara braggii (Gillette). Picea glauca.
Cinara gracilis (Wilson). Pinus banksiana.
Cinara coloradensis (Gillette). Picea glauca; P. mariana.
Cinara curvipes (Patch). Abies balsamea.
Cinara fornacula Hottes. Picea glauca; P. mariana.
Cinara harmonia Hottes. Pinus resinosa.
Cinara hottesi (Gillette and Palmer). Picea glauca; P. mariana.
Cinara juniperi (deGeer). Juniperus communis.
Cinara laricifex (Fitch). Larix laricina.
Cinara manitobensis Bradley. Juniperus horizontalis.
Cinara obscura Bradley. Picea glauca.
Cinara ontarioensis Bradley. Pinus banksiana.
Cinara palmerae (Gillette). Picea glauca.
Cinara pergandei (Wilson). Pinus banksiana.
Cinara petersoni Bradley. Juniperus horizontalis.
Cinara pinea (Mordvilko). Pinus sylvestris L.

Cinara piniradicis Bradley. *Pinus banksiana.*
Cinara pinivora (Wilson). *Pinus banksiana.*
Cinara rara Bradley. *Picea mariana.*
Cinara saskensis Bradley. *Picea glauca.*
Cinara spiculosa Bradley. *Larix laricina.*
Cinara strobi (Fitch). *Pinus strobus.*
Cinara subterranea Bradley. *Larix laricina.*
Colopha ulmicola (Fitch). *Ulmus americana.*
Coloradoa absinthii (Lichtenstein). *Artemisia absinthium.*
Coloradoa artemisiae (Del Guercio). *Artemisia absinthium.*
Cryptaphis poae (Hardy). *Bromus inermis.*
Cryptomyzus galeopsidis (Kaltenbach). In flight.
Cryptomyzus ribis (Linnaeus). *Ribes* spp.

Dactynotus ambrosiae (Thomas). *Ambrosia trifida.* *Solidago* spp.
Dactynotus cirsii (Linnaeus). *Cirsium arvense.*
Dactynotus erigeronensis (Thomas). *Erigeron canadensis.*
Dactynotus hieracicola Hille Ris Lambers. *Hieracium umbellatum.*
Dactynotus nigrotuberculatus Olive. *Solidago* spp.
Dactynotus paucosensoriatus Hille Ris Lambers. *Aster* sp.
Dactynotus pseudambrosiae Olive. *Lactuca scariola.*
Dactynotus richardsi Robinson. *Grindelia squarrosa.*
Dactynotus rudbeckiae (Fitch). *Rudbeckia laciniata.*
Dactynotus russellae Hille Ris Lambers. *Anaphalis margaritacea*
Dactynotus taraxaci (Kaltenbach). *Taraxacum officinale.*
Drepanaphis acerifoliae (Thomas). *Acer negundo.*
Drepanaphis spicatum Smith. *Acer spicatum.*
Dysaphis tulipae (Boyer de Fonscolombe). Iris and tulip in greenhouse.

Epameibaphis frigidae (Oestlund). *Artemisia frigida.*
Eriosoma americanum (Riley). *Ulmus americana*
Eriosoma crataegi (Oestlund). *Crataegus* sp.
Eriosoma lanigerum (Hausmann). *Ulmus americana.*
Euceraphis punctipennis (Zetterstedt). *Betula papyrifera.*

Forda formicaria Heyden. Roots of *Agropyron repens* and *Poa* spp.
Forda marginata Koch. Roots of *Agropyron repens* and *Poa* spp.
Fullawaya hughi MacGillivray. *Populus tremuloides.*

Gypsoaphis oestlundi (Hottes). *Lonicera* spp.

Hamamelistes spinosus Shimer. *Betula papyrifera.*
Holcaphis frequens (Walker). *Agropyron repens.*
Hoplochaitophorus quercicola (Monell). *Quercus macrocarpa.*
Hyadaphis foeniculi Passerini. *Sium suave.*
Hyalopterus pruni (Geoffroy). *Phragmites communis.* *Prunus nigra.*
Hysteroneura setariae (Thomas). *Prunus nigra, Prunus pumila,*
Triticum aestivum.

Kakimia essigi (Gillette and Palmer). *Aquilegia* sp.
Kakimia robinsoni Richards. *Delphinium* sp.

Lachnus montanus (Wilson). Quercus macrocarpa.
Lipaphis pseudobrassicae (Davis). Brassica sp., Thlaspi arvense.
Longistigma caryae (Harris). Tilia americana.

Macrosiphoniella absinthii (Linnaeus). Artemisia absinthium.
Macrosiphoniella frigidicola (Gillette and Palmer). Artemisia abrotanum, Artemisia biennis.
Macrosiphoniella ludovicianae (Oestlund). Artemisia ludoviciana.
Macrosiphoniella pennsylvanica (Pepper). Achillea millefolium.
Macrosiphoniella tanacetaria (Kaltenbach). Tanacetum vulgare.
Macrosiphum avenae (Fabricus). Aegilops sp., Agropyron cristatum, Agropyron intermedium, Agropyron repens, Agropyron trachycaulum, Agropyron trichophorum, Agrostis scabra, Agrostis stolonifera, Alopercurus pratensis, Andropogon gerardi, Avena fatua, Avena sativa, Bromus inermis, Elymus sp., Elymus junceus, Elymus striatus, Hordeum vulgare, Panicum miliaceum, Phleum pratense, Secale cereale, Setaria sp., Setaria italica, Setaria viridis, Sorghum sudanense, Triticum aestivum, Typha latifolia.
Macrosiphum californicum (Clarke). Salix sp.
Macrosiphum coryli Davis. Corylus sp.
Macrosiphum euphorbiae (Thomas). Althaea rosea, Amaranthus retroflexus, Brassica sp. (rapeseed), Cucurbita sp. (pumpkin), Fragaria sp., Gladiolus sp., Iris sp., Iva xanthifolia, Lactuca sativa, Lactuca scariola, Linum sp., (flax), Papaver sp., Peony, Phaseolus sp. (garden bean), Polygonum aviculare, Portulaca oleracea, Rosa spp., Solanum tuberosum, Spiraea sp., Tulipa sp., Verbena sp., Zinnia sp.
Macrosiphum geranii Oestlund. Geranium sp.
Macrosiphum manitobensis Robinson. Cornus stolonifera.
Macrosiphum pseudorosae Patch. Agrimonia triata, Aster sp., Chenopodium album, Cicuta maculata, Gladiolus sp., Lysimachia sp., Oenothera sp., Ranunculus sp.
Macrosiphum ptericolens Patch. Pteridium aquilinum.
Macrosiphum rosae (Linnaeus). Rosa spp.
Macrosiphum valerianae (Clarke). Epilobium spp.
Maculolachnus sijpkensi Hille Ris Lambers. Rosa spp.
Masonaphis (Ericobium) alni Mason. Alnus sp.
Masonaphis (Ericobium) grindeliae s. sp. palmerae MacGillivray, Grindelia squarrosa.
Masonaphis (Oestlundia) rubicola (Oestlund). Rubus spp.
Masonaphis (Ericobium) spiraecola (Patch). Spiraea sp.
Masonaphis (Ericobium) wahnaga (Hottes). Convallaria majalis.
Microsiphoniella artemisiae (Gillette). Artemisia ludoviciana.
Mindarus abietinus Koch. Abies balsamea, Picea glauca.
Mordvilkoja vagabunda (Walsh). Populus spp.
Myzocallis (Neomyzocallis) discolor (Monell). Quercus macrocarpa.
Myzocallis (Neomyzocallis) punctata (Monell). Quercus macrocarpa.
Myzus cerasi (Fabricius). Prunus pennsylvanica, Prunus virginiana.
Myzus ornatus Laing. House plant.

Myzus persicae (Sulzer). Amaranthus retroflexus, Antirrhinum sp., Brassica spp., Calceolaria sp., Capsella bursapastoris, Chrysanthemum sp., Crocus sp., Dentura sp., Lilium sp., Oleander sp., Petroselinum hortense, Saintpaulia sp., Thlaspi arvense, (mostly in greenhouses or on house plants.

Nasonovia lactucae (Linnaeus). Ribes spp., Sonchus oleraceus.
Nasonovia pallida Hille Ris Lambers. Ribes spp., Sonchus oleraceus.
Nearctaphis bakeri (Cowen). Crataegus spp.
Nearctaphis crataegifoliae (Fitch). Crataegus sp.
Nearctaphis (Amelancheria) sensoriata Gillette and Bragg. Amelanchier sp.
Neoceruraphis viburnicola (Gillette). Viburnum spp., V. lentago, V. opulus.
Neomyzus circumflexus (Buckton). Resting on oak leaves.
Neoprociphilus attenuatus (Osborne and Sirrine). Smilax herbacea.

Oestlundiella flava (Davidson). Alnus rugosa.

Paraprociphilus tessellatus (Fitch). Alnus sp.
Paraschizaphis scirpicola Hille Ris Lambers. Scirpus sp.
Pemphigus balsamiferae Williams. Roots of Beta vulgaris (sugar beet), Chenopodium album, Lactuca sativa.
Pemphigus monophagus Maxson. Populus balsamifera.
Pemphigus populicaulis Fitch. Populus sp.
Pemphigus populitransversus Riley. Populus sp.
Periphyllus negundinis (Thomas). Acer negundo.
Phorodon humuli (Schrank). Humulus lupulus.
Pleotrichophorus gnaphalodes (Palmer). Artemisia ludoviciana.
Prociphilus aceris (Monell). Acer negundo.
Prociphilus americanus (Walker). Pinus sylvestris.
Prociphilus fraxinifolii (Riley). Fraxinus sp.
Pseudocercidis rosae Richards. Rosa spp.
Pterocallis alnifoliae (Fitch). Alnus rugosa.
Pterocomma bicolor Oestlund. Salix spp.
Pterocomma populifoliae (Fitch). Populus balsamifera.
Pterocomma salicis (Linnaeus). Salix sp.
Pterocomma smithiae (Monell). Salix spp., Populus tremuloides.

Rhodobium porosum (Sanborn). Rosa sp.
Rhopalomyzus lonicerae (Siebold). Lonicera spp.
Rhopalosiphum cerasifoliae (Fitch). Prunus virginiana.
Rhopalosiphum enigmae Hottes and Frison. Typha sp.
Rhopalosiphum fitchii (Sanborn). Cotoneaster acutifolia, Crataegus spp., Malus spp., Sorbus americana. Cultured in greenhouse on wheat, oats and barley.
Rhopalosiphum maidis (Fitch). Agrostis stolonifera, Alopecurus pratensis, Avena sativa, Bromus inermis, Echinochloa crusgalli, Elymus striatus, Festuca pratensis, Hordeum jubatum, Hordeum vulgare, Phalaris arundinacea, Phalaris canariensis, Phleum pratense, Poa pratensis, Setaria sp., Setaria italica, Setaria viridis, Zea mays.

Rhopalosiphum nigrum Richards. Alisma sp., Zizania aquatica.
Rhopalosiphum nymphaeae (Linnaeus). Alisma sp., Ceratophyllum sp., Prunus virginiana.
Rhopalosiphum padi (Linnaeus). Aegilops sp., Agropyron cristatum, Agropyron repens, Agrostis stolonifera, Alopecurus aequalis, Alopecurus pratensis, Avena sativa, Bromus inermis, Echinochloa crusgalli, Elymus striatus, Festuca pratensis, Hordeum jubatum, Hordeum vulgare, Phalaris arundinacea, Phleum pratense, Poa pratensis, Prunus padi, Prunus virginiana, Secale cereale, Setaria italica, Setaria viridis, Triticum aestivum, Zea mays.
Rhopalosiphum rufulum Richards. Crataegus sp.

Schizaphis graminum (Rondani). Aegilops sp., Agropyron intermedium, Agropyron repens, Agropyron trachycaulum, Agropyron trichophorum, Agrostis stolonifera, Alopecurus pratensis, Avena fatua, Avena sativa, Bromus inermis, Dactylis glomerata, Danthonia sp., Echinochloa crusgalli, Elymus sp., Elymus junceus, Festuca pratensis, Hordeum jubatum, Hordeum vulgare, Lolium perenne, Panicum miliaceum, Phalaris arundinacea, Phleum pratense, Poa pratensis, Secale cereale, Setaria viridis, Triticum aestivum.
Schizolachnus piniradiatae (Davidson). Pinus resinosa.
Sipha agropyrella Hille Ris Lambers. Aegilops sp., Agropyron cristatum, Agropyron repens, Agropyron trachycaulum, Agropyron trichophorum, Agrostis stolonifera, Bromus inermis, Hordeum jubatum, Hordeum vulgare, Phleum pratense, Setaria viridis, Triticum aestivum.
Sitomyzus (Glabromyzus) rhois (Monell). Rhus glabra.
Stegophylla quercicola (Monell). Quercus macrocarpa.
Symydobius americanus (Baker). Betula papyrifera.

Tetraneura ulmi (Linnaeus). Poa pratensis (roots).
Thecabius affinis (Kaltenbach). Populus balsamifera.
Thecabius populiconduplifolius Cowen. Populus balsamifera.
Thecabius populimonilis (Riley). Populus balsamifera.
Therioaphis riehmi (Börner). Melilotus alba, Melilotus officinalis.
Tinocallis (Melanocallis) ulmifolii (Monell). Ulmus americana.
Trama rara Mord. Taraxacum officinale (roots).
Tuberolachnus salignus (Gmelin). Salix spp.

REFERENCES

Bird, R. D. 1961. Ecology of the aspen parkland of Western Canada. Can. Dep. Agr. publ. 1066.

Kendrew, W. G. and Currie, B. W. 1955. The climate of Central Canada. Queen's Printer, Ottawa.

Rowe, J. S. 1962. Forest regions of Canada. Bull. 123, Can. Dep. Northern Affairs and Natural Resources, Ottawa.

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THE ROLE OF SOIL IN INTEGRATED CONTROL OF PESTS

O. W. Grussendorf
Harperville, Manitoba.

An opinion often expressed these days is that agricultural chemicals are essential to maintain our level of crop production. Nevertheless, for many years many people throughout the world have operated successful farms and gardens without using chemicals by considering the plant in relation to its environment, particularly to the soil nutrients. These people, and I am one of them, consider soil fertility as the basic requirement but not so much the quantity of nitrogen-phosphorus-potassium (NPK) as the quantity and quality of soil organic matter. We strive to replenish the humus content of the soil to supply the plants primarily with organic matter.

This method of farming, often called "organic farming", aims at producing high quality food products in as great a quantity as possible. Produce grown on humus-amended soils has better taste, flavour, tenderness, crispness and keeping ability than other produce and is free from pesticide residues. Another advantage is that the plants obtain a relative degree of freedom from insect attack.

As an example, some years ago I observed a difference in the population of bean aphids on beans (Phaseolus vulgaris) that I grew in two adjoining plots. One plot was treated with the usual mineral fertilizer mixture; the other had only humus added. The plants on the plot treated with the mineral fertilizer became so densely covered with aphids that they looked blackish even from a distance; the plants on the plot treated with humus had hardly any aphids on them.

Similar observations have been made on populations of Colorado potato beetles. My neighbour's field treated with mineral fertilizer was infested with the beetles while my fields, planted with the same variety of potato and treated with humus, had uneconomic populations of the beetle. Furthermore, in 1952 I had a severe infestation of Colorado potato beetles on plants grown on some poor land I had acquired to test further the possibilities of the organic approach to agriculture. A 1/2% rotenone dust was used to control the beetles the first year. But, no insecticide has been used since, even though the beetles have been present every succeeding year. The incidence of feeding and damage has become proportionately less each year as I have improved the soil and simultaneously improved the vitality of the seed. Finally the beetles became economically unimportant even though egg clusters were seen on many young plants. In addition, the seed has not been changed since 1953 and does not show the slightest indication of "running out" as it does for growers using large quantities of mineral fertilizers.

This resistance to insect attack is lost to a greater or lesser extent when the plant does not have optimum nutrition for a number of generations. For example, I demonstrated in a group of peach trees infested with aphids that trees treated with compost were much less infested at the end of the season than trees that were not treated with compost.

Similar observations have been made by Wittwer and Haseman (1946) and Haseman (1946, 1950) working in Missouri. Wittwer and Haseman (1946) noticed that New Zealand spinach plants grown on soil containing a low level of nitrogen were severely attacked by greenhouse thrips, Heliothrips haemorrhoidalis (Bouchē), whereas plants grown on soil with two higher levels of nitrogen and the highest level of calcium were barely attacked. To quote Haseman (1946), "For some reason the thrips consistently avoided the larger, deep green plants growing on the two higher nitrogen levels. Actually the plants which the thrips avoided were the luxuriant kinds generally available on the market for human consumption. This was the most perfect picture of insect response to a mineral deficiency we have yet seen".

Considerable research was stimulated by these observations, but it has been of a conflicting nature: One worker would find that the application of mineral fertilizer resulted in larger populations of insects, while another worker would find the opposite result in his soils. As a result, little has been done in the way of controlling insects through adding nutrients such as nitrogen, phosphorus, potassium, calcium and the trace elements to the soil (Haseman 1950).

These contradictory results were obtained because only the mineral nutrients were considered. The amount of these nutrients present was considered to be a measure of soil fertility whereas fertility is actually related to the kind of plants you want to grow, the environment, climate, physical condition of the soil and type of the body of the soil. The true fertility which will make a permanent practical agriculture possible depends on the nature, composition and quality of the organic matter or humus of the soil. This aspect was completely overlooked by the workers mentioned previously which may account for their contradictory results.

A plant is well-fed when it is growing on an ample supply of good humus and will then be able to resist the attack of insects, fungi, bacteria and nematodes. A well-fed plant has obtained both humic and mineral materials from the soil in balanced proportions. The quality of humus cannot be measured adequately by the soil carbon content as obtained by combustion. New tests for determining the quality of the soil and the humus have been developed by organizations investigating organic agriculture and what is known as "bio-dynamic" farming. With these new tests astounding discoveries have been made, not only about the soil, but about the food plants grown on such soils.

In most soils, the humus content has been depleted and this cannot be amended by further additions of mineral fertilizers. This upsets the balance of nutrients and affects the quality of the plants.

Pests such as insects, fungi, bacteria and nematodes may be looked on as agents of evolution which select the plants of low quality for attack, thus leaving the plants of high quality to reproduce. Therefore by attacking the pests with pesticides, we are actually perpetuating the plants of poor quality. The best method of controlling pests is to improve the soil by increasing the content of high-quality humus. Otherwise, biological control by itself will not be a sufficiently powerful agent of control.

Other practises needed to produce healthy plants are to avoid monocultures, to use well-planned rotations, to grow plants in habitats suitable for them, to encourage biological control, and to use resistant varieties. In addition, good agronomic practises must be practised such as using the appropriate tillage methods and avoiding the use of waterlogged, compacted and plow-panned soil.

Therefore, economic entomologists would do well to always consider the whole plant in relation to its ecosystem. Valuable insight of use to agriculture would thus be gained. If all the pertinent, available knowledge about a biologically sound agriculture was put to use today, pesticides would only be used for temporary control where soil conditions had become unbalanced and for the protection of public health in some areas.

REFERENCES

Wittwer, J. H. and Haseman, L. 1946. Soil nitrogen and thrips injury on spinach. J. Econ. Entomol. 38: 615.

Haseman, L. 1950. Controlling insect pests through their nutritional requirements. J. Econ. Entomol. 43: 399.

Haseman, L. 1946. Influence of soil minerals on insects. J. Econ. Entomol. 39: 8.

Howard, Albert. Farming and Gardening for Health or Disease. Faber and Faber, London, 1954.

APPENDIX I

EXECUTIVE

1964-65	1965-66
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Secretary	
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E. A. R. Liscombe Board of Grain Commissioners for Canada 1181 Grain Exchange Bldg., Winnipeg 2, Manitoba	
Editor	
W. J. Turnock Dept. of Forestry of Canada Forest Research Laboratory 25 Dafoe Road Winnipeg 19, Manitoba	L. B. Smith Research Station Canada Agriculture 25 Dafoe Road Winnipeg 19, Manitoba

APPENDIX II

MEMBERSHIP LIST

Members are requested to check their addresses on this list and notify the Secretary of any errors or omissions. All addresses are 25 Dafoe Rd., Winnipeg 19, Manitoba, Canada, except where specified otherwise.

Honorary Members

The Minister of Agriculture for Manitoba

Members

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Bird, R. D. Research Station, Canada Agriculture.

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Chiang, H. C. Department of Entomology and Economic Zoology, University of Minnesota, St. Paul 1, Minnesota, USA.

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

✓ Liscombe, E. A. R. Board of Grain Commissioners for Canada, 1181 Grain Exchange Building, Winnipeg 2.

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Nairn, L. D. Forest Research Laboratory, Department of Forestry of Canada.

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

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Romanow, W. Research Station, Canada Agriculture.

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

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Smith, L. B. Research Station, Canada Agriculture.

Turnock, W. J. Forest Research Laboratory, Department of Forestry of Canada.

Watters, F. L. Research Station, Canada Agriculture.

Webb, F. E. Forest Research Laboratory, Department of Forestry of Canada, Fredericton, New Brunswick.

Westdal, P. H. Research Station, Canada Agriculture.

Wong, H. R. Forest Research Laboratory, Department of Forestry of Canada.

APPENDIX III

FINANCIAL STATEMENT AS OF NOVEMBER 3, 1965.

Cash on hand in bank as of November 12, 1964:

Savings	$441.59	
Current	6.10	
Total		$447.69

Income

Dues, Entomological Society of Canada	$216.00	
Dues, Entomological Society of Manitoba	66.00	
Sale of Proceedings	33.43	
Sale of Reprints	318.00	
Interest on Savings Account	6.21	
	$639.64	$639.64
Total		$1,087.33

Expenditures

Dues, Entomological Society of Canada	$208.00	
Rubber Stamp Co.	2.27	
Norquay Cafeteria -- re coffee	3.50	
Univ. of Manitoba -- re coffee	3.75	
Reprints	21.52	
Typing proceedings	74.13	
Spring banquet (deficit and gratuities)	18.16	
Postage and stationery	6.50	
Express charges for shipping Proceedings	5.05	
Bank service charges	2.60	
Outstanding cheques	4.50	
Overdraft	22.49	
Total	$372.47	$372.47
Balance		$714.86

Cash on hand in Bank: $714.86

APPENDIX IV

ADDITIONS TO THE LIBRARY OF THE ENTOMOLOGICAL SOCIETY OF MANITOBA

Acta entomologica musei nationalis Pragae, v. 36, 1965.

American Museum of Natural History, New York. American Museum novitates, no. 2157, 2161, 2170, 2175, 2185, 2188, 2189, 2196, 2198: 1963-64.

American Museum of Natural History, New York. Bulletin, v. 127, art. 2, 1964.

Entomological Society of British Columbia. Proceedings, v. 61, 1964.

Gembloux, Belgium. Laboratoire de zoologie générale institut agronomique de l'état. (Reprints from Jean Leclerq.)

Hatch, Melville Harrison. The beetles of the Pacific northwest; pts. 3-4. Seattle, Univ. of Washington Press, 1962-65. 2 v. illus.

Institut royal des Sciences naturelles de Belgique, Brussels. Bulletin, t. 35, no. 33, 1959.

Nebraska. Agricultural Experiment Station. Quarterly, 1965.

Nebraska. University. College of Agriculture. (Reprint material, 1965.)

Nebraska. University. College of Agriculture. Research bulletins, 218-221.

Nederlandsche Entomologische Vereeniging, Amsterdam. Entomologische berichten, v. 24, no. 12, 1964; v. 25, 1965; v. 26, no. 1-2, 1966.

Pest infestation research (Great Britain. Agricultural Research Council. Report of the Pest Infestation Laboratory, Slough, England), 1964.

Polska akademia nauk. Instytut zoologiczny, Warsaw. Annales zoologici, t. 22, no. 11-28, 1964-65; t. 23, no. 1-10, 1965.

Polska akademia nauk. Instytut zoologiczny, Warsaw. Fragmenta faunistica, t. 11, no. 16-28, 1964-65; t. 12, no. 1-10, 1965.

Polski zwiazek entomologiczny, Warsaw. Klucze do oznaczania owadow Polski (Keys to the designation of insects in Poland), no. 45-48, 1965.

Science abstracts of China. Biological sciences, v. 2, no. 3-6, 1964; v. 3, 1965. (Library Institute of Scientific and Technical Information of China, Peking.)

Sofia. University. Faculty of Agriculture and Silviculture. Yearbook, v. 16, 1962/63.

Studi sasseresi (Annula della Facolta di agraria dell' Universita di Sassari, Sassari, Italy), sez. 3, v. 11-12, 1963-64.

Zastita bilja; Plant protection, no. 78-82, 1964; no. 84, 1965. (Savenzni institut zastitu bilja, Belgrade.)