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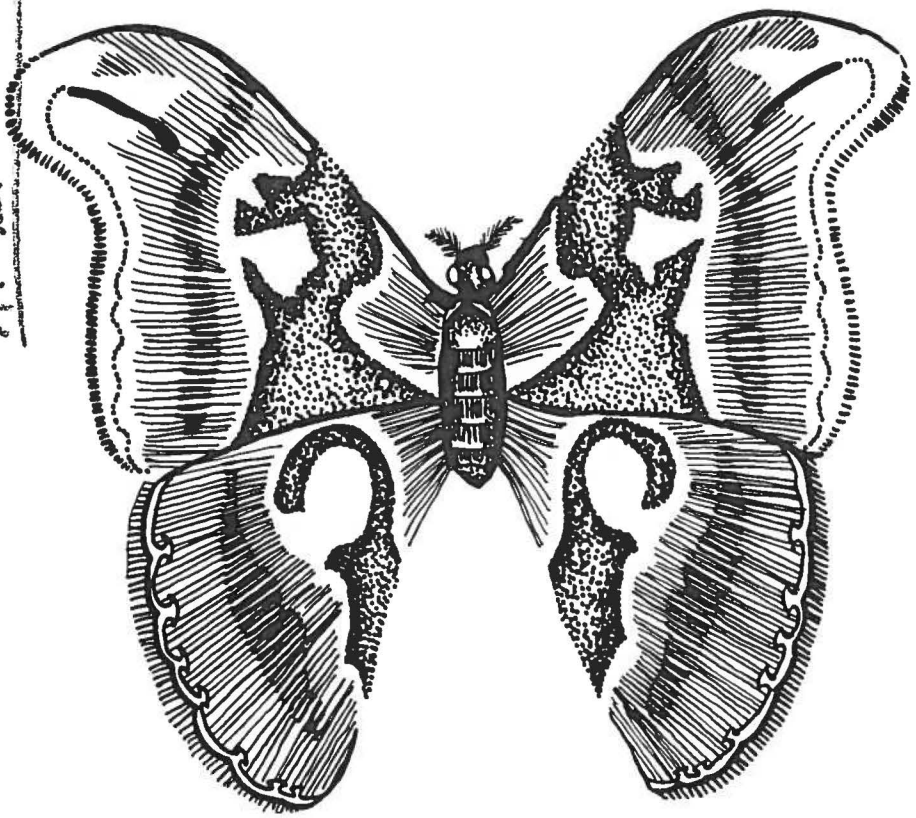

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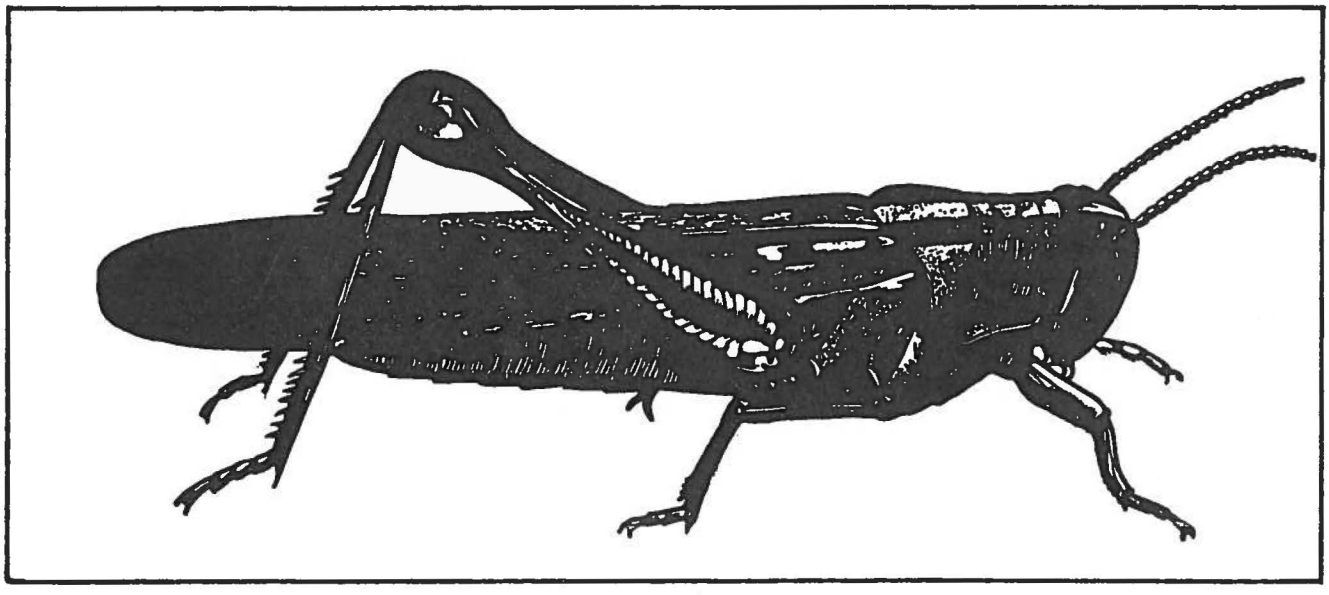

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THE MANITOBA ENTOMOLOGIST

An official publication of the Entomological Society of Manitoba, an organization to foster the advancement, exchange and dissemination of entomological knowledge

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SURVIVAL OF EGGS OF THE RUSTY GRAIN BEETLE, *CRYPTOLESTES FERRUGINEUS* [STEPHENS], IN DRY AND DAMP WHEAT TREATED WITH HYDROGEN PHOSPHIDE.[1]

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ABSTRACT: Survival of eggs of *Cryptolestes ferrugineus* (Stephens) was about the same in dry (13.5% moisture content) and damp (18.0% mc) wheat treated with aluminium phosphide pellets. Initial concentrations of the hydrogen phosphide generated were greater in the damp wheat than in the dry wheat, but this difference did not persist after day 2.

INTRODUCTION

Phosphorous unites with many metals to form phosphides (Parkes and Mellor, 1940). One of these is aluminium phosphide which reacts with ambient moisture to produce hydrogen phosphide and aluminium hydroxide (Monro, 1969). The rate at which aluminium phosphide reacts with ambient moisture depends on the concentration of moisture in the air surrounding the aluminium phosphide. Tateya *et al.*, (1974) showed that hydrogen phosphide was generated more rapidly at high than at low relative humidity (for a constant temperature) in accordance with the law of mass action (Parkes and Mellor, 1940). Tateya *et al.*, (1974) did not, however, evaluate the rate of hydrogen phosphide generation in terms of insect response; neither did they evaluate gas evolution in a mass of cereal.

Hydrogen phosphide is widely used for the control of insects in bulks of cereals (Monro, 1969; Anonymous, 1971). This work was performed to evaluate the control of eggs of *Cryptolestes ferrugineus* (Stephens) by hydrogen phosphide generated in dry and damp wheat.

MATERIALS AND METHODS

Eggs of *C. ferrugineus* were exposed, in drums, to wheat treated with hydrogen phosphide.

The wheat to be treated was of 2 moisture contents (mc), dry (13.5% mc) and damp (18.0% mc). The dry wheat, which had 8% dockage, was obtained from a local farm. The damp wheat was obtained by adjusting the mc of the dry wheat as follows: 979.8 kg (36 bushels) of the wheat was spread on a large polyethylene sheet to form a layer about 15 cm deep. Water (20.3 liters) was then sprayed on the wheat to bring the moisture content to 18%. The wheat was mixed thoroughly to distribute the dampened kernels and covered with a polyethylene sheet. The wheat was re-mixed on 3 consecutive days and tested to verify the mc (C.A.E. Moisture Master, Model 101A).

The containers used in these experiments were steel drums 1.80 m tall and 0.60 m in diameter with a capacity of 0.436 m^3 (12 bushels).

Eggs of *C. ferrugineus* were obtained by placing 20 adult beetles on 8 g of wheat of 16.0% mc in each of 135 glass vials. The vials were 7 cm high and 3 cm in diameter, fitted with snap-on caps. A hole, 1.5 cm in diameter, was drilled in each cap and covered with No.

[1]Contribution No. 689, Agriculture Canada, Research Station, Winnipeg, Manitoba.

60 brass screen (25 threads per cm) to allow gas exchange and prevent the escape of beetles. The vials containing the beetles were then placed in incubators at 30°C and 75% R.H. for 3 days for oviposition.

After the period allowed for oviposition, three vials, taken at random, were attached to each of 45 nylon cords 2.20 m long; the points of attachment were at 7, 109, and 172 cm from one end of the cord. Five cords with their attached vials, taken at random, were hung from the inside rims of each of 9 steel drums so that the mouths of the vials were 7, 109, and 172 cm from the bottoms of the drums.

Aluminium phosphide pellets were used to generate the hydrogen phosphide (PH_3). The pellets, at a rate of 6 per drum (= 1.2 g of PH_3), were added to the surface of the grain when the drums were about half filled with wheat; the drums were then filled to the brim. The gas was thus released at about 1.00 m from the top or bottom of the drums. There were three treatments, dry and damp wheat, respectively, treated with pellets, and untreated dry wheat, each replicated 3 times.

One cord with its attached vials was withdrawn from each drum after 1, 2, 3, 4, and 7 days. All the beetles in the vials were discarded, but the grain containing the eggs was retained and incubated at 30°C and 75% R.H. for 30 days after which the number of beetles that had emerged were counted. The number of beetles was used as a measure of the number of eggs that survived the treatments.

Gas concentrations were determined by means of Drager tubes (Dragerwerk - AG, Lubeck, Germany) when the cords and vials were withdrawn from the wheat. The gas samples were taken at 7 (bottom), 109 (middle), and 172 (top) cm from the bottoms of the drums.

Wheat temperatures ranged from 11.5 to 16.0°C (Figure 3).

RESULTS AND DISCUSSION

Egg survival, as indicated by adult emergence, was the same in the treated and untreated drums on day 1 and averaged 13.94 ± 5.5 insects per vial. Survival in the controls was reduced, but was constant at 6.6 ± 4.6 insects per vial on days 2, 3, 4, and 7. However, egg survival declined steadily in the treated wheat regardless of depth in grain or mc, from the start of the experiment to day 3 (Figure 1). From day 3 onward, egg survival did not decline appreciably at the top level in the damp wheat, but declined somewhat further in the dry wheat by day 7. On day 4, two eggs survived at the middle level in the dry wheat. There was also some survival of eggs in the dry wheat at the middle and bottom levels after 7 days (1 and 2 eggs, respectively), but there was no survival at these two levels in the damp wheat after 4 days (Figure 1). The high mortality of eggs in the damp wheat may have been due in part, at least, to higher initial gas concentrations (in excess of 1200 ppm) in the damp wheat than in the dry wheat (650 to 916 ppm PH_3).

The survival of even small numbers of eggs on day 7 is surprising since it has been suggested (Anonymous, 1971) that the use of 150 to 205 aluminium phosphide pellets per 1000 bushels of rice at 12 to 15°C during 4 days is sufficient for insect control. In this experiment a dose of 6 pellets per 12 bushels (500 pellets per 1000 bu) did not effectively eliminate all beetle eggs at the surface of either the dry or damp grain.

Gas concentrations were higher in the damp than in the dry wheat during the first day of the experiment (Figure 2). There were slight, although not significant, differences between the gas concentrations found in the dry and damp wheat at the 3 locations from day 3 onwards, the concentrations being consistently higher in the dry wheat. These results confirm the findings of Tateya *et al.*, (1974) for the evolution of hydrogen phosphide at temperatures 5, 15, and 25°C at 68 and 100% R.H. The temperatures in this experiment were, on average, slightly lower (Figure 3) than the constant 15°C used by Tateya *et al.*, (1974).

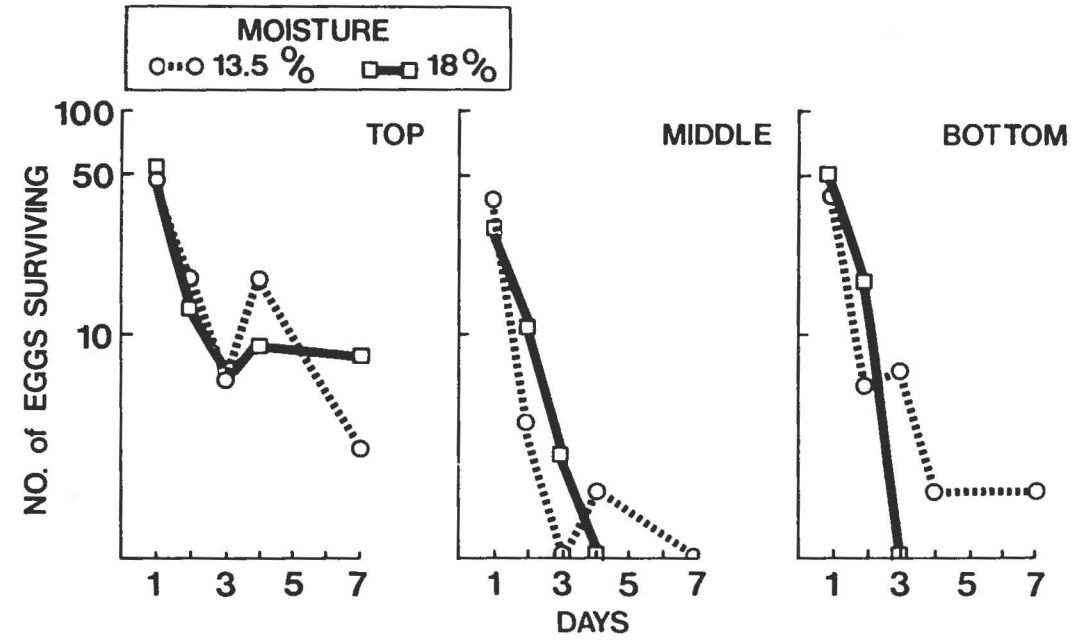

Figure 1. The total numbers of *Cryptolestes ferrugineus* eggs surviving at the top, middle and bottom of drums filled with wheat of 13.5 and 18% moisture content treated with PH_3.

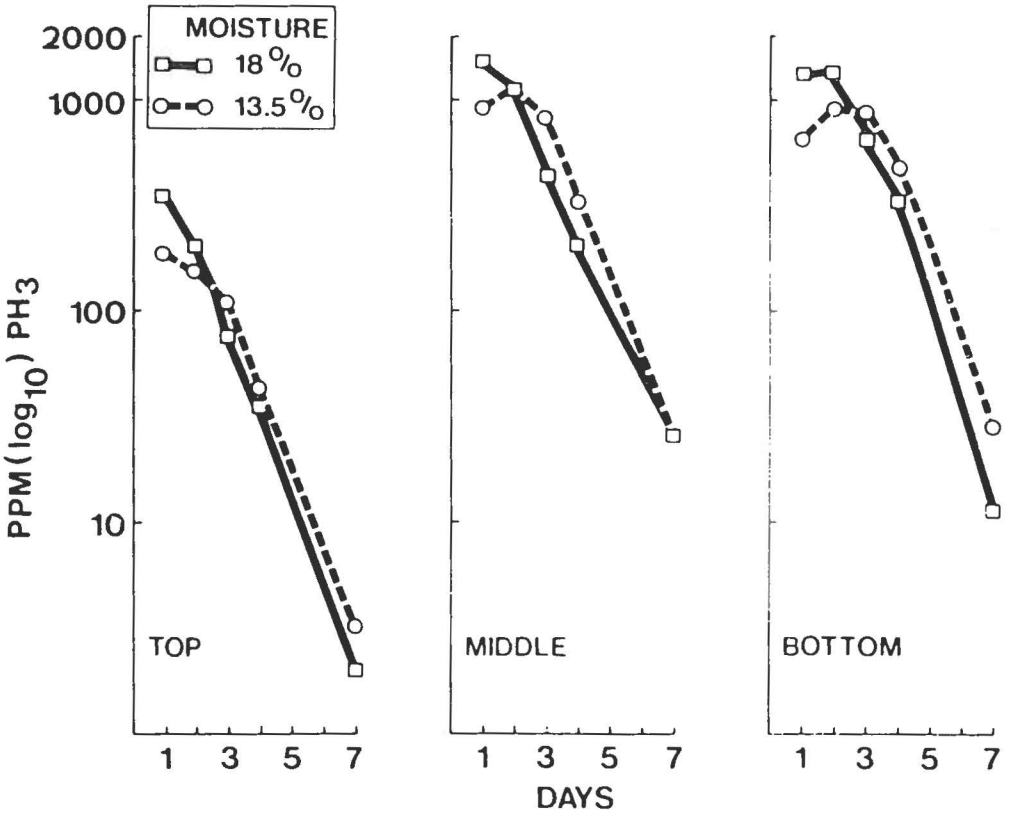

Figure 2. The concentrations of PH_3 (in ppm) found at the top, middle and bottom of drums filled with wheat of 13.5 and 18% moisture content.

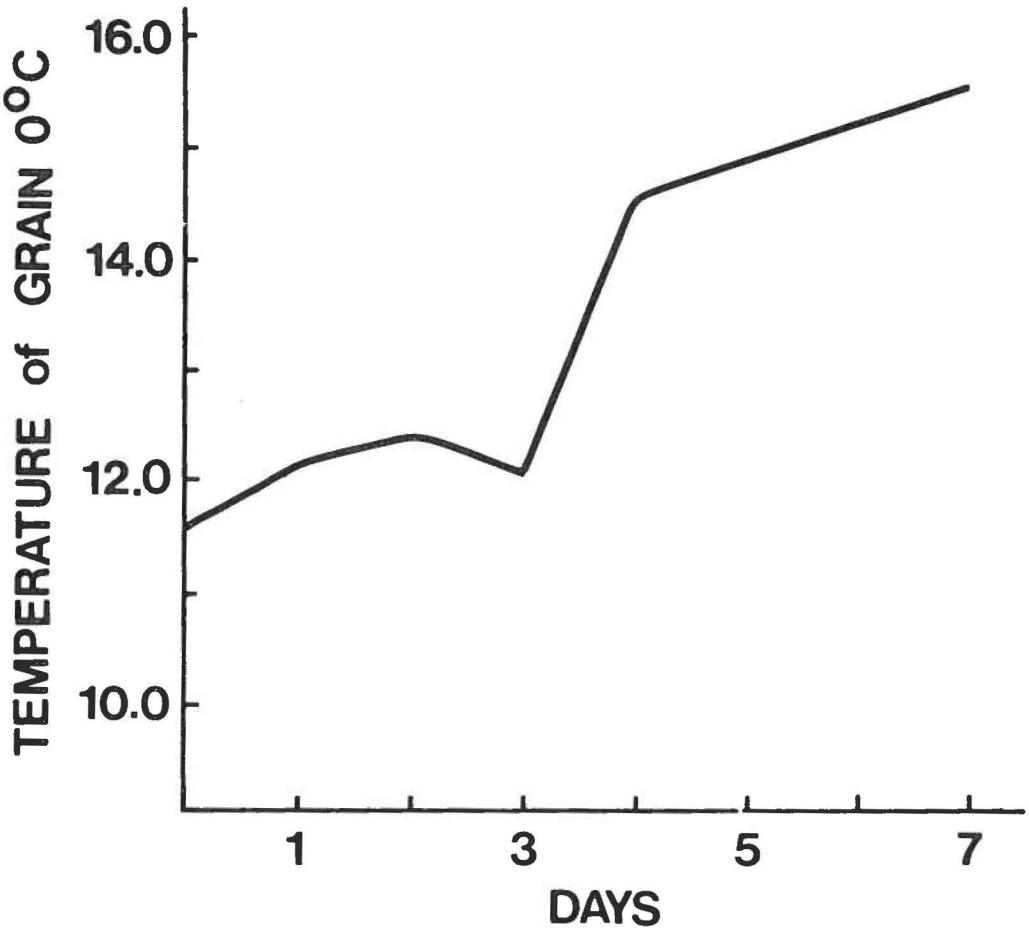

Figure 3. The average temperatures (°C) of the wheat on days 0 to 7.

This experiment showed that survival of *C. ferrugineus* eggs was about the same in dry and damp wheat treated with hydrogen phosphide. Furthermore, 100% mortality of eggs was obtained only where hydrogen phosphide concentrations exceeded 1200 ppm for more than 1 day at the start of the experiments.

ACKNOWLEDGEMENTS

Thanks are due to L. B. Smith, R. N. Sinha, F. L. Watters, and P. H. Westdal for their comments on the manuscript. Thanks are also due to D. Kurtz for his technical assistance.

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(Received 22 October, 1975)

MOVEMENTS OF ENGLISH GRAIN APHIDS ON BARLEY PLANTS

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ABSTRACT: Movements of the English grain aphid, *Macrosiphum* [*Sitobion*] *avenae* (Fabricius), on plants of Conquest barley, *Hordeum vulgare* L., were studied both in field plots and in a growth cabinet. In the field there was considerable movement of aphids on individual plants and between plants. In general, the aphids moved upwards onto the heads of the grain, and when the kernels ripened they moved downwards again.

In a growth cabinet, single apterous adults were placed on young barley plants. During the first 8 days only about half of these adults moved, but when their progeny began to reproduce, the large numbers of aphids present began to move on and off the plants, due to excessive crowding. Movements of aphids on individual plants and between plants apparently help to establish a density equilibrium.

INTRODUCTION

Several species of aphids occur on cereal crops in Manitoba (Robinson and Hsu, 1963). The damage which they may cause by sucking plant sap, or by transmission of plant viruses, has been studied in Manitoba by Apablaza and Robinson (1967) and by Burnett and Robinson (1973), among others. The English grain aphid, *Macrosiphum* [*Sitobion*] *avenae* (Fabricius), is the only one of the several species of aphids which occurs on the heads of grain. Although it does not overwinter in Manitoba, it is present in grain fields every year. Population fluctuations for the years 1968-1969 were reported by Malyk and Robinson (1971). During those studies, and further investigations by Bakker (1974), it became apparent that population fluctuations of aphids can be better understood by studying the movements of individuals or colonies on or off the plants. Information on population fluctuations is essential to decisions on the necessity for application of chemical controls. Few studies on the movements of grain aphids have been made, but one important investigation was made on 3 species by Ito (1960) in Japan. This is a report on studies made in Manitoba, in 1972, on the movements of English grain aphids on barley, *Hordeum vulgare* L., plants in both field and laboratory.

MATERIALS AND METHODS

Both Malyk and Robinson (1971), and Bakker (1974) in his first year of investigations (in 1971), tried to follow the progress of individual colonies on selected plants in the field by making counts at 5-day intervals. These counts were useful to show general trends within the field, but usually inadequate to determine the fate of individuals or colonies. In our studies in field plots, in 1972, counts were made at 3-day intervals whenever possible. Fifty plants of Conquest barley with one or more aphids on one leaf were selected on three dates, 15 July, 17 July, and 27 July, and observations continued on each plant until 16 August at which time very few aphids remained. Leaves were numbered I through VII, starting at the base of the plant and using only one tiller of the plant. The observations indicated whether colonies increased or decreased in numbers, whether aphids arrived on or departed from the plants, and whether they moved upwards or downwards, including movements on to the head.

In the laboratory studies, Conquest barley plants were grown in pots in a growth cabinet at a temperature of 21°C, photoperiod of 16L:8D and relative humidity varying between 40-70 per cent. Individual plants were enclosed by tall, square, plastic cages with a device to remove air slowly through the top (Bakker, 1974). This kept temperatures within the cages the same as in the growth cabinet. Before this device was used, temperature within the cage might be 5-6°C higher than that outside the cages.

When the barley plants were in the 3-leaf stage, a newly-molted apterous adult aphid was placed at the base of the plant, and the plant enclosed by a cage. Notes were made daily on the location of the aphids on the plant, their numbers, and their orientation, i.e. toward or away from the base of the leaf.

RESULTS AND DISCUSSION

Field Studies

When first observations were recorded on 15 July all plants had already reached the flag-leaf stage (leaf VII). When counts were made all the aphids on one leaf, or on a head, were designated as one "leaf colony". If a colony disappeared, sampling continued on that leaf on successive dates, and if leaves became reinfested the condition was referred to as first reinfestation, or second reinfestation. Detailed data from all those observations are given in Table VI and others in Bakker (1974). From those field counts we made the following observations:

1. On any given sampling date more than half of all colonies contained no adult aphids.
2. Small colonies disappeared, and new ones reappeared on other tillers or on other plants, both from movement of nymphs and apterous adults, and from newly arriving alate adults.
3. There were indications that more aphids moved just before and just after the time of peak numbers.
4. Alatoids (fourth instar nymphs destined to become alatae at the next moult) only began to appear about August 1, appearing in both old and reinfested colonies in about equal numbers.
5. Almost no predators were present on the plants.
6. There were no significant numbers of aphids before the plants reached the flag-leaf stage.

Table 1 shows gains on all heads or leaves which had not had any aphids on the previous sampling date, of the 50 plants being sampled. During the whole infestation period only once were aphids found on Leaf II, and these were arbitrarily added to Leaf III for that plant. When heads or leaves were found infested for the first time, this could be by aphids moving from other leaves on the same plant, or from other plants. Aphids on the heads of the plants probably came from lower on the same plant rather than from another plant. Leaf VII tended to have fewer colonies than the 2 leaves below it or the head above it. This may be due to the much smaller leaf area on the flag leaf of Conquest barley. After 4 August, numbers of aphids on heads declined, and increased on Leaves V and VI, possibly because the kernels of grain were hardening, and becoming unsuitable for aphid feeding. The overall picture in Table 1 is that of continual movement of aphids on barley plants in the field.

Laboratory Studies

In the studies of the aphids in the growth cabinets, adult apterae did not all begin to reproduce on the first day, so the data were arranged so that the first day was the day on which the first progeny were found. Observations for the first 8 reproductive days are shown in Table 2.

Table 1. Total number and location on plant of English grain aphids found on all the heads or leaves where there had been no aphids on the previous sampling date, on three groups of 50 plants of Conquest barley in field plots, July - August, 1972 (number of adults in parentheses)

Location on plant	Sampling dates								
	July					August			
	17	21	24	27	29	1	4	11	16
Group 1									
Head	0	13(8)	17(5)	24(5)	20(3)	15(7)	13(4)	16(2)	8
Leaf VII	3	2	0	2(2)	0	0	1(1)	7(3)	0
VI	1	6(1)	2	2(2)	2	4(2)	1(1)	32(11)	8(4)
V	1	6(1)	2	1	2(2)	3(1)	5(2)	24(2)	7(2)
IV	8(1)	2(1)	1	1	4(2)	0	9(1)	2	0
III	0	4	11(2)	2	0	6(1)	11(2)	1(1)	0
Group 2									
Head		7(3)	6(1)	27(7)	15(8)	12(5)	24(7)	9	2
Leaf VII		2	2	0	0	0	1(1)	1	1
VI		2	0	0	14(1)	2(1)	2	33(6)	8(2)
V		3(1)	3(1)	0	5(1)	8(1)	23(7)	5(1)	2
IV		0	5	0	5(1)	0	0	4(3)	0
III		0	5	0	1	0	3	0	0
Group 3									
Head					39(9)	40(12)	7(2)	16(1)	4
Leaf VII					2	4(1)	4(1)	3(2)	0
VI					6(3)	7(3)	11(4)	46(11)	7(1)
V					13	17(2)	5(2)	9(2)	2
IV					1	8(1)	5(1)	11(3)	1
III					0	1	4	5	0

About half of the aphids settled on the second leaf of their plant, and during the first 7 days there were always more on it than on any of the others. As the fourth leaf appeared, by the fifth day, an upward movement began, but about half of those originally on first or second leaves did not move during the 8 days. During the 8-day period of observations, 0-5 aphids per day moved up the plants, 0-2 moved down; 28 of the 30 aphids faced towards the base of the leaf.

The observations on the 30 adult aphids continued for 15 days, but data were not tabulated after the eighth day because many of the first progeny had become adults and were beginning to reproduce. By the fifteenth day there were about 200 aphids per plant. Many of the aphids no longer oriented towards the base of the leaf. From the tenth to the fifteenth day progressively more aphids were found wandering over the plant, on the soil or on the inside of the cage. These movements might be attributed to crowding, or nutritional deficiencies (plants drying), or a combination of both.

Table 2 shows that 15 of the adult females did not move from their original positions during the first 8 days. Only a small number of the total progeny per plant moved during the first few days when there was little crowding, but some did move, and their movements were about equally upwards or downwards on the young plants. There was some indication that by the eighth day numbers moving were increasing, because of crowding.

Table 2. Movements of 30 apterous adults of the English grain aphid, each on single plants of Conquest barley in a growth cabinet, during their first eight reproductive days

No. of apterae present on	Reproductive day								No. of apterae not moving
	1	2	3	4	5	6	7	8	
Leaf I	8	8	8	8	4	4	5	5	3
II	17	16	15	15	16	15	14	12	8
III	5	6	7	7	8	9	10	12	4
IV					2	2	1	1	

In the field, numbers of aphids on plants would not normally build up as rapidly as in a growth cabinet, because of possible mortality in the field resulting from weather, parasites or predators. Observations from the above experiments indicate that a considerable number of the aphids are moving each day, on individual plants and between plants. These movements which enable them to find leaves or plants with more favorable habitats than the crowded ones from which they have departed, in the long run contribute to population increases. These observations agree with those of Ito (1960), who showed that when the leaves of a plant became crowded, aphids moved to other leaves; when whole plants became crowded, emigration from the plant occurred, and that a density equilibrium was maintained by these movements, rather than by increased mortality or decreased fecundity.

ACKNOWLEDGEMENTS

The data reported here form part of the MSc Thesis of T. Bakker. This study was supported by a grant from the National Research Council of Canada to A. G. Robinson.

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(Received 15 April, 1976)

COMPARISON OF TWO FORMULATIONS OF HYDROGEN PHOSPHIDE FOR THE CONTROL OF ADULTS OF *TRIBOLIUM CASTANEUM* [HERBST] AND ADULTS AND EGGS OF *CRYPTOLESTES FERRUGINEUS* [STEPHENS][1]

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ABSTRACT: Concentrations of hydrogen phosphide in wheat were similar whether generated from aluminium phosphide applied as powder in bags or as pellets, and gas concentrations declined at about the same rate with both formulations.

All adults of *Cryptolestes ferrugineus* (Stephens) and *Tribolium castaneum* (Herbst) were killed in both treatments on day 1, during which gas concentrations exceeded 160 ppm. Eggs of *C. ferrugineus* survived at all depths in the grain in both treatments on day 1; some eggs survived on days 2 and 3 at the middle and bottom of the drums where gas concentrations declined from 1600 to 350 ppm, but survival was noted mainly near the top of the grain. In general, despite the similarity in gas concentrations between treatments, significantly fewer eggs survived the pellet treatment than the powder treatment indicating that the pellet formulation was superior to the bagged powder formulation.

INTRODUCTION

Hydrogen phosphide has been used for many years for the control of insects in stored grains (Heseltine and Thompson, 1957) and the effectiveness of this gas against various species of insects of stored products has been assessed in the laboratory (Lindgren and Vincent, 1966). Hydrogen phosphide is generated during the reaction of air moisture with aluminium phosphide (Monro, 1969). Aluminium phosphide is marketed as a powder in small paper bags (sachets), or as pellets or tablets (Heseltine and Thompson, 1957).

The objective of this experiment was to compare the efficacy of the bagged powder with the pelleted formulation for the control of eggs and adults of *Cryptolestes ferrugineus* (Stephens) and adults of *Tribolium castaneum* (Herbst), two species found in granaries in the Canadian Prairie Provinces (Liscombe and Watters, 1962).

MATERIALS AND METHODS

Twenty adults of *C. ferrugineus* (8 to 15 days old), 10 to 15 adults of *T. castaneum* (9 to 16 days old) and 8 g of wheat were placed in each of 270 glass vials (7 x 3 cm) fitted with snap-on-caps. A hole, 1.5 cm in diameter, was drilled in each cap and covered with No. 60 mesh (25 threads per cm) brass screen to allow gas exchange. The vials containing the insects were placed in incubators at 30°C and 75% R.H. for 3 days, to allow the beetles to lay eggs.

Six vials were attached to each of 45 nylon cords and were spaced so that when the cords were hung from the rims of steel drums (1.9 m high and 0.6 m in diameter), the mouths of the vials would be 8, 41, 71, 112, 145, and 175 cm below the rims.

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[1] Contribution No. 691, Agriculture Canada, Research Station, Winnipeg, Manitoba.

Five cords with their attached vials were hung from the top inside rims of each of 9 steel drums described above. The drums were filled with wheat to a depth of 1 m. Each of three drums received 5 aluminium phosphide pellets (= 1 g PH_3) (Degesch, Frankfurt am Main, West Germany), each of three drums received one small "research size" paper bag of aluminium phosphide powder (= 1 g PH_3) (Research Products Co., Salina, Kansas, and Werner Freyberg, Chemische Fabrik, 694 Weinheim/Bergstrasse, West Germany); and three drums were not treated and were used as checks. The drums were then filled to the brim with wheat. Approximately 12 bushels (327 kg) of wheat were used per drum. Lids were placed loosely on each drum. The experiment was arranged in a split-block design with three replicates in which each treatment was subdivided according to depth in the grain.

One cord with its attached vials was withdrawn from each drum after 1, 2, 3, 4, and 7 days. The adults, dead or alive, in each vial were sieved off, placed on clean grain at 30°C and 75% R.H. and assessed for mortality after 10 days. The grain from the treated vials was retained and incubated at 30°C and 75% R.H. for 30 days and then examined for the emergence of adults of *C. ferrugineus*. *T. castaneum* did not lay eggs under the conditions of this experiment. It was assumed that the number of adults obtained from the grain were proportional to the numbers of eggs which survived the treatment.

Concentrations of hydrogen phosphide were determined by means of Drager tubes (Dragerwerk AG, Lubeck, West Germany) at 1, 2, 3, 4, and 7 days after treatment. Gas samples were taken at 8, 71, and 175 cm from the top rims of the drums.

RESULTS AND DISCUSSION

The comparison of the gas concentrations near the top, middle and bottom of the drums showed that there were only slight differences in concentration between treatments for corresponding depths (Figure 1). Gas concentrations at the top, middle, and bottom also declined at about the same rate in both treatments.

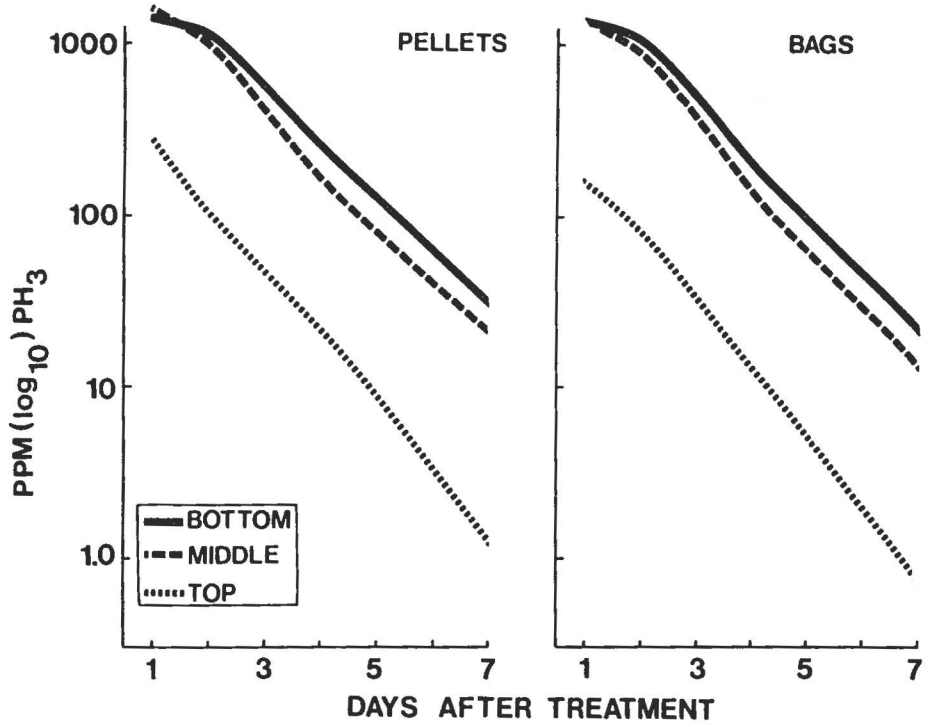

Figure 1. The concentrations of hydrogen phosphide (ppm) generated in wheat from aluminium phosphide in "pelleted" and "bagged" formulations.

All adults of both species were killed during the first day of exposure to hydrogen phosphide. If assessment of insect control is done exclusively on the basis of adults, the results so obtained can be misleading since some of the eggs can survive gas concentrations which kill all adults of the same species.

Eggs of *C. ferrugineus* were more resistant to hydrogen phosphide than were the adults of either species, and eggs survived at all depths below the grain surface in both treatments on day 1 (Figure 2). These eggs survived gas concentrations which rose to a maximum of 1600 ppm during day 1 (Figure 1).

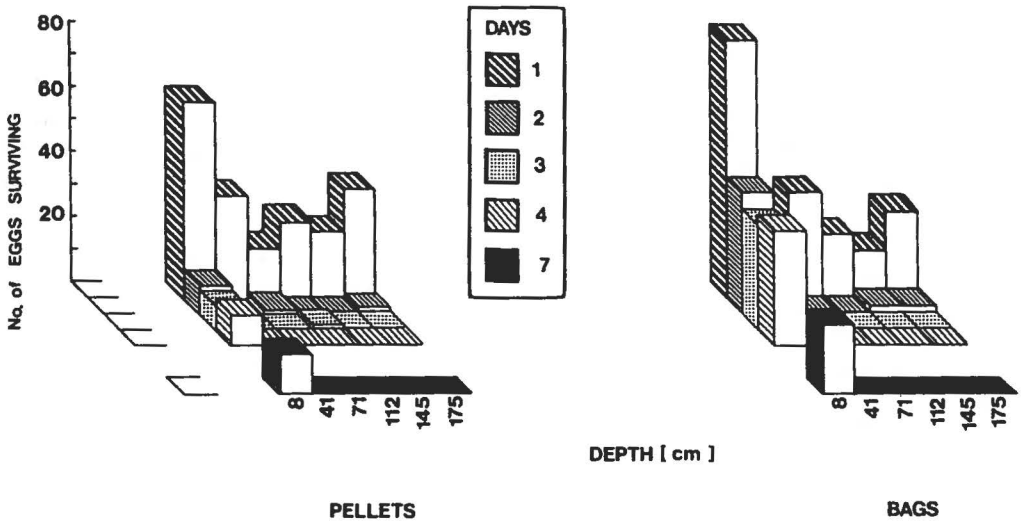

Figure 2. The number of eggs of *C. ferrugineus* surviving treatment with hydrogen phosphide on 5 dates after initiation of treatment and at 6 depths in the grain.

On day 2, eggs of *C. ferrugineus* also survived in both treatments. At the 8 cm depth 10 eggs survived in the "pellet" treatment, whereas 38 eggs survived in the "bag" treatment. At the 175 cm depth, one egg survived in each of the treatments (Figure 2) though the gas concentrations had only declined to 1200 ppm at that depth (Figure 1).

On day 3, the gas concentrations at the bottoms of the drums were 350 ppm (Figure 1) and there was no egg survival at that depth (Figure 2). One egg survived at the 112 cm depth in the "pellet" treatment and several survived at 8 cm in both treatments.

Egg survival at the 8 cm depth for days 3, 4, and 7 was similar to that found on day 2 for each treatment (Figure 2) and the survival in the "bag" treatment was significantly greater than that for the "pellet" treatment ($p < 0.01$).

Gas concentrations at the top of the drums declined steadily from 100 ppm on day 2 to about 1 ppm on day 7 (Figure 1), but there was no increment in the mortality during the same time interval (Figure 2). It is apparent that these gas concentrations were not sufficient to reduce egg survival. During this experiment, temperatures declined from about 22 to about 19.5°C which is above the minimum of 15°C suggested by Monro (1969) for successful fumigation with hydrogen phosphide.

The gas concentrations produced by both formulations were too high (100% mortality of all adults on day 1) to permit an assessment of the susceptibility of adults of the two species to hydrogen phosphide and they were sufficiently high at the middle and bottom of the drums to kill all eggs of *C. ferrugineus* when the exposure period exceeded 3 days. However

it was possible, on the basis of egg survival at the top of the drums, to differentiate between the two formulations and show that the pelleted was superior to the bagged powder formulation.

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Thanks are due to S. R. Loschiavo and F. L. Watters for their comments on the manuscript and to D. Kurtz for his technical assistance.

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POPULATION TRENDS OF THE ENGLISH GRAIN APHID, *Macrosiphum avenae* [HOMOPTERA:APHIDIDAE], ON CEREAL CROPS IN MANITOBA, 1971-72

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ABSTRACT: Population trends of the English grain aphid, *Macrosiphum* [*Sitobion*] *avenae* (Fabricius), were studied, in 1971, on oats, *Avena sativa* L., and triticale, X *Triticosecale* Wittmack, and, in 1972, on barley, *Hordeum vulgare* L., in grain fields in Manitoba. Observations were made on increases or decreases in numbers, morphs, predators, parasites, fungus disease, immigration and emigration, of individual colonies on staked plants over several sampling days. In 1971, the aphids were more abundant on triticale than on oats, parasitization increased towards the end of the season, and a small percent mortality was due to fungus disease of the aphids. In 1972, parasites and disease were not important mortality factors. Predation was low in both years. In each year, on at least one occasion, catastrophic losses occurred due to high winds accompanied by heavy rain or hail.

INTRODUCTION

Several species of aphids occur on field crops in Manitoba (Robinson and Hsu, 1963) during July and August of each year, but only rarely in sufficient numbers to require the application of insecticides for control. The greenbug, *Schizaphis graminum* (Rondani), is normally present in very low numbers. The corn leaf aphid, *Rhopalosiphum maidis* (Fitch), is occasionally a serious problem on late-seeded barley. But the English grain aphid, *Macrosiphum* [*Sitobion*] *avenae* (Fabricius), occurs more commonly than the other species, on more kinds of cereal crops, and also may be found on the heads of grain. However, growers observe aphids on the crops, and recognize them as a potential threat not only in direct losses, but also as vectors of barley yellow dwarf virus, and they ask for advice on population levels which require chemical controls. In order to try to find an economic threshold value for the English grain aphid, population studies were begun in 1968, and some observations have been reported (Malyk and Robinson, 1971). Present studies are being made on the progress of individual colonies on the plants, to try to determine what may cause population fluctuations. Further findings on this subject, on work done in 1971-72, are presented in this paper.

MATERIALS AND METHODS

Studies were made in fields at Glenlea Research Station, 12 miles south of Winnipeg, on the English grain aphid. In 1971, the observations were made in fields of Harmon oats, *Avena sativa* L., and Rosner triticale, X *Triticosecale* Wittmack, and, in 1972, in fields of Conquest barley, *Hordeum vulgare* L.

In 1971, 100 tillers of each of oats and triticale were staked. Each staked tiller had at least one aphid on it. Counts on the number of aphids were made approximately every 5 days, rain and muddy soil permitting, and notes were kept on the distribution of the various aphid morphs (apterae, alatae, alatoid and apterous nymphs) and numbers of parasites and predators on the top 4 leaves. When observations began the plants were beginning the flag leaf stage. The same 100 tillers were examined until observations ceased. In addition, on each sampling day, 100 plants of each crop were examined at random, and data were recorded for any aphid colonies found.

In 1972, the sampling procedure was changed, and counts were made at 3-day intervals whenever possible. A colony was defined as all the aphids on one leaf. Fifty plants with one or more aphids on one leaf were selected on 15 July, another 50 plants on 17 July, and 50 more on 27 July, and observations continued on each plant until 16 August at which time very few aphids remained. Detailed information on the position of the aphids on the different leaves and the head, and their movements on or off the plants, most of which is not reported in this paper, may be found in Bakker (1974).

RESULTS AND DISCUSSION

Results from the counts made in 1971 are given in Table 1. Sampling started about mid-July, when there was a sufficient number of plants infested for worthwhile observations. By mid-August, plants were maturing, and aphid numbers were declining due to the

Table 1. Total number of different morphs of the English grain aphid, number parasitized, percent of plants infested, and stage of plant growth on 100 staked plants and 100 plants chosen at random of oats or triticale on different dates in 1971.

Date	Adult apterae	Adult alatae	Nymphs	No. of parasitized mummies	% plants infested	Plant stage
Harmon Oats (staked)						
15 July	114	7	378	0	100	5-leaf
20	71	2	464	0	78	heading
26	24	10	187	0	70	headed
3 August	53	7	231	3	76	headed
9	27	14	157	10	63	headed
Harmon Oats (random)						
15 July	65	21	272	0	28	
20	98	6	455	0	39	
26	71	19	393	2	40	
4 August	124	3	407	23	76	
9	76	11	254	43	74	
Rosner triticale (staked)						
17 July	157	5	848	0	100	headed
22	131	1	1038	1	95	headed
2 August	107	8	502	27	87	headed
8	152	0	384	161	91	headed
13	28	6	87	246	55	headed
Rosner triticale (random)						
17 July	92	14	742	0	7	
22	136	7	700	2	31	
2 August	146	11	946	57	54	
8	248	0	427	214	93	
13	45	5	155	373	64	

ripening of the plants and parasitization. There were about twice as many aphids on triticale as on oats during the sampling period, which may indicate both a preference for and an increased fecundity on triticale compared with oats. Triticale is a new species derived from wheat and rye, and these results show that its relationship to aphids was similar to that shown by wheat. Apablaza and Robinson (1967-1968) showed that the English grain aphid preferred wheat over oats, and caused less damage to oats, presumably because of decreased fecundity. The percentage of plants infested, of those chosen at random, increased as the season progressed, until about 8 August and then declined (Table 1). Staked plants which lost their colonies occasionally became re-infested due to immigration by alate aphids. Exact figures for this may be found in Bakker (1974).

Aphids were much more heavily parasitized on triticale than on oats, mainly by *Aphidius avenaphis* (Fitch). No explanation can be offered at present for this phenomenon. The decline in numbers of live aphids on triticale after 8 August is probably mostly due to parasitization and ripening of the plants (Table 1). The most catastrophic losses on the staked plants were caused by two days of high winds, accompanied by heavy rainfall, on 23-24 July (Table 1). Sampling in the triticale field had to be delayed for 10 days due to muddy soil.

In 1972, observations were made on 3 separate groups of 50 barley plants, each of which contained aphid colonies. Detailed observations were made on the fate of colonies on each leaf sampled. Table 2 gives some of the data for colonies on leaves which were infested on the first sampling day, until the colonies disappeared. On subsequent counts many leaves which had lost their aphid colonies became reinfested once, or even twice, and other leaves became infested for the first time (Table 3). Field infestations were sufficiently high to begin first sampling on 15 July, at which time all plants had already reached the flag-leaf stage.

The number of original colonies of aphids on the leaves declined steadily in all 3 groups as sampling continued (Table 2). This was compensated for by a steadily increasing number of plants becoming reinfested (Table 3). Reinfestation occurred mainly by immigration of alatae from other grains or grasses in the area. For most of the period over which samples were examined, colonies remaining from original infestations always had a much greater number of aphids per colony then did those from reinfestations. Not until 4 or 11 August did the total number of live aphids in reinfestations outnumber those in original infestations. The peak of aphid numbers occurred between 27 and 29 July (Table 2). This may have been because the viviparous parthenogenetic females produced by the first immigrants on the plants had become adult and had begun reproducing. In the third group of 50 plants, on which sampling did not begin until 27 July, the plants chosen at random had populations larger than those of the other two groups where sampling began about 10-12 days earlier, but these populations declined more rapidly after 29 July than on the other two. The decline after 29 July was apparently normal, resulting from combined effects of plant ripening, emigration, parasitization and predation.

In both 1971 and 1972 few predators were observed, and percent aphids parasitized was not as great in 1972 as in 1971. However, after populations had stabilized on about 11 August, catastrophic losses occurred on the night of 12 August when high gusty winds occurred, accompanied by a heavy hailstorm. These losses are reflected in the very low counts on 16 August.

If we compare our present findings for the English grain aphid with those for 1968-69 by Malyk and Robinson (1971) we may conclude: (1) the English grain aphid usually does not become abundant on cereal grains in Manitoba until plants are well advanced in growth, (2) populations decline slowly as plants ripen, (3) the influence of parasites, predators and fungus disease of the aphids varies greatly from year to year, and (4) greatest losses are those caused by high winds along with heavy rain or hail.

Any attempts to establish an economic threshold number must take into account stage of plant growth and possibility of heavy losses from high winds and heavy rains.

Table 2. Population changes in English grain aphids on each of 3 groups of 50 plants of barley, July-August 1972; changes recorded throughout infestation only on leaves that were infested on the first sampling day.

Date	No. of live aphids	Change in numbers from *previous date* gain	loss	net	No. of colonies remaining	No. of live aphids	Change in numbers from *previous date* gain	loss	net	No. of colonies remaining	No. of live aphids	Change in numbers from *previous date* gain	loss	net	No. of colonies remaining
	First 50 plants					Second 50 plants					Third 50 plants				
15	191	-	-	-	55										
17	174	32	49	- 17	43	218	-	-	-	51					
21	110	3	67	- 64	33	188	48	78	- 30	38					
24	70	10	50	- 40	21	167	26	47	- 21	32					
27	105	52	17	+ 35	14	175	55	47	+ 8	28	554	-	-	-	68
29	225	124	4	+120	14	261	117	31	+ 86	22	740	218	32	+186	64
1	173	14	66	- 52	11	203	21	79	- 58	19	574	97	263	-166	54
4	109	0	64	- 64	9	98	0	105	-105	13	344	50	280	-230	48
11	22	5	92	- 87	4	20	1	79	- 78	6	114	17	247	-230	28
16	14	0	8		2	1	0	19	- 19	1	5	0	109	-109	5

Table 3. Population changes in English grain aphids on each of 3 groups of 50 plants of barley, July-August 1972; changes recorded only on leaves which became infested or reinfested after the first sampling date.

Date	No. of live aphids	Change in numbers from *previous date* gain	loss	net	No. of colonies remaining	No. of live aphids	Change in numbers from *previous date* gain	loss	net	No. of colonies remaining	No. of live aphids	Change in numbers from *previous date* gain	loss	net	No. of colonies remaining
	First 50 plants					Second 50 plants					Third 50 plants				
15															
17	13	13	-	+ 13	7										
21	43	36	6	+ 30	20	14	14	-	+ 14	9					
24	65	42	20	+ 22	25	32	26	8	+ 18	16					
27	97	54	22	+ 32	32	70	44	6	+ 38	25					
29	121	53	29	+ 24	40	117	67	20	+ 47	35	61	61	-	+ 61	16
1	127	46	40	+ 6	46	148	67	36	+ 31	37	128	94	27	+ 67	44
4	175	85	37	+ 48	57	157	63	54	+ 9	58	147	78	59	+ 19	57
11	227	144	92	+ 52	70	169	91	79	+ 12	62	171	112	88	+ 24	57
16	62	26	191	-165	40	35	16	150	-134	23	51	21	141	-120	25

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CONTROL OF *TRIBOLIUM CASTANEUM* [HERBST] ADULTS AND *CRYPTOLESTES FERRUGINEUS* [STEPHENS] ADULTS AND EGGS WITH HYDROGEN PHOSPHIDE IN GRAIN AT TEMPERATURES BETWEEN 1 and 11°C.[1]

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ABSTRACT: Wheat at low temperatures was treated with hydrogen phosphide (PH_3) to control adult *Tribolium castaneum* (Herbst) and eggs and adults of *Cryptolestes ferrugineus* (Stephens). At temperatures of 8.5 to 11.3°C, a 100% kill of adult. *T. castaneum* and *C. ferrugineus* was obtained when PH_3 concentrations rose from 0 to more than 100 ppm in one day. There was also 100% kill of adult *C. ferrugineus* when gas concentrations rose from 0 to more than 100 ppm during the course of 2 days. At these temperatures *C. ferrugineus* eggs survived gas concentrations which reached 900 ppm and then declined to 720 ppm during 4 days. The eggs also survived an exposure period of 7 days when gas concentrations reached a maximum of 110 ppm on day 3 and then declined to 50 ppm on day 7.

At temperatures of 1.1 to 7.2°C, a 100% kill of adult *C. ferrugineus* was obtained only after a 4-day exposure to PH_3 though gas concentrations reached 540 ppm on day 4. At these temperatures *C. ferrugineus* eggs survived 7 days at gas concentrations which reached 520 ppm on day 4 and then declined to 400 ppm on day 7.

INTRODUCTION

The rusty grain beetle, *Cryptolestes ferrugineus* (Stephens), is the most important stored-grain pest found in empty granaries in the Prairie Provinces of Canada (Liscombe and Watters, 1962) and ranks third in frequency of occurrence in samples of insects taken during routine ship inspections in Canada (Monro, 1969a). *Tribolium castaneum* (Herbst) was the species found most frequently in ship inspections (Monro, loc. cit.). During the early 1950's, *C. ferrugineus* was found by United Kingdom authorities only in the after holds of ships loaded with Canadian grain which had been warmed by heat from the propeller shaft tunnels (Freeman, 1968).

Adults of *C. ferrugineus* undergo a process of acclimation which enables them to tolerate freezing temperatures for a few months and thus survive the Canadian winter climate (Smith, 1970). Since Canadian grain is often exported during the cold season, the fumigation of cold grain during the winter months may be a prerequisite for shipment of infested grain.

Hydrogen phosphide (PH_3) is one of the most common fumigants used to control insects in grain in the Canadian Prairie Provinces, and its use has been suggested for bulk grain at temperatures as low as 10°C (Monro, 1969b). Burns-Brown (1944) commented that most published toxicity data had been obtained at about 25°C though most commercial fumigations in England were carried out at 10 to 20°C. In Canada, where temperatures are somewhat lower than in England, it is advisable to evaluate the effectiveness of a fumigant at even lower temperatures. An evaluation of the effectiveness of PH_3 for the control of *C. ferrugineus* and *T. castaneum* at 1 to 11°C is presented in this paper.

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[1] Contribution No. 721, Agriculture Canada, Research Station, Winnipeg, Manitoba.

MATERIALS AND METHODS

Twenty adult *C. ferrugineus*, 15 adult *T. castaneum* and 8 g wheat were placed in each of 180 vials which were 7 cm high and 3 cm in diameter, and fitted with snap-on caps. A hole, 1.5 cm in diameter, was drilled in each cap and covered with No. 60 mesh brass screen to allow gas exchange. The vials with the insects were placed in incubators at 30°C and 75% R.H. for 3 days to allow the beetles to lay eggs.

Six vials were attached to each of 30 nylon cords. The vials were spaced along the cords so that when the cords were hung from the rims of steel drums (1.90 m tall and 0.60 m in diameter), the mouths of the vials would be 8, 40, 71, 112, 142, and 175 cm from the rims of the drums.

Five cords with their attached vials were hung from the inside rims of each of 6 drums. Three drums each received 3 aluminium phosphide pellets which generated 0.6 g PH_3 per drum. The drums were then filled to the brim with wheat. Approximately 327 kg (12 bushels) of wheat were used per drum. Lids were then placed loosely on each drum. Three of the drums were not treated and were used as checks. The experiment was arranged as a randomized block with 3 replicates. The adult insect mortality was adjusted according to Abbott's (1925) correction factor. The data for egg survival was reckoned as a percentage of survival in the checks. The aluminium phosphide pellets were produced by Degesch, Frankfurt am Main, West Germany.

One cord with its attached vials was withdrawn from each drum at the ends of days 1, 2, 3, 4, and 7. All adults insects were sifted from the wheat and put in vials of fresh wheat which were then placed in an incubator at 30°C and 75% R.H. Mortality assessments were made after 10 days. The grain from the treated vials, which contained the beetle eggs, was retained and incubated for 30 days at 30°C and 75% R.H. after which it was assessed for adult beetle emergence. It was assumed that the number of adults obtained from the grain was proportional to the number of eggs that survived treatment.

PH_3 concentrations were determined by Drager tubes (Drager-werk-AG-Lubeck, W. Germany) when the nylon cords were drawn from the wheat. Gas samples were taken at the same depths as the vials containing the insects.

There were two experiments, each with a different temperature regime (Figure 1). In experiment A, the adults of *C. ferrugineus* were 7 to 14 days old and those of *T. castaneum* 0 to 7 days old. Temperatures ranged from 8.5 to 11.3°C. In experiment B, the adults of *C. ferrugineus* were 0 to 7 days old. *T. castaneum* was not tested. Temperatures ranged from 1.1 to 7.2°C.

RESULTS AND DISCUSSION

The PH_3 concentrations at the six depths showed that there were differences in the patterns of gas evolution under the two temperature regimes (Figures 1 and 2). When grain temperatures fluctuated between 11.3 and 8.5°C, gas concentrations reached 900 ppm on day 3, and declined to about 200 ppm on day 7 (experiment A). Similar data on the production and subsequent loss of PH_3 from wheat-filled steel drums at about 10°C was previously presented by Barker (1974). Between 1.1 and 7.2°C, gas concentrations reached a maximum of 600 ppm on day 4 and declined to about 400 ppm on day 7 (experiment B).

All *T. castaneum* adults were killed by PH_3 concentrations which rose from 0 to more than 100 ppm during the first day. At concentrations that approached 100 ppm after one day there was some survival (2.4%). There was no survival of *T. castaneum* after 2 days when gas concentrations rose from 0 to 100 ppm during the first 2 days (Figure 2, experiment A).

At 9.8 to 11.2°C, *C. ferrugineus* adults did not survive gas concentrations that reached more than 100 ppm, and 4% survived PH_3 concentrations that approached 100 ppm at the end of 2 days (Figure 2, experiment A). At 1.1 to 4.1°C, *C. ferrugineus* adults survived

(3.97%) gas concentrations which rose from 0 to slightly over 500 ppm during the first 3 days, but none of the insects survived 4 days of exposure to PH_3 even at gas concentrations which did not exceed 75 ppm (Figure 2, Experiment B).

Survival of *C. ferrugineus* eggs was considerably greater than that of adults. At fluctuating temperatures between 1.1 and 7.2°C, 25% egg survival was obtained when gas concentrations reached 600 ppm, and then declined to 400 ppm, even after a 7-day exposure (Figure 3, experiment B). At fluctuating temperatures between 11.3 and 9.1°C, *C. ferrugineus* eggs survived gas concentrations which had risen to 900 ppm on day 3 and then declined to 720 ppm on day 4. There was also a 44% survival of eggs exposed to 110 ppm PH_3 on day 3, which declined to 50 ppm on day 7 (Figure 3, experiment A).

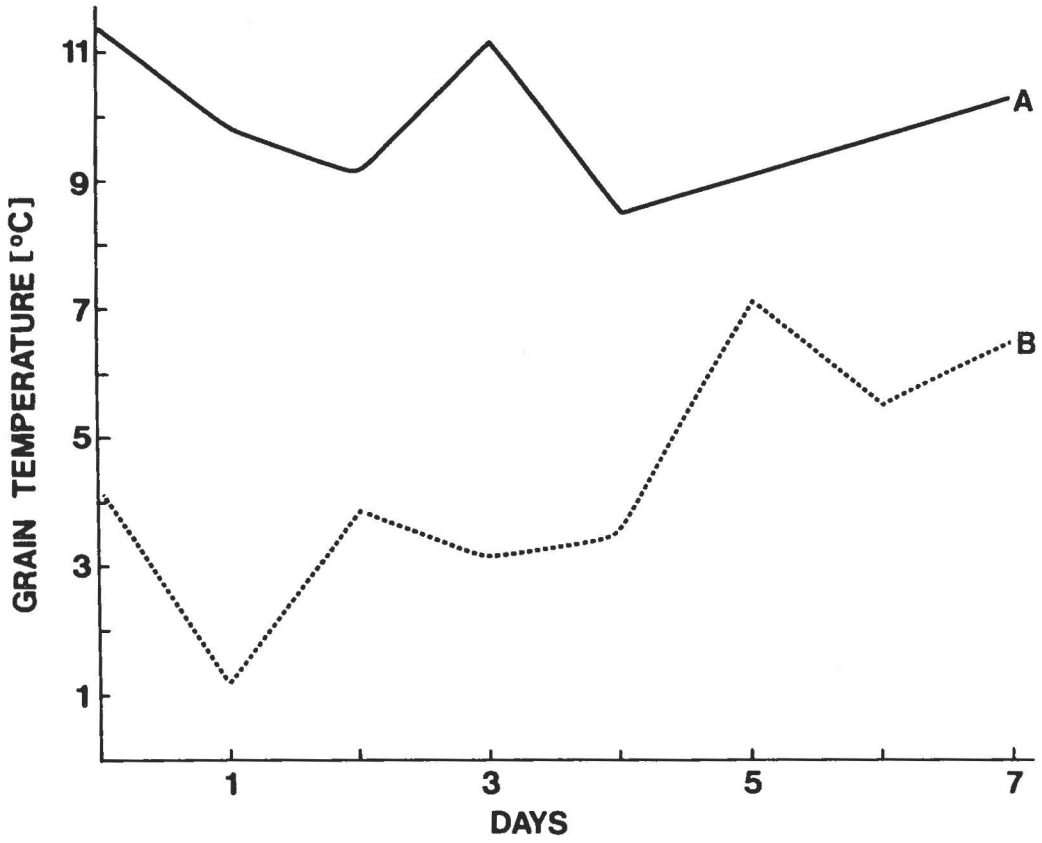

Figure 1. Daily temperatures of grain in experiments A and B.

Smith (1970) showed that *C. ferrugineus* adults could survive 367 days (LT_{50}) at 2°C, or 85 days (LT_{50}) at -6°C, if they had been appropriately acclimatized. Eggs, on the other hand, do not last more than 35 days at temperatures lower than 16°C, regardless of the acclimation regimes (Smith, unpublished).

From the viewpoint of practical control, it is not very important to obtain a high kill of eggs in grain at temperatures lower than 16°C for more than 35 days, because the eggs would not hatch. In situations where the grain could conceivably be warmed soon after treatment, egg survival could become important.

This work shows that insect control by fumigation with hydrogen phosphide is possible at temperatures between 1 and 10°C. The eggs survive the gas under these conditions, but they can be eliminated by exposing them to these same temperatures for over 35 days.

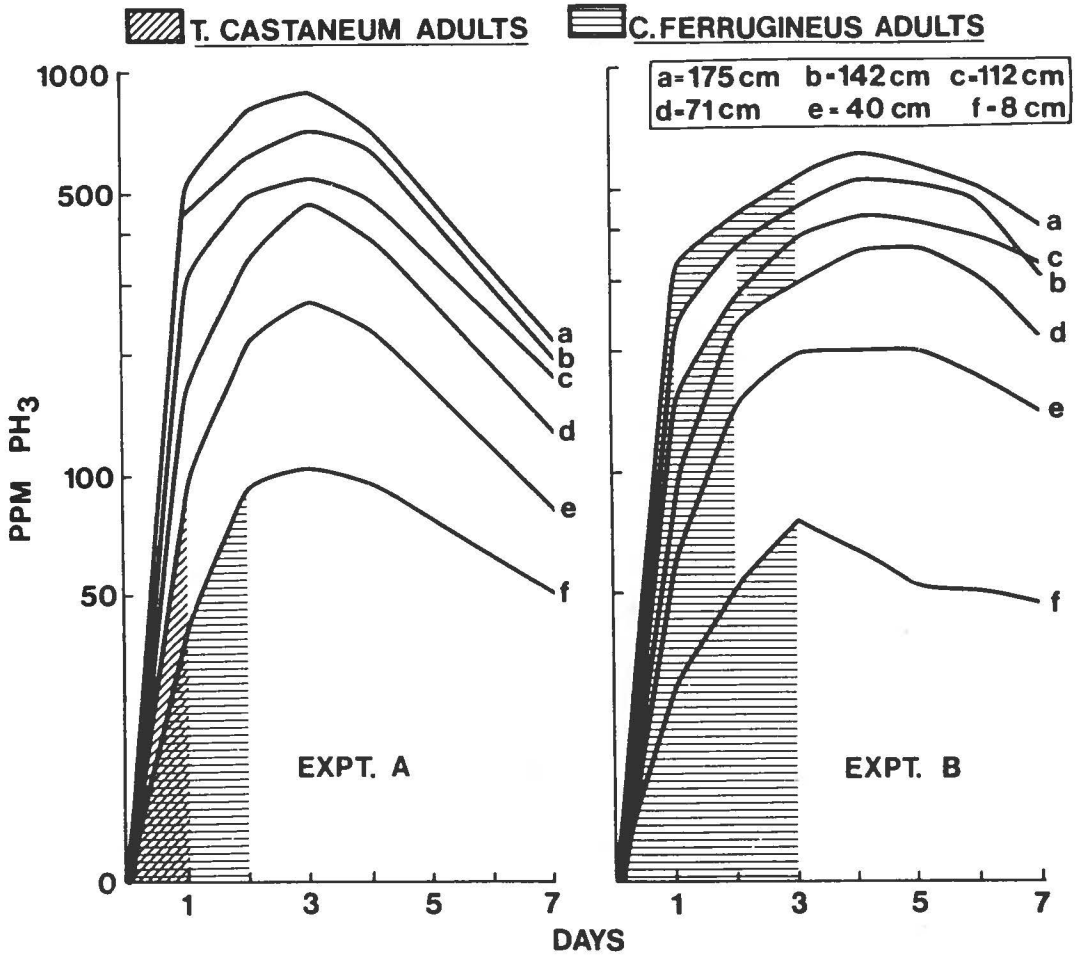

Figure 2. The survival of adults of *T. castaneum* and *C. ferrugineus* (shaded areas) in relation to hydrogen phosphide concentrations (lines) at six depths (8, 40, 71, 112, 142, and 175 cm) in grain in experiments A and B.

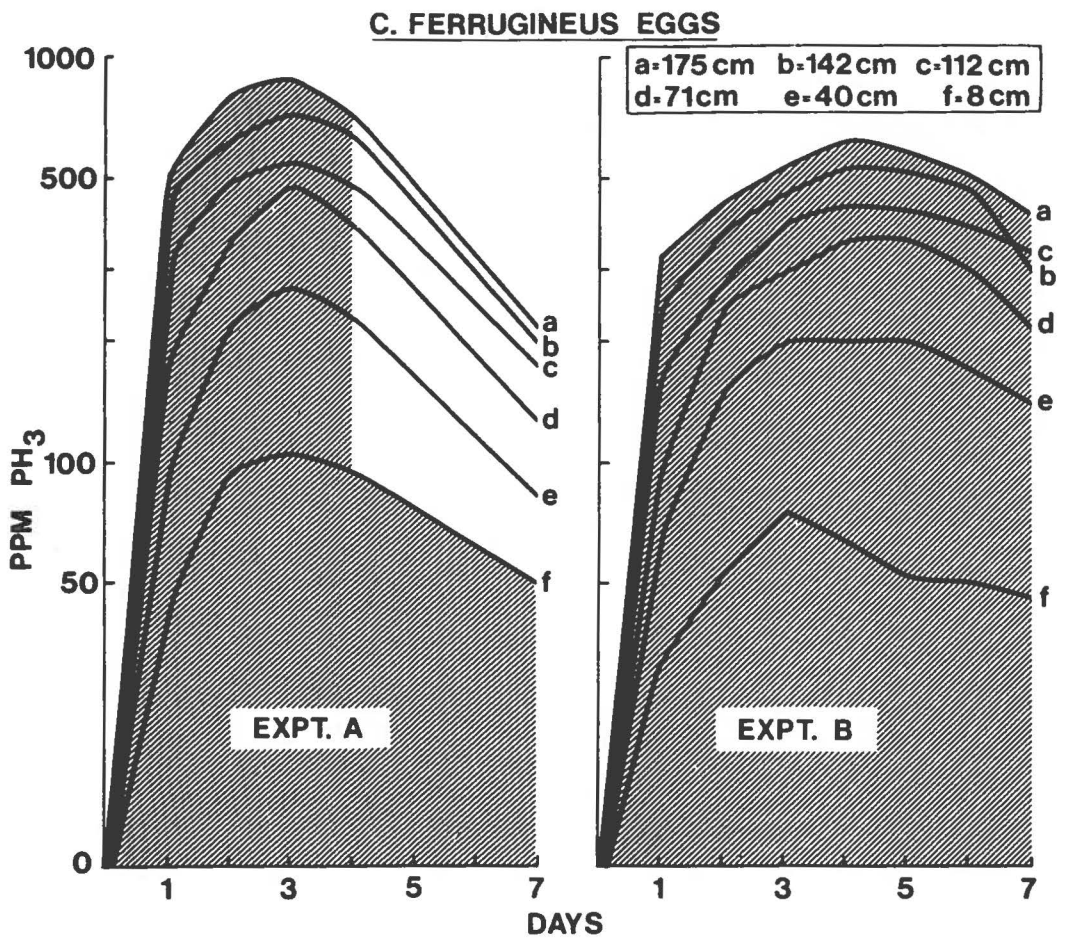

Figure 3. The survival of eggs of *C. ferrugineus* (shaded area) in relation to hydrogen phosphide concentrations (lines) at six depths (8, 40, 71, 112, 142, and 175 cm) in grain in experiments A and B.

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RELATIONSHIP BETWEEN LOCOMOTOR ACTIVITY AND RESPIRATION RATE OF THE RUSTY GRAIN BEETLE, *CRYPTOLESTES FERRUGINEUS* [STEPHENS] AT TEMPERATURES FROM 1 TO 30°C

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ABSTRACT: The quantitative relationship between temperature and locomotion and respiration was studied with the rusty grain beetle, *Cryptolestes ferrugineus* (Stephens). The rates of locomotion and respiration increased as the temperature increased from 1 to 30°C. Respiration and locomotion were shown to be logarithmic functions of temperature over the temperature range studied.

INTRODUCTION

The main factors which influence locomotor activity of grain insects and, consequently, their distribution are temperature, moisture, food supply, and population density. Temperature is the primary factor which affects locomotion. Gunn and Hopf (1942) stated that "temperature has a great effect on the speed of biological processes." Babbitt (1945) and Oxley (1949) found that thermal conductivity of cereal grain was low, and since air temperature changed more rapidly than that of grain, there was a lag between mean daily air temperature and grain temperature. Air temperatures may fluctuate greatly, but temperatures in grain masses change relatively slowly.

In previous work with different species of insects, the rates of locomotion and respiration were found to increase with increasing temperature (Gunn and Hopf, 1942; Perttunen and Paloheimo, 1964; Watters, 1969). Birch (1947) using the Warburg respirometer, and Somme (1968) the Kirk respirometer, obtained similar results.

It is important to know how changes in temperature affect the locomotion of insects that infest stored grain. A laboratory experiment was, therefore, conducted to determine the rates of locomotion (dispersal) and respiration (metabolic activity) of the rusty grain beetle, *Cryptolestes ferrugineus* (Stephens), at five temperatures from 1 to 30°C.

MATERIALS AND METHODS

The test insects were adults of the rusty grain beetle that had been reared at 28 ± 1°C and 65 ± 5% relative humidity. Prior to each test, they were conditioned at the experimental temperatures of 1, 9, 15, 21 and 30°C.

Locomotion

The distance travelled per unit of time by the beetles was measured at each experimental temperature. Because of the possible effect of phototaxis on locomotory activity, observations were made under dim red light. The paths of individual beetles were

[1]Contribution No. 777, Agriculture Canada, Research Station, Winnipeg, Manitoba.

traced on Kraft paper, 66 x 51 cm, for a period of 2 min, or less if the insect left the paper before 2 min elapsed. The paper was equilibrated at the appropriate experimental temperature prior to testing. The paths of 11 to 30 beetles were traced individually at each temperature. The lenght of the lines, representing the distance travelled by each insect, was measured with a map meter and recorded in mm/sec.

Respiration

A Gilson Differential Respirometer was used to measure oxygen consumption. Respiration rate was measured on insects in groups of 100 in tygon-tube cages, 1.5 cm x 0.9 mm, covered at each end with bolting cloth which permitted air movement. For each test, a cage with insects was placed horizontally on the floor of each of 2 respirometer flasks. The flasks were lowered into a water bath, held for 15 minutes before being closed and thereafter for an additional 15 minutes to allow the system to equilibrate. In addition, 2 flasks each containing only 10% KOH, absorbing wicks, and an empty insect cage were used as controls for each test. Oxygen consumption data was recorded hourly for 4 hours, and the insects were then removed and weighed. The oxygen consumption of each temperature was calculated as ul/g/h. Nine to 12 groups of insects were tested at each temperature.

RESULTS AND DISCUSSION

An increase in temperature caused an increase in respiration rate and locomotor activity (Table 1) and within the range of 15 to 30°C these activities were parallel, indicating that both increased at the same rate (Figure 1).

Table 1. The influence of temperature on the rates of respiration and locomotion of *Cryptolestes ferrugineus*.

	Respiration		Locomotion	
Temperature °C	No. of groups tested*	Mean rate of respiration (ul/g/h ± S.E.)	Number of insects tested	Mean rate of locomotion (mm/sec ± S.E.)
1	11	338.53 ± 12.82	25	0.00
9	11	692.20 ± 19.10	25	1.75 ± 0.07
15	10	807.92 ± 15.00	23	3.53 ± 0.13
21	12	1596.35 ± 35.15	11	6.46 ± 0.32
30	9	3462.68 ± 55.00	30	10.48 ± 0.40

*100 insects per group

Regression analysis for respiration ($r = 0.98$) and locomotion ($r = 0.96$) indicated that both were directly related to temperature. Consequently, either respiration rate or rate of locomotion can be used as an indicator of the effect of temperature on the biological activity

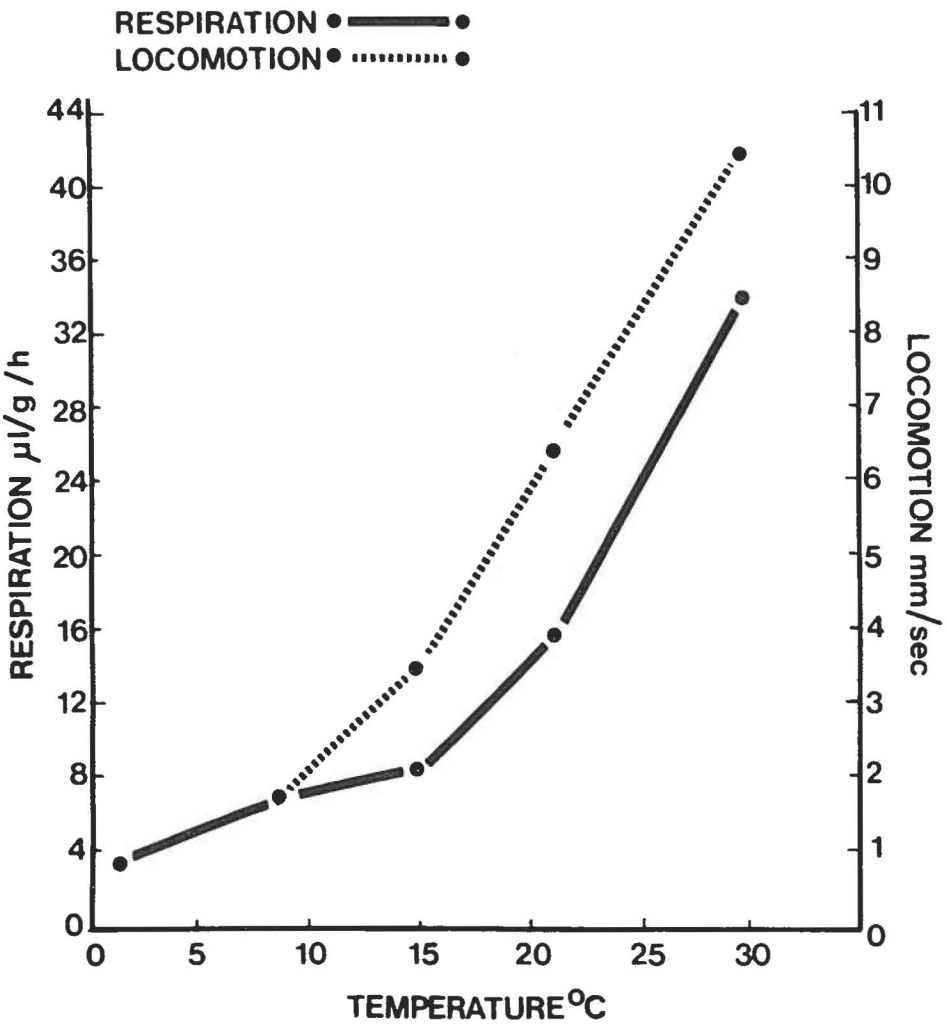

Figure 1. Influence of temperature on the respiration and locomotion rates of *C. ferrugineus*. (Respiration scale, 1/100 of actual).

of this insect. Extrapolation of the linear regression for rate of locomotion (Figure 2) indicates that locomotion ceases between 0 and 5°C, probably near 2°C. The temperature at which respiration ceases could not be predicted.

The locomotion-temperature response is almost a straight line when locomotion is plotted as the logarithm of the distance travelled (Figure 2). These results agree with those of Mellanby (1939) for the bed bug, *Cimex lectularius* L.; above the chill-coma temperature, healthy bugs moved at approximately the same speed, and within limits, the higher the temperature the higher the speed. Henson (1964) studying *Conophthorus coniperdus* (Schwarz), and Perttunen and Paloheimo (1964), studying *Tenebrio molitor* L., found a middle temperature range in which the speed of movement did not change. In *C.* coniperdus this middle range was between 20 and 25°C, and in *T. molitor* between 20 and 30°C.

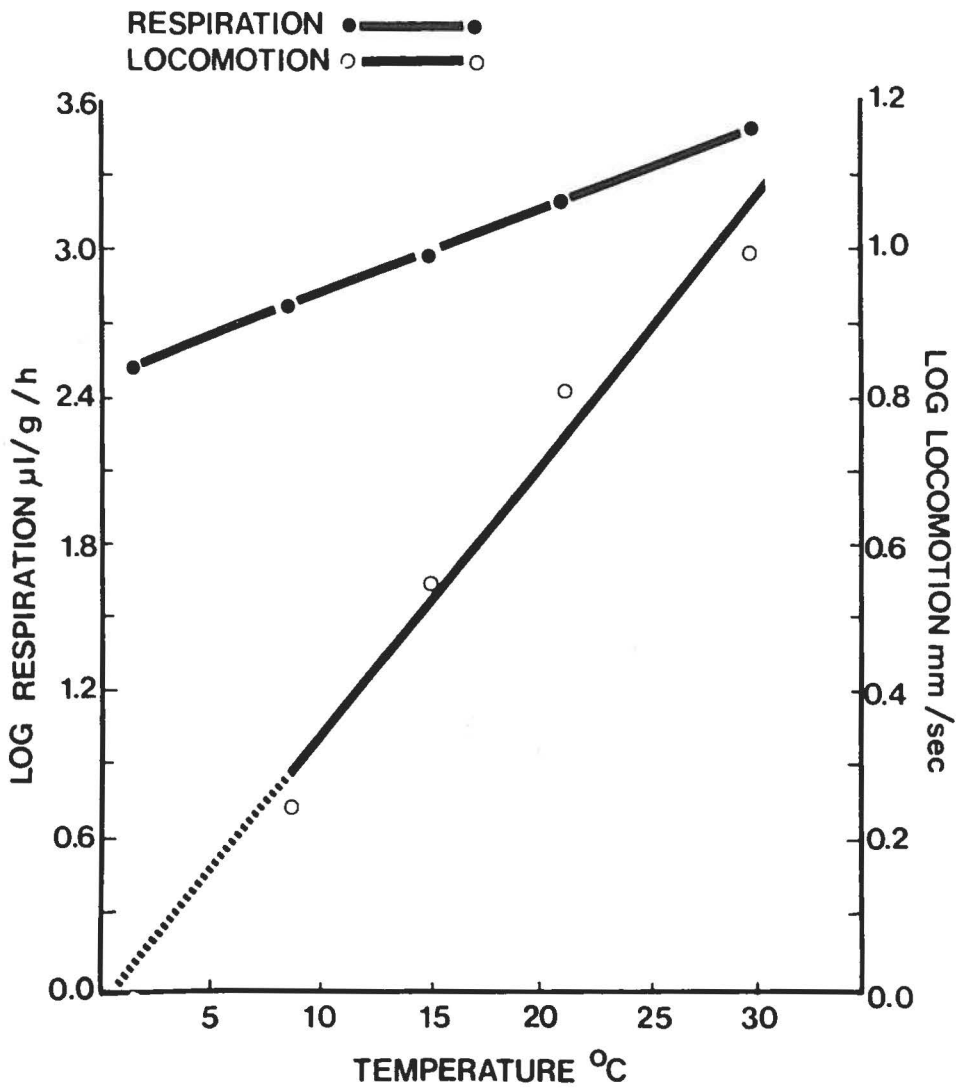

Figure 2. Relationship between respiration, locomotion and temperature for *C. ferrugineus*. (Log. respiration = 2.4866 0.0339 T; Log. locomotion = 0.0369 T — 0.0361).

The distance travelled by the rusty grain beetle decreased progressively as temperature decreased from 30 to 9°C (Figure 3). No movement was observed at 0°C.

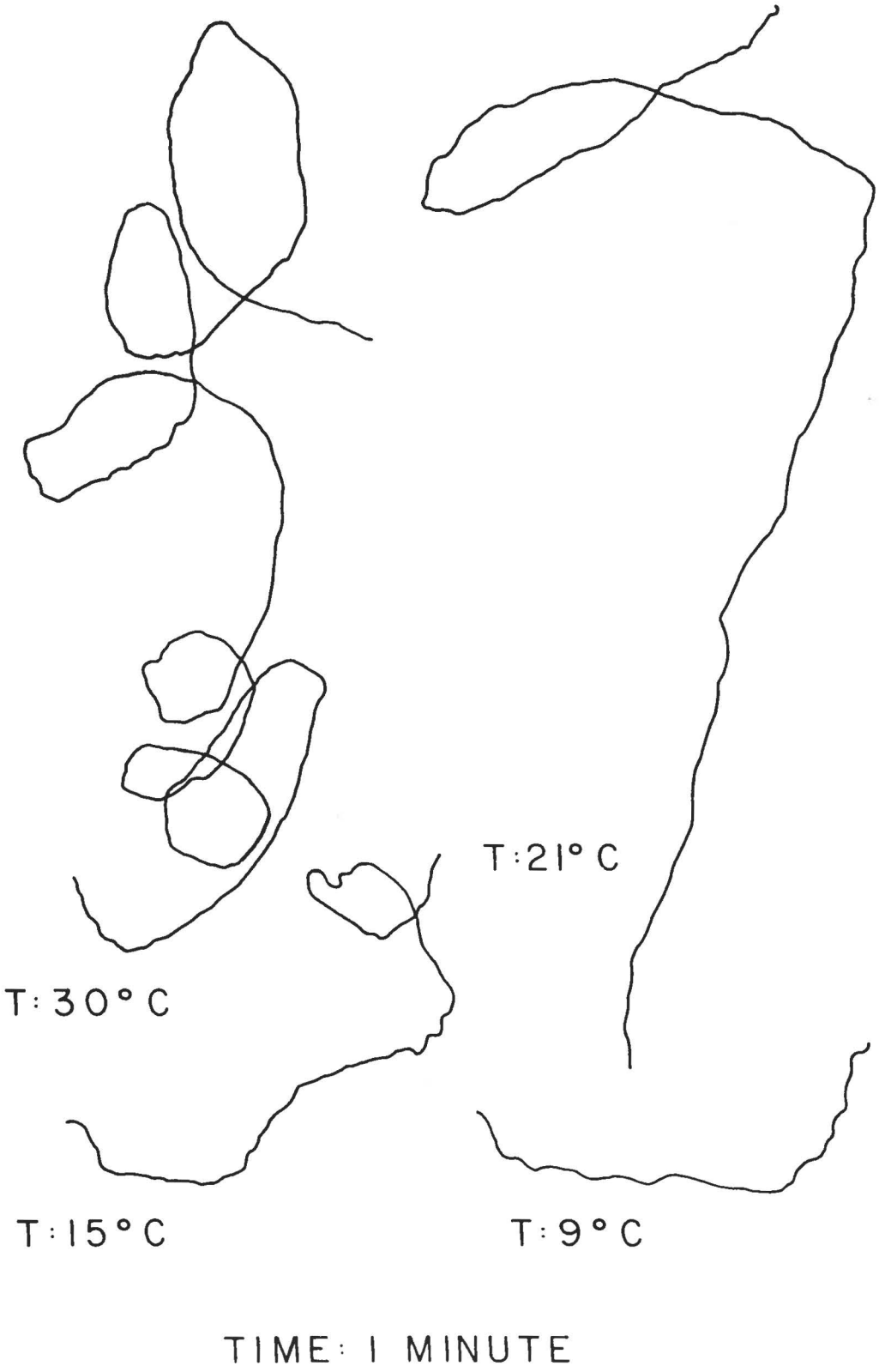

Figure 3. Paths travelled by *C. ferrugineus* in a one minute period at various temperatures.

CONCLUSIONS

Most experiments concerning locomotion have been conducted to determine theoretical relationships between insect activity and environmental stimuli. This experiment, demonstrating that locomotor activity of the rusty grain beetle increases with rising temperature, has practical implications. Since the reliability of insect-detection devices in stored grain depends on insect locomotion, more rusty grain beetles should be trapped at 30°C than at lower temperatures. The results of this study suggest that near 2°C the beetles do not move and, therefore, would not be detected. It would be useful to conduct an experiment to test the sensitivity of insect-detection devices in grain at different temperatures.

ACKNOWLEDGEMENTS

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THE SUSCEPTIBILITY OF FABABEANS TO INSECT PESTS IN MANITOBA IN 1973 AND 1974

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ABSTRACT: During 1973 and 1974, fields of fababeans, *Vicia faba* L., in various areas of Manitoba were surveyed for actual or potentially injurious insect pests. Three species of blister beetles were found; namely, the Nuttall blister beetle, *Lytta nuttalli* Say, the black blister beetle, *Epicauta pennsylvanica* (DeGeer), and the ash-grey blister beetle, *Macrobasis unicolor* (Kirby). These beetles were transitory, spending one or two days in a field, and therefore control measures were not necessary. The pea aphid, *Acyrthosiphon pisum* (Harris), and cutworms infested several fields in 1974, but the crops were so late that control was not warranted.

INTRODUCTION

Fababeans, *Vicia faba* L., are relatively new as a crop in Manitoba. They were grown on a commercial scale in the province in 1972, and in 1973 about 15,000 acres were grown. In 1974, the acreage was approximately 3,000 acres, probably due to unfavorable weather during the planting period.

Workers in several provinces observed only negligible insect damage to fababeans during 1973 and 1974 (personal communications). D. J. Hough, in Nova Scotia, reported some damage to fababeans by the black bean aphid, *Aphis fabae* Scopoli, during 1973. He found blister beetles, leaf miners and marsh caterpillars on beans but the damage was insufficient to warrant control. E. W. Hicks indicated that, during 1974, there were no insect problems on fababeans in Ontario. M. E. Taylor reported some damage by blister beetles to experimental plots in Saskatchewan in 1973, but no problems arose with cutworms, wireworms, grasshoppers or aphids. M. G. Dolinski reported that, in 1973, about 50 acres of beans in Alberta were sprayed to control blister beetles, grasshoppers, aphids and cutworms in some fields, but damage was insignificant.

METHODS

In Manitoba, during 1973 and 1974, fields of fababeans in various regions of the province were surveyed for insect damage. Only those regions where insect damage occurred are reported. Leaf-feeding insects were collected with an insect net from 200 plants. Cutworm larvae were collected by digging around the roots of the same number of plants. The cutworm larvae were reared to adults in the laboratory on an artificial diet. Parasites that emerged during cutworm rearing were collected and identified.

RESULTS AND DISCUSSION

Blister Beetles

The number of blister beetles captured on 200 fababean plants during 1973 and 1974 in various locations in Manitoba is shown in Table 1.

Three species of blister beetles were collected; the Nuttall blister beetle, *Lytta nuttalli* Say, the black blister beetle, *Epicauta pennsylvanica* (DeGeer), and the ash-grey blister beetle, *Macrobasis unicolor* (Kirby). Fifty-five percent of the beetles found on the plants were Nuttall blister beetles, 35% were black blister beetles and the remainder were ash-grey

Table 1. Number of blister beetles captured on 200 fababean plants at various locations in Manitoba in 1973 and 1974

Year	Date	Location	Number of beetles
1973	July 2	Portage la Prairie	20
	3	Carman	2
	4	Stonewall	3
	7	Fort Whyte	4
	9	St. Norbert	3
			32
1974	July 3	Manitou	1
	4	Cypress River	2
	8	Elgin	14
	11	Glenlea	47
	11	St. Norbert	4
	14	Glenlea	14
	17	Swan River	1
			83

blister beetles. The beetles were always found at the periphery of the fields of beans. The damage was insignificant and did not warrant control measures.

Cutworms

Cutworms were found only in 4 fields in 1973. During 1974, the infestations were light, except at Glenlea in July (Table 2).

Many of the cutworm larvae were parasitized (Table 3). The most common parasite was *Meteorus leviventris* (Wesmeal). It is difficult to evaluate the role of parasites in controlling the population of cutworms because cutworms killed by parasites in the field were difficult to find. The live, parasite-infested cutworms brought into the laboratory suffered high mortality which could have been caused by parasites or by an inadequate diet. Diet was probably the more important factor because even in non-parasitized and apparently healthy larvae only about 20% emerged as adults.

Aphids

Aphids were not a problem on fababeans during 1973. In 1974, two fields were heavily infested by the pea aphid, *Acyrthosiphon pisum* (Harris). In the middle of August a field near Homewood had approximately 100 aphids per plant on the basis of a 200 plant sample. Another field, approximately 80 acres near Darlingford, was destroyed by aphids. The count of aphids in this field on 18 August 1974, averaged 2,200 aphids per plant on a 200 plant sample. Feeding by aphids caused the leaves to turn black and the plants withered and died. Growers may need to use insecticides to control the pea aphid if damage of this severity continues in future years.

Table 2. Number of cutworm larvae found near 200 fababean plants at different locations in Manitoba during 1973 and 1974

Year	Date	Location	Number of larvae
1973	May 31	St. Norbert	7
	June 8	Portage la Prairie	9
	9	Fort Whyte	8
	22[1]	St. Norbert	6
			30
1974[2]	June 28	Glenlea	1
	July 3	Carman	2
	3	Manitou	1
	3	Jordan	1
	4	Cypress River	2
	4	Darlingford	1
	8	Deloraine	0
	15	Glenlea	117
	Aug. 6-8	Dauphin, Swan River, Brandon, Neepawa, Treherne, Morden	0
			125

[1]On this date larvae had ceased to feed and were pupating. Pupae were difficult to find, especially in the heavy soils in the Red River Valley. A. Kolach (personal communication), reported the same problem in finding Bertha armyworm pupae even in known infested fields.

[2]In 1974, seeding was late, i.e. on 28 June the plants were only one to two inches high. Most of the fields that were surveyed did not mature and the plants either froze or were plowed before maturity.

Table 3. Parasites reared from cutworm larvae

Order	Species
Hymenoptera [1]	*Phobocampe flavipes* (Prov.)
	Gelis apantelis Cush.
	Meteorus leviventris (Wesmeal)
Diptera	*Poecilanthrax alcyon* (Say)
	Villa alternata alternata (Say)

[1]Identification by Biosystematics Research Institute, Ottawa.

CONCLUSIONS

The potential insect pests of fababeans in Manitoba are blister beetles, cutworms and aphids. The damage caused by these insects during 1973 and 1974 was sporadic and control was not warranted. If fababeans become an important special crop in Manitoba, these insects, especially aphids, could pose a problem.

ACKNOWLEDGEMENTS

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THE RESPONSES OF EIGHT STRAINS OF *TRIBOLIUM CASTANEUM* [HERBST] TO HYDROGEN PHOSPHIDE.[1]

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ABSTRACT: Tolerance of adults of 8 strains of *Tribolium castaneum* (Herbst) to hydrogen phosphide was measured. The LD_{50}'s of the 8 strains varied between 0.0356 and 0.0433 mg PH_3/1. A maximum potency ratio of 1.2 (at the LD_{50}) showed that none of the strains examined was unusually resistant to PH3.

INTRODUCTION

The concentrations of hydrogen phosphide (PH_3) required to kill 50% of populations of various species of insects that infest stored foods have been obtained by Lindgren and Vincent 1966, Barker (1969) and Anonymous (1975).

Lindgren and Vincent (1966) found that the LD_{50} of *Tribolium confusum* du Val was 0.01 mg PH_3/1 during a 24 hour exposure (Concentration X Time product = 0.24 mg h/1). The CXT product of 9 other species tested by these authors varied from 0.1 to 0.24 mg h/1 at 26°C. Barker (1969) obtained similar results for *Cryptolestes turcicus* (Grouvelle) which had an LD_{50} ranging from 0.03 to 0.035 mg PH_3/1 for an exposure of 5 h at 24°C (CXT = 0.15 to 0.175 mg h/1) for groups of adults whose ages ranged from 11 to 22 days. He also showed that the LD_{50} of groups of *C. ferrugineus* (Stephens) of 10 to 23 days of age varied from 0.046 to 0.058 mg PH_3/1 (CXT = 0.23 to 0.29 mg h/1). Anonymous (1975) mentioned that the LD_{50} of *T. castaneum* (Herbst) was 0.009 mg PH_3/1 for a 20 h exposure (CXT = 0.18 mg h/1).

The experiments in this study were performed to evaluate the relative susceptibility of eight strains of *T. castaneum* to hydrogen phosphide.

MATERIALS AND METHODS

The sources of the 8 strains of *T. castaneum* were as follows: the strain labelled Agriculture Canada (Table 1) has been maintained at this laboratory for many years; the strains labelled Letellier, Starbuck 1 and 2, and Lethbridge were from elevators in the respective towns in the provinces of Manitoba and Alberta, and the Montreal strain came from a flour mill in Montreal, Quebec. The exact sources of the two Texas strains are unknown.

The insects were reared on flour fortified with 5% (by volume) brewer's yeast in gallon Mason jars (3.8 1) covered with filter paper sealed with parafin wax of a low melting point. The cultures were kept at 30°C and about 75% R. H.

The cultures were sieved at regular intervals to obtain 9 to 16 day old adults; batches of 10 beetles were placed in open vials 7 cm high and 2.9 cm in diameter. These were fumigated in 6.1 liter desiccators. The desiccators had perforated lids plugged with rubber stoppers. The rubber stoppers were perforated and fitted with glass tubes 1 cm in diameter which were sealed with rubber serum vial stoppers. The eight strains of *T. castaneum* were tested at one time and each strain was replicated 3 times so that each desiccator contained 24 vials. This system was similar to the one suggested by Anonymous (1975).

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[1]Contribution No. 686 Agriculture Canada, Research Station, Winnipeg, Manitoba.

Hydrogen phosphide was generated in a 500-ml burette fitted with a 1-holed rubber stopper fitted with a short (5-cm long, 1-cm diameter) glass tube sealed with a rubber serum vial stopper. The burette was filled with a 10% solution of sulphuric acid; 3 aluminium phosphide pellets, each providing 0.2 g PH_3, were then dropped into the burette which was then sealed with the rubber stopper. As the hydrogen phosphide was generated, the acid solution was pushed through the open stopcock of the burette, through a rubber hose and into a large glass bulb. About 520 ml of gas was generated; the exact volume depending on the barometric pressure at the time each experiment was performed. Aliquots (0.14 to 0.28 ml) of the gas generated were drawn from the burette by means of a gastight microsyringe and transferred to the desiccators. Eight concentrations of hydrogen phosphide and an untreated check were used. The fumigation period was 5 h. The entire experiment was repeated twice at 22°C.

The data obtained were examined by the minimum logit chi-square method which offers the advantage that iteration is not necessary and that the logistic estimates obtained are "sufficient statistics" (Ashton 1972; Howe 1974). The logits were modified according to Anscombe (1956) as follows:

$$\text{logit} = \ln \frac{(p + 0.5)}{(100 - p + 0.5)}$$

in which p is percent mortality.

In the regression equation $Y = A + BX$, the logit-mortality was Y and the Log_{10} dosage was X.

RESULTS AND DISCUSSION

The median lethal dosage (LD_{50}) of the 8 strains of *T. castaneum* ranged from 0.0356 to 0.0433 mg PH_3/1 for a 5— hour exposure (Table 1). The CXT product ranged from 0.18 to 0.216 mg PH_3 h/1. The lowest and highest LD_{50} were obtained for the Texas 14 and Lethbridge 53 strains, respectively. The Lethbridge strain was about 1.17 times more tolerant than the Texas 14 strain at the LD_{50} level. This range of concentrations was similar to that found by Barker (1969) for 11 to 22 day old adults of the Winnipeg strain of *C. turcicus* (Grouvelle). Howe (1973), however, showed that the CXT product concept had to be modified when PH_3 was the toxicant used, because mortality was influenced more by duration of exposure than by concentration of the gas, and he suggested that for constant gas concentrations a log-CXT probit-mortality regression could be used (except at the highest mortalities) to describe this relationship.

The LD_{95} showed a greater range of variability than the LD_{50} and ranged from a minimum of 0.0554 (Starbuck 1) to a maximum of 0.0737 mg PH_3/1 (Texas 11).

Anonymous (1975) mentions that a normal LD_{50} for *T. castaneum* is 0.009 mg PH_3/1 for a 20-hour exposure which is equivalent to a CXT of 0.18 mg PH_3 h/1, identical to the CXT obtained for the Texas 14 strain (untransformed data). Bond and Upitis (1973) considered that 0.05 mg PH_3/1 for a 5-hour exposure was a sublethal dosage for the *T. castaneum* strain which they used; their CXT product was considerably higher than the ones used in these experiments and may reflect a higher level of tolerance to PH_3 in the strain which they used.

The chi-square values showed some variability and were high for the Montreal 135 and Texas 14 strains in both experiments, though none were significant at the 5% level, and all lines showed a good fit.

The slopes of the lines were compared and all lines were found to be parallel in experiment 1. In experiment 2, the slope of Texas 11 was not parallel to the slopes of Agriculture Canada and Montreal 135; Starbuck 1 was not parallel to Montreal 135 at the 5% level.

Table 1. Some parameters of the responses of 8 strains of *Tribolium castaneum* to hydrogen phosphide.

Strain	Expt. No.	Intercept A	Slope B	LD_{50} mg/litre	LD 95 mg/litre	Chi-Square	Standard error Log_{10} - LD_{50}
Agric. Can.	1	18.3563	12.8663	0.0374	0.0634	9.3643	0.008923
	2	24.1692	17.1652	0.0390	0.0581	2.7180	0.006799
Letellier 154	1	19.2661	13.4234	0.0367	0.0608	3.4653	0.005404
	2	20.1515	14.0772	0.0370	0.0599	1.4004	0.007980
Lethbridge 53	1	22.4831	16.1597	0.0406	0.0617	2.5534	0.007418
	2	20.0289	14.6884	0.0433	0.0686	4.7523	0.007786
Montreal 135	1	20.7583	14.7699	0.0393	0.0622	9.3884	0.007998
	2	25.2756	18.4976	0.0430	0.0620	9.4845	0.006501
Starbuck 1	1	26.5573	18.7991	0.0386	0.0554	6.5041	0.006686
	2	19.1138	13.4495	0.0379	0.0627	5.0011	0.008300
Starbuck 2	1	14.8553	10.3060	0.0361	0.0698	1.0745	0.010424
	2	20.4922	14.3763	0.0375	0.0602	4.6562	0.010220
Texas 11	1	15.1942	10.8198	0.0394	0.0737	3.3252	0.010204
	2	16.9298	11.9902	0.0387	0.0681	3.0829	0.008796
Texas 14	1	21.8907	15.1268	0.0356	0.0558	8.4101	0.008133
	2	18.6026	13.0135	0.0372	0.0626	7.0953	0.008658

A maximum potency ratio (major LD_{50}/minor LD_{50}) of 1.2 was found between Texas 14 (expt. 1) and Lethbridge 53 (expt. 2), at the LD_{50}. The potency ratios between other pairs of strains were close to unity indicating that there was no real tolerance to PH_3 in any of the strains tested.

The data presented show that concentrations of 0.0361 to 0.0433 mg PH_3/1 during exposure periods of 5 h are sufficient to kill 50% of adult *T. castaneum* of the 8 strains tested. The low potency ratio of 1.2 showed that none of the strains were uunusually resistant to PH_3.

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TESTS OF FOUR SYNTHETIC INSECT GROWTH REGULATORS WITH JUVENILE HORMONE ACTIVITY AGAINST SEVEN SPECIES OF STORED PRODUCTS INSECTS[1]

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ABSTRACT: Four insect growth regulators (IGRs), methoprene, hydroprene, triprene and kinoprene in hexane solution were added to insect diets at 1, 5 and 10 ppm, and their effects observed in 7 species of stored products insects. Larval survival of the confused flour beetle, *Tribolium confusum* Jacquelin duVal, declined with increasing concentration of hydroprene. No live, normal adults emerged from diets with 5 and 10 ppm of hydroprene. Most of the pupae died during metamorphosis to the adult stage, and all showed morphogenetic malformations. Developmental time for larvae of the confused flour beetle was 5 days longer, and for the red flour beetle, *T. castaneum* (Herbst), up to 6.5 days longer on food treated with hydroprene and methoprene at 10 ppm than on untreated food. This species also showed morphogenetic malformations. Triprene and kinoprene had no effect on larval survival or development in either species. Adult emergence in the merchant grain beetle, *Oryzaephilus mercator* Fauvel, and the sawtoothed grain beetle, *O. surinamensis* (L.) was totally suppressed with hydroprene treatments. At 5 and 10 ppm of either compound most of the adults died at emergence and were malformed. Those that emerged as normal adults at 1 and 5 ppm produced normal-appearing F_1 progeny. Progeny production by the granary weevil, *Sitophilus granarius* (L.), was totally, or almost totally, suppressed on wheat treated with methoprene and hydroprene in emulsifiable concentrate formulation (EC), and by triprene, but that of the rice weevil, *S. oryzae* (L.) was unaffected by anyconcentration of the compounds. The Indian meal moth, *Plodia interpunctella* (Hübner), produced no progeny on diets treated with hydroprene (tech and EC) at any of the concentrations, with methoprene (EC) or triprene at 5 and 10 ppm, with methoprene (tech) at 10 ppm, or with kinoprene at 10 ppm.

INTRODUCTION

Because traditional methods of chemical control pose problems associated with environmental hazards or resistance, alternate methods of effective insect pest management should be explored. One such alternative is the use of potent insect growth regulators (IGRs) which disrupt normal function in several species of insects (Henrick *et al.*, 1973). The IGRs are reportedly non-toxic to warm-blooded animals (Antognini, 1972). Sláma (1971) states that chemists can prepare compounds with juvenile hormone activity that produce harmless non-toxic degradation products. He reports that juvenile hormone analogues are selective against specific insect pests and are effective in minute amounts. Unlike insecticides which cause immediate destruction, they cause developmental disturbances and prevent reproduction. These desirable properties suggest that compounds with juvenile hormone activity are potentially useful in the control of insect pests of stored cereal products (Thomas and Bhatnagar-Thomas, 1968; Bhatnagar-Thomas, 1973; Strong and Diekman, 1973). The aim of this study was to assess the effectiveness of 4 IGRs with juvenile hormone activity against 7 species of economically important stored products insects.

[1]Contribution No. 702, Agriculture Canada, Research Station, Winnipeg, Manitoba.

MATERIALS AND METHODS

IGRs received from Zoecon Corporation, California, were as follows:

Common name	Chemical name	Trade name	Code no.	Formulation
methoprene	Isopropyl 11-methoxy-3, 7,11-trimethyldodeca-2, 4-dienoate	Altosid R	ZR-515	tech (62.1% AI) EC(52.7% AI)
hydroprene	Ethyl 3, 7, 11 - trimethyldodeca-2, 4-dienoate	Altozar R	ZR-512	tech (73.3% AI) EC (66.7% AI)
triprene	Ethyl 11-methoxy-3, 7, 11-trimethyldodeca-2, 4-dienethiolate	———	ZR-619	tech (90.3% AI)
kinoprene	Prop-2-ynyl 3, 7, 11-trimethyldodeca - 2, 4-dienoate	Enstar TM	ZR-777	tech (92.8% AI)

They were labelled by code number when received, but further references in the text will be by their common names because the use of trade names or other descriptions do not designate the chemical, but rather a formulation marketed for a specific purpose.

The compounds were prepared in hexane and applied to wheat at concentrations of 1, 5, and 10 parts of formulation per million parts of wheat (ppm). The mixture was placed in a rotating flask evaporator at 40°C to remove the hexane. Preliminary tests with a dye indicator showed that this method of mixing improved the distribution of the compounds in the food. Wheat tended to slide rather than tumble in the rotating flask and this problem was overcome by a baffle formed by indenting the flask.

The species of insects tested were the confused flour beetle, *Tribolium confusum* Jacquelin duVal; red flour beetle, *T. castaneum* (Herbst); merchant grain beetle, *Oryzaephilus mercator* Fauvel; sawtoothed grain beetle, *O. surinamensis* (L.); granary weevil, *Sitophilus granarius* (L.); rice weevil, *O. oryzae* (L.); and Indian meal moth, *Plodia interpunctella* (Hübner). One hundred newly emerged first instar larvae of the flour beetle, grain beetle, and meal moth species were separated from cultures by sieving and gentle aspiration, and placed into 450-ml glass jars containing 50 g of food medium.

The food media were: 95% unenriched flour and 5% brewers' yeast by weight for flour beetles; 95% whole wheat flour and 5% brewers' yeast by weight for moths; rolled oats (ground and whole), cornmeal, or 95% whole wheat flour and 5% brewers' yeast by weight for the grain beetle species; and whole wheat for the weevil species. The foods used as controls were untreated, or treated with hexane.

The jars were kept at 30 ± 1°C and 63 ± 3% RH. Flour beetles were examined daily after the 15th day. Pupae were removed each day. Grain beetles were examined daily after the 14th day. Adults were removed as they emerged. The criteria used for IGR effectiveness were: for the flour beetle species, larval and pupal survival and development time, adult emergence, and the incidence of morphogenetic effects; for the grain beetle species, larval survival, and duration of the developmental period from hatching to adult emergence; for the weevils and Indian meal moth, adult emergence.

Larval and pupal development could not be observed in the weevil species which develop inside the grain kernel. One hundred adults of each species were placed in each

100-g sample of treated or untreated wheat of 15% moisture content for 7 days and then removed by sifting. Adult progeny were counted and removed 5, 7 and 8 weeks later. Up to 20 of the F_1 adults from treated wheat were placed in untreated wheat for 7 days to determine whether their fecundity or fertility was impaired.

RESULTS

Flour Beetles

Survival of larvae of the confused flour beetle declined with increasing concentration of methoprene and hydroprene in both formulations (Table 1). Hydroprene was more effective then methoprene, particularly at 5 and 10 ppm.

Table 1. Percentage of normal and malformed adults, dead and alive, and dead papae of the confushed flour beetle taken from food, treated with four IGRs at 3 concentrations, in which 100 newly emerged larvae were reared.

Treatment	Concentration No. (ppm)	No. pupating	% emerging as adults				% dead pupae
			Normal		Malformed		
			Live	Dead	Live	Dead	
Control[a]		95	98	2	0	0	0
Control + hexane		96	97	3	0	0	0
Methoprene (tech)	1	94	55	26	0	18	1
	5	85	3	7	0	89	0
	10	70	0	1	1	97	0
Methoprene (EC)	1	91	55	27	1	16	0
	5	96	4	4	2	90	0
	10	74	0	5	0	93	1
Hydroprene (tech)	1	98	35	10	2	46	7
	5	62	0	5	0	95	0
	10	30	0	0	0	93	7
Hydroprene(EC)	1	96	47	20	0	25	8
	5	52	0	0	0	96	4
	10	23	0	4	0	87	9

[a]95% unenriched flour + 5% brewers' yeast (w/w).

Of those that pupated, none emerged as normal live adults from diets containing 5 or 10 ppm of hydroprene (tech or EC), or 10 ppm of methoprene (tech or EC). Most of the insects exposed to the 5 and 10 ppm concentrations died as pupae or while trying to emerge as adults. All were abnormal in appearance (Fig. 1).

In a separate experiment to determine survival to the pupal stage of flour beetles, that of the confused flour beetle at 1 and 10 ppm, respectively, was 94 and 80% in food treated with methoprene, 94 and 35% with hydroprene, 95 and 93% with triprene, and 96 and 100% with kinoprene. Larval development time (days ± S.E.) was 19.3 ± 0.1 days in untreated food. In methoprene-treated food it increased from 20.6 ± 0.2 days at 1 ppm to 25.4 days at

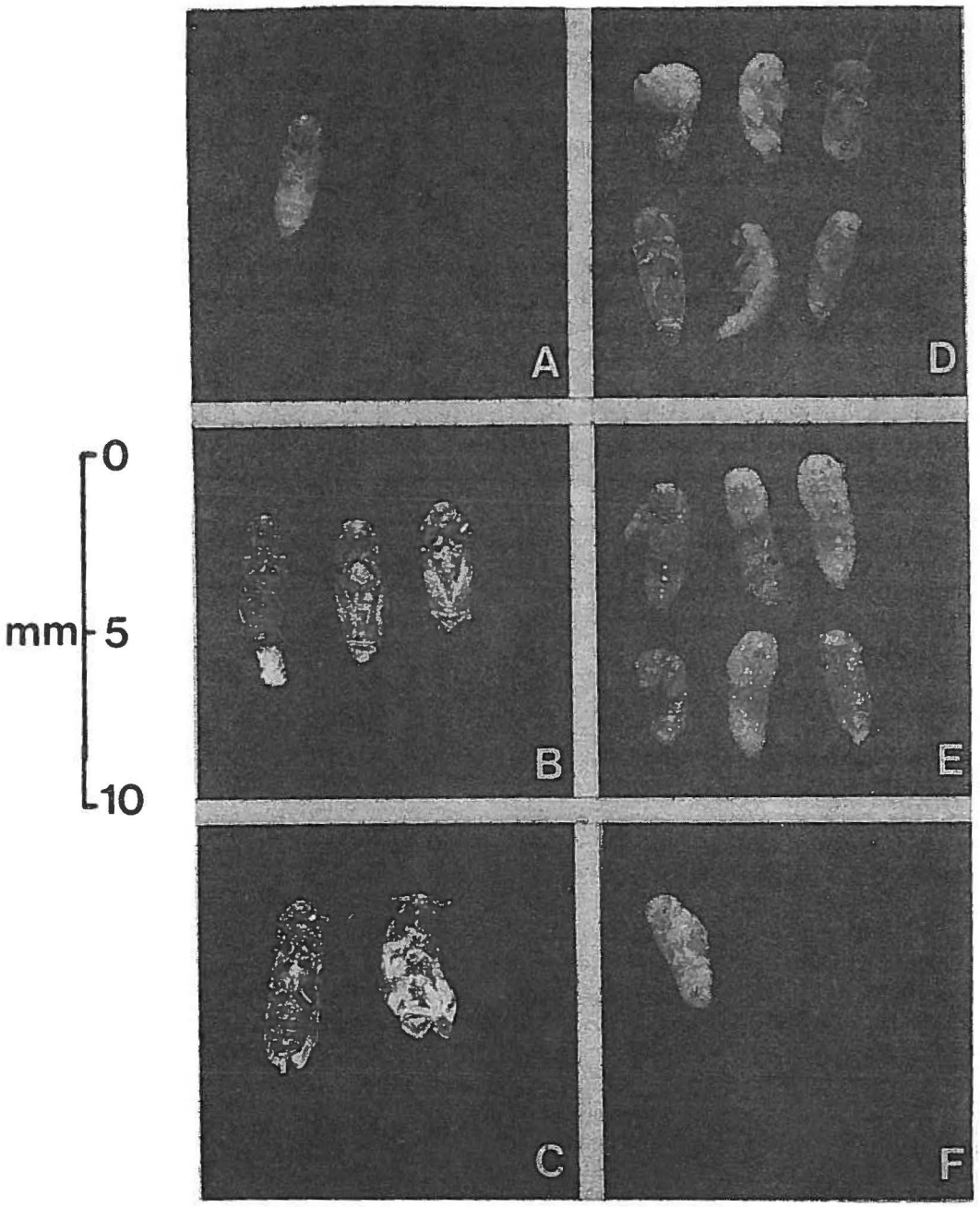

Fig. 1 -- Malformations in pupae and adults of flour beetles from larvae reared in medium treated with IGRs. A - C, the confused flour beetle; A, methoprene (tech), 1 ppm, pupa with adult characters at anterior end; B, methoprene (tech), 5 ppm, pupal-adult intermediates; C, hydroprene (tech), 5 ppm, malformed adults. D - F, the red flour beetle; D, methoprene, 5 ppm, larval-pupal and pupal-adult intermediates. Note attached pupal skin and deformed wings; E, methoprene, 10 ppm, larval-pupal and pupal-adult intermediates. Note shrivelled desiccated appearance; F, methoprene, 5 ppm, pupa with deformed wings.

10 ppm. It was about the same in hydroprene-treated food, namely, 20.3 ± 0.2 days to 25.1 ± 0.2 days. In triprene-treated food at 5 ppm, it was 19.0 ± 0.2 days and at 10 ppm, 21.6 ± 0.3 days. Kinoprene had no effect on larval development time (mean 19.5 days) at any of the concentrations tested.

In the same experiment, percentage survival of larvae of the red flour beetle was unaffected by any of the IGRs at 1 ppm but was drastically reduced at higher concentrations of methoprene, hydroprene and triprene. It was 19 and 8% at 10 ppm of methoprene tech and EC, respectively, 4 and 1% at 10 ppm of hydroprene tech and EC, respectively, and 46% at 10 ppm of triprene. Kinoprene had no effect at any concentration. Larval developmental time in untreated food was 17.5 ± 0.1 days. In methoprene-treated food it increased from 18.8 ± 0.1 days at one ppm of the technical formulation to 21.1 ± 0.5 days at 10 ppm, and from 19.4 ± 0.1 days at one ppm of the EC formulation to 23.9 ± 0.5 days at 10 ppm. In hydroprene-treated food, the comparable figures were 18.9 ± 0.2 to 20.8 ± 0.3 for the technical, and 18.8 ± 0.1 to 23.0 for the EC formulations, respectively. In triprene-treated food, larval developmental time increased from 17.4 ± 0.1 days at one ppm to 19.7 ± 0.3 days at 10 ppm. Kinoprene had very little effect.

These results indicate that methoprene and hydroprene have similar effects on survival and larval development of both species of flour beetles. However, at the highest concentrations the red flour beetle suffered a higher mortality than did the confused flour beetle, while the latter species required a longer time to complete larval development. Also, the red flour beetle was affected more by the EC formulation of hydroprene than by any other compound. Triprene affected survival of the red flour beetle, but only at 10 ppm. It had a slight effect on larval developmental time. It had no effect on the confused flour beetle. Kinoprene had little or no effect on either species.

Grain Beetles

Larvae of the merchant grain beetle and sawtoothed grain beetle did not survive in rolled oats treated with either formulation of methoprene at any concentration. From 66 to 68% of both species reached the adult stage at 1 ppm of hydroprene in rolled oats. Adult emergence of the merchant grain beetle and sawtoothed grain beetle was 51 and 41%, respectively, at 10 ppm of hydroprene (tech).

The developmental time from larval to adult emergence on untreated ground rolled oats was 22.7 ± 0.2 and 22.1 ± 0.3 days in the merchant grain beetle and sawtoothed grain beetle, respectively. In rolled oats treated with hydroprene, it ranged from 22.8 ± 0.2 to 23.1 ± 0.1 in the merchant grain beetle, and 20.7 ± 0.2 to 22.1 ± 0.2 in the sawtoothed grain beetle. Thus, hydroprene at the concentration used, had no observable effect on larval developmental time in both species of grain beetles.

No pupae or adults of either species emerged from cornmeal treated with methoprene at any concentration. Live larvae in treated food continued to molt but failed to pupate even after 3 months from the date of hatching. Adult emergence of merchant grain beetles in hydroprene-treated cornmeal was 82, 29 and 0%, and of sawtoothed grain beetles, 74, 5 and 0% at 1, 5 and 10 ppm, respectively. This decrease in adult emergence with increasing concentration of hydroprene did not occur with treated rolled oats. This difference in results may be due to differences in the absorptive properties of rolled oats and cornmeal that may affect the amount of compound encountered by the insect.

Mortality in the hydroprene-treated food occurred mostly during metamorphosis from pupa to adult. More than 90% of the dead adults in both species were malformed and showed teratogenic effects similar to those observed in flour beetles (Fig. 1).

No live adults of either species emerged within 48 days after introduction of newly emerged larvae into a diet of 95% wheat flour and 5% brewers' yeast by weight, treated with methoprene or triprene at any concentration (Table 2). Many of the larvae initially placed in the treated food died during the 3rd or 4th stadium. At 1 ppm of methoprene 58 to 78% of the merchant grain beetles and 89% of the sawtoothed grain beetles died while emerging as

adults. Similarly, on food treated with triprene, most of the mortality occurred at adult emergence. Many of these adults showed the same abnormalities noted in flour beetles (fig. 1).

Table 2. Number of live and dead adults and F_1 progeny of the merchant grain beetle and the sawtoothed grain beetle 48 days after introduction of 100 newly emerged larvae on whole wheat flour-brewers' yeast medium treated with four IGRs at three concentrations.

Treatment	Concentration ppm	Number of adults: Merchant grain beetle Live	Merchant grain beetle Dead	Sawtoothed grain beetle Live	Sawtoothed grain beetle Dead
Control [a]		66	3	159[b]	3
Control + hexane		66	7	151[b]	6
Methoprene (tech)	1	0	58	0	89
	5	0	0	0	0
	10	0	0	0	0
Methoprene (EC)	1	0	78	0	89
	5	0	0	0	12
	10	0	0	0	0
Hydroprene (tech)	1	68	2	137[b]	5
	5	70	3	73[b]	50
	10	38	18	0	84
Hydroprene (EC)	1	69	5	163[b]	11
	5	56	7	71[b]	49
	10	30	26	3	91
Triprene (tech)	1	0	55	0	87
	5	0	57	0	74
	10	0	68	0	73
Kinoprene (tech)	1	63	5	115[b]	11
	5	70	3	107	7
	10	66	3	111[b]	12

[a] 95% whole wheat flour + 5% brewers' yeast (w/w).

[b] Second generation progeny present.

The number of live adults to emerge from food treated with hydroprene decreased with increasing concentration, particularly in the sawtoothed grain beetle, none of which emerged at 10 ppm of hydroprene (tech) and only 3 at 10 ppm of hydroprene (EC). Kinoprene had no effect on adult emergence of either species at any concentration.

The presence of F1 adult progeny of the sawtooth grain beetle in food treated with hydroprene at 1 and 5 ppm indicated that, at these concentrations, this compound did not adversely affect reproductive ability (Table 2). F_1 adult progeny were present in food treated with kinoprene at all concentrations.

The absence of F_1 adult progeny of the merchant grain beetle in untreated as well as in treated food suggests that this species does not develop as rapidly as the sawtoothed grain beetle on a diet of 95% whole wheat flour and 5% brewers' yeast by weight.

Weevils

Few or no progeny of the granary weevil emerged from wheat treated with 1, 5 or 10 ppm of methoprene (EC), hydroprene (EC), and triprene (tech) (Table 3). This result suggests either that reproduction was suppressed, or that larvae hatching from eggs were unable to survive on the treated wheat.

Table 3. Number of F_1 adults of the granary weevil and the rice weevil to emerge during an 8-week period after exposure of 100 adults for 1 week on wheat treated with four IGRs at three concentrations.

Treatment	Concentration ppm	No. progeny		Productivity Index[a]	
		Granary weevil	Rice weevil	Granary weevil	Rice weevil
Control		177	267	-	-
Control + hexane		215	177	121	66
Methoprene (tech)	1	137	243	77	91
	5	10	91	6	34
	10	191	190	108	71
Methoprene (EC)	1	4	119	2	44
	5	7	183	4	68
	10	6	316	3	118
Hydroprene (tech)	1	7	274	4	103
	5	49	297	28	111
	10	47	202	26	76
Hydroprene (EC)	1	10	212	6	79
	5	10	253	6	95
	10	0	289	0	108
Triprene	1	14	206	8	77
	5	1	180	1	67
	10	4	186	2	70
Kinoprene	1	163	134	92	50
	5	16	321	9	120
	10	42	293	24	110

[a] $\frac{\text{Progeny in treated wheat}}{\text{Progeny in untreated wheat}} \times 100$

In an experiment to determine the effect of hexane added to wheat after 500 adults of the granary weevil had oviposited in it for 1 week, mean adult emergence after 2 months was 1621 ± 16 compared with 2278 ± 24 in untreated wheat. Thus, hexane treatment after

oviposition, reduced, but did not inhibit adult emergence. Since hexane that was applied to wheat before eggs were laid did not reduce progeny production by the granary weevil (Table 3), the observed reduction in productivity must have been due to IGR activity.

None of the IGRs affected the productivity of the rice weevil. Eggs laid in the treated wheat developed normally. The productivity index (Table 3) shows that only granary weevils were adversely affected.

Adults of both species when placed in untreated wheat, after emergence from treated wheat, produced normal eggs which hatched and developed at the same rate as those laid by adults that had emerged from untreated wheat.

Indian meal moth

No adults of the Indian meal moth emerged during a 5-month period after introduction of 100 newly emerged larvae into culture medium treated with 2 formulations of hydroprene at 1, 5 or 10 ppm (Table 4). There was no emergence from food treated with methoprene (tech) at 10 ppm, methoprene (EC) at 5 and 10 ppm, or triprene at 5 and 10 ppm. Total emergence (dead and live moths) from food treated with methoprene (tech) at 5 ppm was 2%, of that on untreated food. Kinoprene had little effect at 1 and 5 ppm, but at 10 ppm total emergence was about 3% of that on the untreated food.

DISCUSSION

The insect species used in this study were affected in varying degrees by one or more of the IGRs. Larval survival was affected to a greater extent in the red flour beetle than in the confused flour beetle, particularly at the higher concentrations of hydroprene and methoprene. No adults emerged after addition of 10 ppm of these compounds to the diet. They showed various abnormalities. Strong and Diekman (1973) reported similar results, namely, no reduction in terms of larval mortality, 100% reduction in the number of adults at 10 ppm, and various kinds of malformations in pupae and adults. Williams and Amos (1974) noted that progeny of the red flour beetle placed for 2 days in food treated with Altosid^R (methoprene) and Altozar^R (hydroprene) at 5 and 20 ppm did not survive.

The results with grain beetle species generally agree with those of Strong and Diekman (1973) who found that methoprene but not hydroprene was effective against the sawtoothed grain beetle on treated oatmeal. However, the zero emergence of sawtoothed grain beetles in whole wheat flour-brewers' yeast diet treated with hydroprene (tech) at 10 ppm (Table 2), and in similarly treated cornmeal suggests that insect response to these compounds is affected by food substrate. The results with the merchant grain beetle also agree in general with those of Strong and Diekman (1973) who found that this species was susceptible to methoprene. In addition, both species were highly susceptible to triprene but not to kinoprene.

Strong and Diekman (1973) reported 100% and 92% reduction of the granary weevil with hydroprene at 50 and 10 ppm, respectively, but no useful reduction with methoprene. In the present study, progeny production was greatly reduced in wheat treated with the emulsifiable concentrate formulation of methoprene. Except for this difference the results observed in this study generally agree with those reported by Strong and Diekman.

The results with the Indian meal moth are similar to those reported by Strong and Diekman (1973) except that a few adults emerged from food treated with methoprene (tech) at 5 ppm (Table 4).

In general, methoprene and hydroprene were more effective against a larger number of species, for example, flour beetles, grain beetles, granary weevil and Indian meal moth, than the other compounds tested. Triprene was effective against grain beetles, granary weevils and the Indian meal moth. Kinoprene was effective against the Indian meal moth only at the highest concentration used.

Table 4. Number of adults of the Indian meal moth to emerge during a 5-month period after introduction of 100 newly emerged larvae on whole wheat flour-brewers' yeast medium treated with four IGRs at three concentrations.

Treatment	Concentration ppm	No. of adults		
		Live	Dead	% Live
Control[a]		153	130	54
Control + hexane		115	162	41
Methoprene (tech)	1	39	130	23
	5	2	4	33
	10	0	0	0
Methoprene (EC)	1	55	151	27
	5	0	7	0
	10	0	0	0
Hydroprene (tech)	1	0	0	0
	5	0	0	0
	10	0	0	0
Hydroprene (EC)	1	0	0	0
	5	0	0	0
	10	0	0	0
Triprene	1	22	94	19
	5	0	0	0
	10	0	0	0
Kinoprene	1	93	131	41
	5	85	123	41
	10	2	7	22

[a] 95% whole wheat flour + 5% brewers' yeast (w/w).

These experiments have shown the relative effectiveness of some insect growth regulators with dienoate or dienethiolate structures. The more effective ones were selected for futher testing against stored products insects.

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EFFECT OF INSECTICIDES ON THE EPIDEMIOLOGY OF BARLEY YELLOW DWARF AND THE RELATIONSHIP BETWEEN DISEASE INTENSITY AND YIELD IN OATS [1]

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ABSTRACT: A field of late sown oats, *Avena sativa* L., became heavily infected with barley yellow dwarf virus despite application of dimethoate 12 days after aphids, mainly *Rhopalosiphum maidis* (Fitch), invaded the field. The dimethoate eliminated the aphids, but infection had already taken place and subsequent yield loss was severe. Results from small plot trials, within the field, indicated that had the insecticide been applied about a week earlier, much of the infection and yield loss would have been prevented.

INTRODUCTION

Barley yellow dwarf (BYD) is an important disease of cereals and grasses in many parts of the world (Watson, 1958; Bruel, 1961; Rochow, 1961; Slykhuis, 1962). The disease is caused by a virus known as barley yellow dwarf virus (BYDV) which may be transmitted by many species of aphids (Oswald and Houston, 1953; Rochow, 1961). Several of these species of aphids occur as vectors of BYDV in Manitoba (Gill, 1967).

BYDV was first reported from Manitoba by Smith (1961), and has been recorded in Manitoba since 1964, when regular surveys for the disease were begun (Gill, 1970). Infected plants are usually discolored and stunted, and produce less seed than do healthy plants. The severity of the disease depends on the vector species, the number and percentage of infective aphids, and the virulence of the virus. A yield reduction of 69%, due to BYDV in oats, *Avena sativa* L., has been recorded in Manitoba (Martens and McDonald, 1970).

The spread of BYDV depends on the movement of virus-carrying aphids into and within crops in an area. Migrant aphids are thought to be the main source of aphid populations on cereals in Manitoba (Gill, 1969). The likely source of migrants is from areas south of Manitoba since northerly migrations of aphids occur on warm south winds (Taylor, 1965). Once in the field, aphids spread gradually from the plants on which the migrants land. This accounts for the patchy occurrence of the disease. It has been suggested that movement of aphids from plant to plant may be more pronounced in oats than in other cereals (Rochow, 1961).

Aphid migrations occur in late spring and early summer (Gill, 1970), and late crops tend to be more subject to infestation by aphids, and hence infection by BYDV, than do early crops. Late crops also tend to suffer greater yield loss than do early crops because the disease reaction is more severe in plants infected at an early stage of development than at a late stage of development (Oswald and Houston, 1953).

This is a report on the effect of insecticides, applied to late sown oats at the beginning of an aphid infestation and later as it progressed, on the incidence of BYD and its effect on seed yield.

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[1]Contribution No. 775, Agriculture Canada, Research Station, Winnipeg, Manitoba.

MATERIALS AND METHODS

Oats, cv. Fraser, were seeded in a field of 6 hectares near Portage la Prairie, Manitoba, at the rate of 75 kg/ha (2 bu/acre) on 20 June, 1976. Insecticides (Table 1) were applied, with a boom sprayer using a single TK 75 Flood Jet Nozzle at 310 kPa (45 psi), on 22 July, to oats in plots 1 x 3 m, arranged in a randomized block design replicated 9 times, when the plants were in the tillering stage and about 20 to 25 cm tall. There were 2-m interplots between treatments and the total plot area was about 90 x 9 m. The insecticides, as applied, were originally intended for a purpose other than the control of aphids. The entire field, including the plot area, was sprayed with dimethoate, for the control of aphids, at 0.28 kg/ha (4 oz/acre) with a 15-m boom sprayer at 310 kPa, on 28 July. Oats from an area of $1 m^2$ were harvested from each of the treatments and checks on 17 September. The percentage of infected plants in each sample was rated into one of 4 categories as follows: 0 to 25% infected, 26 to 50% infected, 51 to 75% infected and 76 to 100% infected. For convenience, reference is made, in some instances, to the mid-percentage point in each category, e.g. 12.5%, 37.5%, etc. The samples were threshed and weighed. Analysis of variance and linear regression were applied to the results.

RESULTS AND DISCUSSION

Field treatment

The field in which these tests were undertaken was examined for suitability as a plot area on 16 July and the plots were staked on 19 July. On these dates, few aphids were observed. On 22 July, when the insecticides were applied to the plots, a light population of aphids (mainly the corn leaf aphid, *Rhopalosiphum maidis* (Fitch.)) was evident on the plants. During the subsequent 4 days, 23 to 26 July, the plot area was relatively free of aphids, but the population elsewhere in the field increased markedly and most of the plants became infested. The dimethoate, applied on 28 July, was effective and had eliminated the aphids by 31 July.

The first symptoms of BYDV were noted in the field on 28 July and by 31 July they were readily apparent throughout the field. Subsequently, patches of infected plants, typical of BYD, became evident. Many of these patches later coalesced and the overall infection in the field was rated at 50-75%. Most of the infected plants were severely stunted and failed to produce seed. This may have been the result of infection at an early stage of plant development or due to a strain of BYDV that produced severe symptoms (Toko and Bruel, 1959; Rochow *et al.*, 1965).

Since the minimum time for symptom expression of BYD in oats is 10-12 days (Gill *et al.*, 1969), early infection must have occurred about the time the field was first examined on 16 July. At that time aphids were present only in very small numbers and were probably just invading the field. The population did not develop to a level that would generally be considered to warrant control measures until about 26 July. As spraying was not accomplished until 28 July spread of the disease was possible for a period of 10-12 days as the vector population developed by reproduction and/or further invasions. The application of the insecticide, although effective against the aphids, failed to protect the crop from infection by BYDV because of timing.

Field plots

None of the treatments provided adequate protection from aphids since there was a high incidence of BYDV infection in all the treatments (Table 1). Yields were 12.7 to 45.1% greater on treated plots than on untreated plots, but, due to large variations within treatments, the differences were not statistically significant ($P>0.05$). Nevertheless, the differences in incidence of disease and in yield suggest some degree of aphid control and the data are useful from the point of view of the epidemiology of the disease. The yields with the

pyrethroid compounds were greater than those with the other treatments. The pyrethroids have a fast knock-down action which would provide good initial control, but their short residual action would permit reinvasion of the crop within 1 or 2 days. Dimethoate, which is the most commonly recommended insecticide for the control of aphids on cereals in Manitoba, did not prevent BYDV infection. This may be because dimethoate is relatively slow acting, allowing existing or reinvading aphids to feed for a period before succumbing to the effects of the insecticide. Virus transmission may take place even with short periods of feeding. Reinvasion of the plots may also have taken place after the effectiveness of dimethoate had diminished. Baygon is relatively ineffective against aphids and as indicated provided very little protection for the crop.

The dimethoate, and particularly the pyrethroid compounds, would probably have provided adequate control of aphids and protection from BYDV had they been applied earlier and under conditions of less reinvasion pressure i.e. had the entire field, rather than a small plot area, been treated at an early stage of aphid infestation.

Table 1. Incidence of barley yellow dwarf virus infection, and yield of oats treated with different insecticides, and of untreated oats.

Treatment	Rate of application (kg/ha)	Incidence of infection (%)[1]	Yield	
			Mean (g/m^2)	Increase over untreated (%)
Synthetic pyrethroid compounds[2]				
WL 43775	0.3	31.9	139.6	45.1
WL 41706	0.3	31.9	135.2	40.5
WL 43467	0.3	29.2	125.9	30.9
Dimethoate	0.3	51.4	110.3	14.6
Baygon	0.6	55.6	108.4	12.7
Untreated		58.3	96.2	-

[1]Calculated from infection ratings.

[2]Shell Canada Limited.

Disease intensity and yield

As noted, there was considerable variation in disease intensity and yield within treatments in the field plots, and consequently, the results regarding the effectiveness of insecticides were inconclusive. However, when the yield values were plotted against the appropriate ratings for disease intensity, regardless of treatment, a significant regression was evident with substantial yield reductions indicated for high levels of BYDV infection (Figure 1). This was also evident in the grain harvested from the field. The yield averaged 901.5 kg/ha (23 bu/acre) or 90.1 g/m^2, remarkably close to that predicted by the regression line for an incidence of infection of 50-75%.

The reduction in yield was related to the proportion of diseased plants, but was not as large as would be expected where most of the diseased plants were severely affected. Since severely affected plants do not produce seed (Martens and McDonald, 1970), the regression of yield on infection would be expected to approach zero at 100% infection. Since this did not occur, it suggests a compensation in yield by the healthy plants. As noted by Machacek

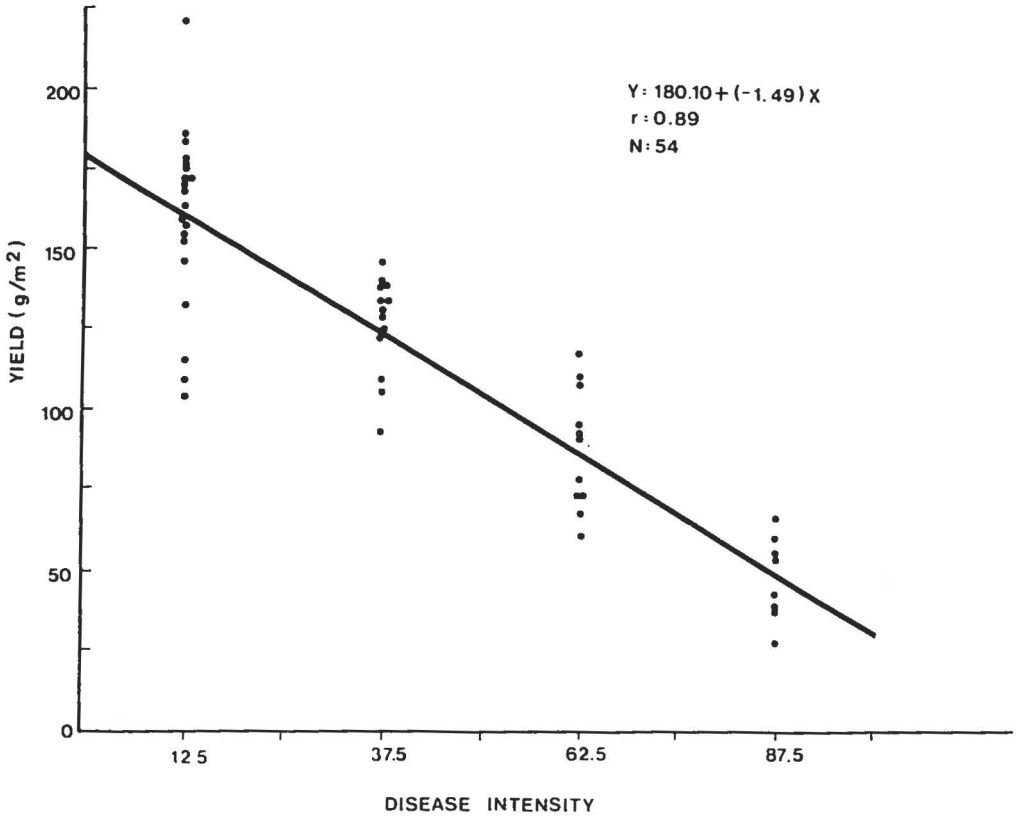

Figure 1. The regression of yield on disease intensity of oats infected with BYDV.

(1943), it is possible that the healthy plants benefitted in their competition with the diseased plants and that their yield was higher than it would have been if all the plants had been healthy. Failure to consider this possibility could lead to an overestimation of yield loss, particularly with a high incidence of severe infection.

CONCLUSIONS

BYDV may spread rapidly in late sown oats, even with a moderate aphid population, and result in severe crop loss. Late sown crops should thus be checked almost daily for the presence of aphids, particularly during early stages of crop development. If aphids are found scattered throughout the crop, insecticides should be applied within a few days to prevent the possible spread of BYDV. Undue delay could severely limit the value of the control measures and result in a waste of time, effort and money.

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BENEFICIAL INSECTS IN THE DIET OF THE COMMON CROW[1]

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ABSTRACT: Regurgitated pellets from the common crow, *Corvus brachyrhyncos* Brehm., collected in two Manitoba fields were composed almost entirely of insect parts. Predaceous carabid beetles were the major prey early in the summer. Later, *Banchus flavescens* Cress., an ichneumonid parasite of the bertha armyworm, *Mamestra configurata* (Wlk.), was the major prey. Ichneumonids have not previously been reported in the diet of crows.

The common crow, *Corvus brachyrhynchos* Brehm., is an omnivorous feeder which tends to take the most numerous and palatable of the accessible foods (Good, 1952). Individual crows within an area have a similar diet (Good, 1952) and, when insects of a particular species are abundant, the crows tend to concentrate feeding on them (Kalmbach, 1920; Hodson, 1943). Sand, gravel and indigestible parts of the food aid in breaking down the food (Barrows and Schwarz, 1895) and when trituration is complete, the indigestible materials are regurgitated in a pellet. Sclerotized portions of insects occur in the pellets and when identified, give an indication of the food components similar to those obtained by the analysis of stomach contents (Platt, 1956; Good, 1952).

During field investigations of the bertha armyworm, *Mamestra configurata* (Wlk.), a pest of rape, *Brassica napus* L. and *B. campestris* L., in the prairie provinces of Canada, three crow pellets were collected in Manitoba. These pellets were collected in fields in which rape had been grown and in which bertha armyworm had been present during the previous growing season. Two pellets were found near Neepawa on 6 July 1973 in a field containing volunteer rape and weed seedlings. One pellet was collected near Bowsman on 12 June 1974 in a field that had been sown to barley but also contained weeds and volunteer rape.

The crow pellets were found on top of insect emergence cages located in the fields. These cages, covering 0.186 m^2 of ground surface, consisted of a cone of screen topped by a plastic trap (Ives *et al.*, 1968). The upper surface of the plastic trap, 10 cm in diameter, was about 0.5 m above the ground surface. The tops of the traps were the only solid perching sites above-ground level available to birds within the fields. The pellets were about 15 mm long and 7 mm in diameter (Figure 1). The contents of each pellet were examined under low magnification and the components separated into categories on the basis of appearance. The volume of each category was estimated as a percentage of the total pellet content. The pellet contents were almost entirely of insect origin: none contained sand or gravel. A few small seeds were found in the pellets from Neepawa. The various insect parts were identified by specialists at the Biosystematics Research Institute, Ottawa. After identification, an estimate of the percentage occurrence of each taxon was calculated.

The pellet from Bowsman contained the remains of about 20 insects, most of which (80%) were predaceous beetles (Carabidae). Parts of a wild bee, *Andrena* sp. (Andrenidae), and an intact humpbacked fly, *Megaselea* sp. (Phoridae) made up 10% of the pellet while the remaining 10% was unidentifiable fragments of cuticle.

The two pellets from Neepawa had almost identical composition and together contained about 50 insect specimens. *Banchus flavescens* Cress., an ichneumon parasite of the bertha armyworm, was the major constituent of these pellets (80%). The remainder of the pellets was made up of heads, legs, pronota and elytra of beetles: predaceous ground beetles,

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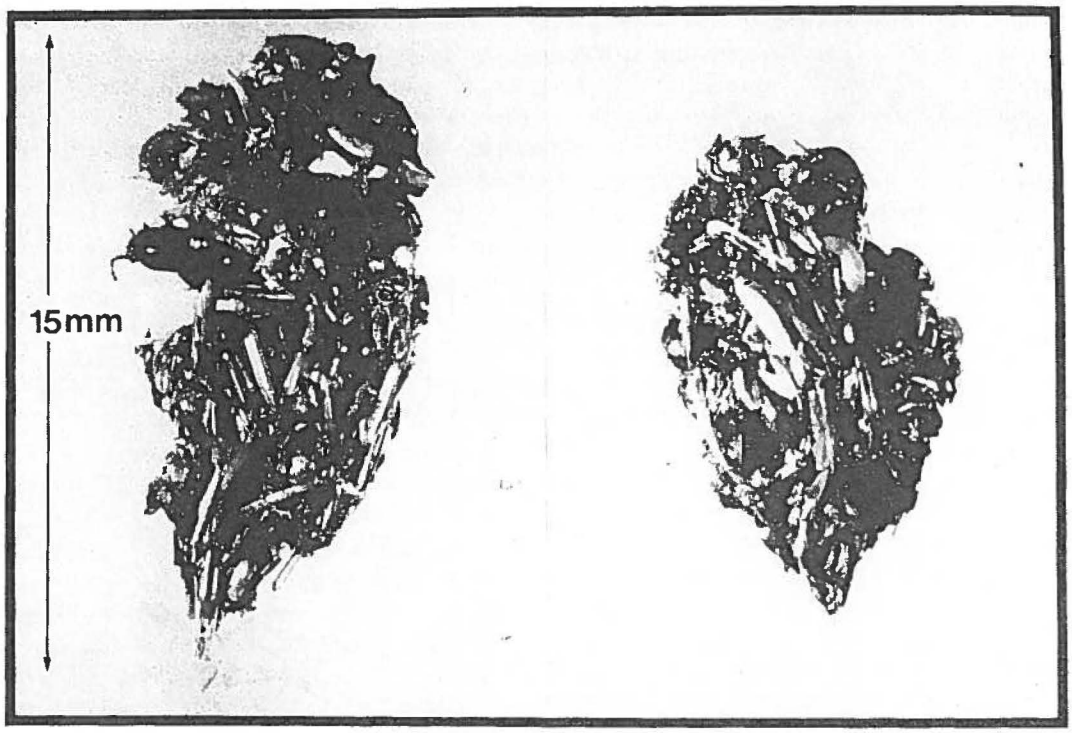

Figure 1. Regurgitated crow pellets containing insect fragments. (Photographed by R. Sims).

probably *Harpalus* sp., and *Pterostichus* sp., (Carabidae) (10%); and carrion or dung feeding beetles, *Onthophagus* sp. probably *orpheus pseudorpheus* Howd. and Cart. (Scarabaeidae) (10%).

When the Bowsman pellet was collected, the most abundant large insects in the field were predaceous beetles (Carabidae) and the aposematically-coloured (red and black) red turnip beetle, *Entomoscelis americana* Brown (Chrysomelidae), a pest of rape plants. The absence of the latter species from the pellet suggests that crows, like European rooks (Holyoak, 1972), may not feed on insects with aposematic colours.

When the two pellets were collected at Neepawa, later in the summer, the most abundant large insects active during the day were the bertha armyworm parasites, *B. flavescens* (Ichneumonidae) and *Athrycia cinerea* (Coq.) (Tachinidae). The reasons for the absence of the latter species in the pellets is not apparent.

The analyses of these pellets confirm previous reports of crows concentrating their feeding on an abundant food source and indicate that at least for short periods, they prey almost exclusively on beneficial insects.

The crow pellets were observed and collected by R. Bilodeau in the course of his maintenance of the emergence traps. The perseverance and knowledge of M. Ivanochko, B. V. Peterson and A. Smetana, Biosystematics Research Institute, Agriculture Canada, Ottawa, in identifying the insect fragments is also gratefully acknowledged.

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COLLOPS VITTATUS [COLEOPTERA:MELYRIDAE]: A PREDATOR OF FLEA BEETLE ADULTS IN RAPESEED[1]

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Adults of *Collops vittatus* Say were observed preying on adult flea beetles, *Phyllotreta cruciferae* Goeze, in experimental plots of rapeseed, containing cultivars of both *Brassica campestris* L. and *B. napus* L., at Glenlea, Manitoba, during the first 2 weeks of July, 1975. This is the first record of an insect predator of flea beetles in rapeseed in Canada.

C. vittatus is widely distributed in North America (Fall 1912). In Canada, it is found from Quebec to Saskatchewan. Adults and larvae of *C. vittatus* are predaceous upon insects (Clausen, 1940) and apparently do not show any particular host preferences. In Arizona, Wildermuth (1914) found them feeding upon living and dead larvae and pupae of the alfalfa caterpillar, *Colias eurytheme* Boisd., in alfalfa fields. In Manitoba, *C. vittatus* adults were collected on sand cherries [*Prunus pumila* L.), potatoes and onions in the 1940's (A. G. Robinson, P. H. Westdal, unpublished observations), but their prey was not determined. In general, species of *Collops* are not host-specific and prey upon a wide variety of insects (Wildermuth, 1914; Balduf, 1935; Clausen, 1940; Knowlton, 1944).

C. vittatus adults are small and have a striking colour pattern. Those collected were 4-5 mm long. The head was black. The pronotum was orange-red, except for a central black spot which varied in shape and size; the spot was absent in one specimen. Each elytra had a central, longitudinal vitta and a pale margin which was continuous on the lateral, apical and sutural sides. The vitta ranged from dark blue or dark green to black, and the margin was orange-red.

The adults were moderately abundant in the rapeseed plots and appeared to be searching for prey on the plants and the ground in the immediate vicinity of the plants. They walked very quickly and could easily catch flea beetles. They grasped the flea beetles with their legs, chewed through the cuticle and fed on the body fluids and tissues. Flea beetles discarded after being attacked had holes in the head, thorax, abdomen, antennae and femurs.

At the time of the observations, flea beetles were the only insects, except for the *C. vittatus* adults, seen in the rapeseed plots. Thus, it would appear that flea beetles were the main prey of this predator during this period. However, counts of destroyed flea beetles were not made and the importance of *C. vittatus* in reducing flea beetle populations is not known.

We gratefully acknowledge the technical assistance of Miss D. Sacher and Mr. G. Hamilton in this study. The *C. vittatus* adults were identified by Dr. D. E. Bright, Biosystematics Research Institute, Ottawa.

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