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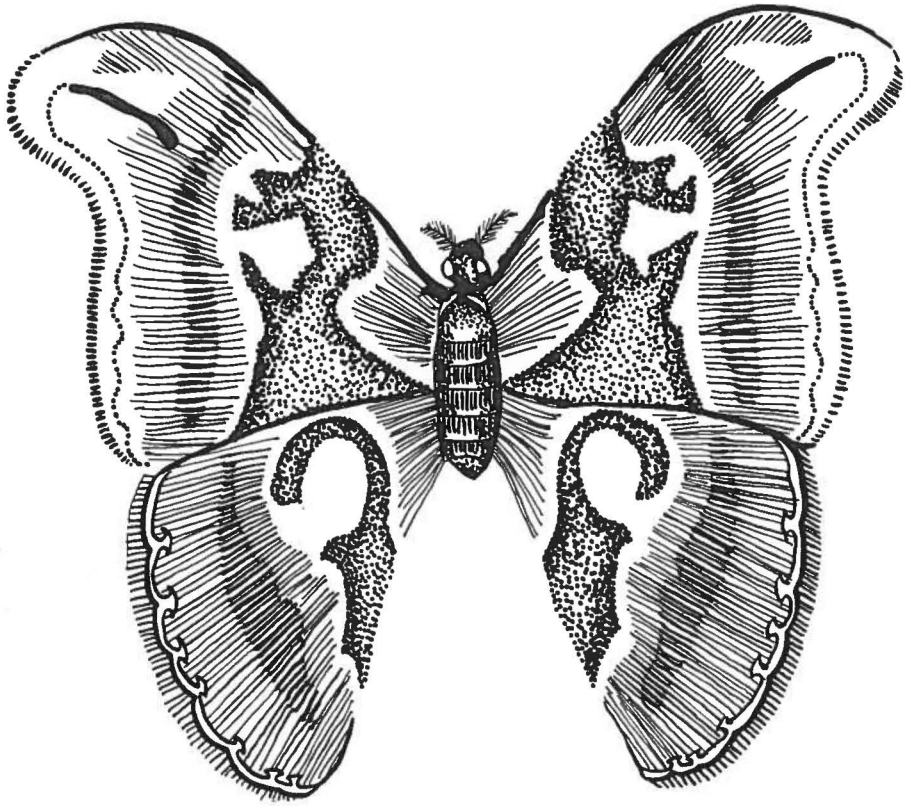
Vol. 6, 1972



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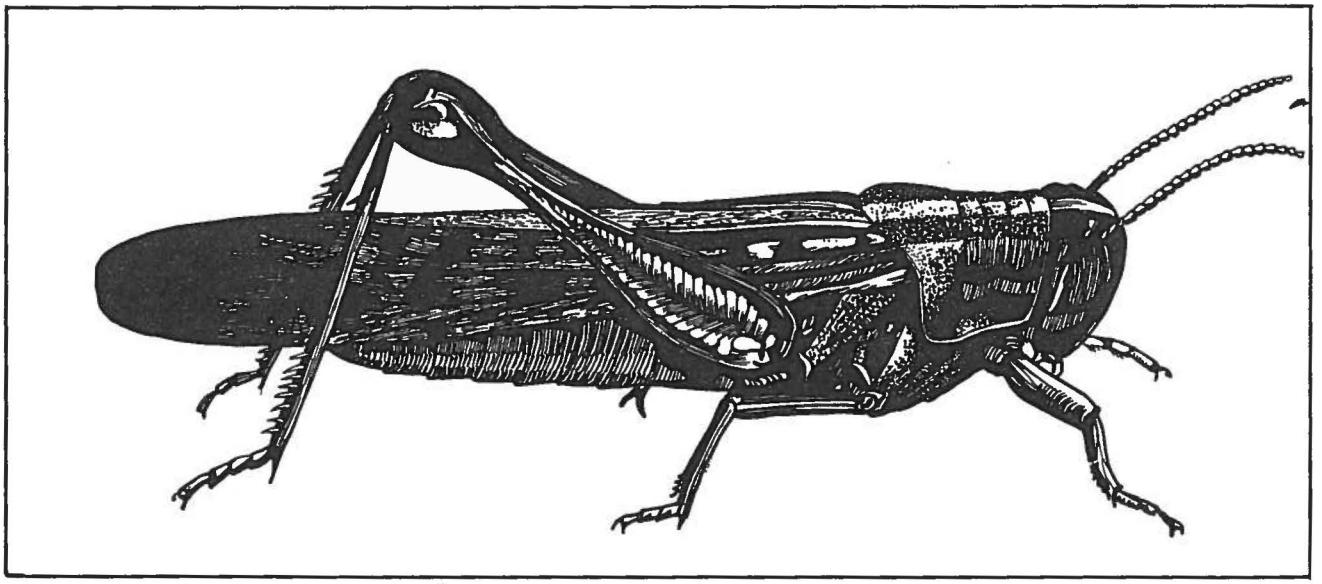

THE ENTOMOLOGICAL SOCIETY OF MANITOBA

25 Dafoe Road,
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MEMO

TO: All Members December 12, 1973.

FROM: Dr. W. J. Turnock

On the occasion of the appearance of Vol. 6 and of the end of my first year as editor, I'd like to bring a few points to your attention:

1. the completion of a volume of the MANITOBA ENTOMOLOGIST involves a) submission of manuscripts to the editor, b) review and correction by author(s) c) acceptance for publication, d) typing of galley proofs e) proof-reading by senior authors f) compilation of the volume, g) printing. Step d) is done by an excellent typist who works evenings on this job. She can and does complete individual manuscripts as they are given to her. If she is given a large number of manuscripts at once, they will take a long time to complete. It is therefore essential to get manuscripts to the typist very early in the year.

2. The lateness of Vol. 6 is directly related to the late dates on which the Editor received manuscripts. These manuscripts went to the typist late, they were not completed before summer vacation time, etc, etc.

3. Therefore, I hereby solicit papers for Vol. 7 from you and urge that they be submitted as soon as possible, by 31 January if you can. However, do not hesitate to submit a manuscript at any time of the year, if it doesn't make the current volume, it will aid the editor to put the subsequent volume out quickly. Good papers on all aspects of entomology are welcome and book reviews are also publishable.

4. The MANITOBA ENTOMOLOGIST is a fully edited journal that is covered by all major abstracting services. In addition it is sent to 69 members, 76 subscribers and 38 institutions with which we have exchange agreements. Publications received in exchanges are listed in the MANITOBA ENTOMOLOGIST and are kept in the Library, Agriculture Canada, Research Station, 25 Dafoe Road, Winnipeg.

5. I welcome the new members of the society and since we have a stock of vols. 2-5 on hand, they may obtain copies on request.

6. Vol. 1 is out of print and has been ordered by some of our subscribers to complete their sets. I would be pleased to receive copies of Vol. 1 from any members wishing to dispose of their copies.

7. I wish you a Happy and Industrious New Year resulting in the early submission of well prepared manuscripts. I promise they will be processed as quickly as possible.

W. J. Turnock

W. J. Turnock,
Editor.

WJT:lr

THE MANITOBA ENTOMOLOGIST

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THE MANITOBA ENTOMOLOGIST

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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

CONTENTS

ESTIMATING NUMBERS OF ADULT HONEY BEES ON LANGSTROTH FRAMES

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ABSTRACT

A numerically graded series of photographs of bees on Langstroth frames was used to train observers to estimate the adult numbers of bees on single frames and in whole colonies. After an initial training period of 4-6 hours using bees on combs, the observers improve little in accuracy.

Compared to all other methods to date this one is rapid, easy, less disruptive to colony life, and relatively accurate.

INTRODUCTION

Many studies of honey bees, involving colony growth, nutrition, queen testing, genetics, etc., require a method for periodic measurement of adult populations which is not only rapid but disrupts the life of the colony to a minimum. In most methods to date the bees are removed from the frames of a colony and their numbers calculated on the basis of their weight. However, Jeffree (1951) devised a method in which a numerically graded series of photographs of bees on frames 8½" x 14" (commonly used in England) were used to estimate numbers of bees; described below are the methods used and results obtained when bees were estimated on the Langstroth frames (9-1/8" x 17-5/8") commonly used in North America.

METHODS

A large number of photographs were taken of various numbers of bees on Langstroth frames, enlarged to nature size, and the number of bees counted on each. From these, a series of photographs* were selected at 150 bee increments (i.e. 150, 300 . . . 1350) with no photographs giving more than 1.6% error of the increment number they represent. These photographs were then mounted, in numerical order, on a portable easel.

Although between 1800-2000 bees can be tightly arranged in a single layer on one side of a Langstroth frame seldom did we ever find more than 1300-1400. In late summer bees in the centre frames were sometimes found tightly arranged in two or more layers. When this occurred each layer was estimated from the appropriate photograph; thus the total resulted from a composite estimate.

An apparatus was designed to accompany the photographs for training observers to estimate bees on frames. It consisted of an upper glass-walled chamber in which a frame, covered with bees, was introduced. Bees were prevented from moving to the other side of the frame by a close fitting lid and side bar arrangement. After the bees on both sides of a frame had been estimated, cyanide gas was introduced to the upper chamber through a cork-covered hole. The dead bees from each side of the frame dropped through metal funnels into plastic bags and were counted. While this was being done the used empty frame was replaced with another frame covered with bees. The actual number of bees counted on the previous frame was then compared with the estimated number. In this way each observer knew if he or she was estimating high or low.

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* These can be obtained from the authors.

Estimates of numbers of bees in whole colonies was done late in the season when colonies in Manitoba are routinely killed before winter; these estimates were done in the morning, before the bees flew, as follows (see also Jeffree 1951): The entrance to the hive was smoked gently and the lid loosened after which the bees were allowed to settle down for 2-3 minutes. Hive lids, one per box, were arranged in a semi-circle around the hive and as the boxes were removed from the hive, they were placed in sequence inside these lids. A wooden frame of 1" x 1" material was first placed inside the lids so that any bees on the undersides of combs would not be crushed. After an empty box had been placed on the original bottom board and the entrance screened the bees on the bottom board were estimated; frames of bees were then removed in sequence from the original bottom box and after the bees on them had been estimated (including those on tops, bottoms and sides) they were placed in the new box on the bottom board in the same sequence. Bees on the walls of the box were estimated next and the lid which had been under this box was then covered with a screened inner cover. This procedure was repeated for each box in turn. Estimates were then made of the bees within the lids and of those which had flown to the entrance screen. Afrer the screen had been removed the bees in the lids were shaken at the entrance and a lid replaced on the hive.

Two groups, neither with prior experience in estimating, were tested in 1968. Group A consisted of three women (Table 1) and two men each with two seasons' experience managing bees. These five people spent 16 hours over a 10-day period estimating bees on frames. Group B consisted of one woman (Table 1) with no experience managing bees and three men each of whom had had at least two seasons' experience managing bees. These four people spent eight hours over a five-day period estimating bees on frames. Group C (1969) consisted of one woman (Table 1) and five men, each of whom had had at least two seasons' experience managing bees; these six people estimated frames having only high numbers of bees on them.

In 1969 and 1970 eight people, (Table 2), only three of whom had had prior experience in estimating bees were used to estimate bees in whole colonies.

RESULTS AND DISCUSSIONS

The use of a numerically graded series of photographs, appears to be a relatively rapid and accurate method of estimating adult numbers of a colony (Table 2) and is less disruptive to colony life than any method devised to date.

When estimating adult numbers in the range of 1—2000 bees per frame side many of the estimators, whether or not they had worked with bees or had had experience in estimating, often had very low mean errors. This low mean error is not evident in Table 2 because it is a summary of all observers estimates. However, five of the eight observers were consistently within a mean error of eight per cent on each colony. As expected the greatest per cent errors occurred when estimating low numbers of bees (i.e. 1-200) but when estimating the total numbers in a colony the effect of this on the over-all error would be negligible. Two people, one acting as beekeeper and one as "estimator", could estimate the bees in 15 colonies between 0600 and 0800 hr. by which time bee flight had usually begun.

Most difficulties, in using this or any other method, occur in estimating adult numbers late in the season when populations are high and the bees are crowded into the hives due to the removal of the top boxes containing honey. At that time (late August) populations usually average 40-50,000 bees. It would take an exceptional estimator to be able to maintain a mean error of less tha 10 per cent when populations are this high and when the colonies are congested. However, most practical studies only require that populations be estimated up to and including the honey flow when populations range between 25—35,000; a good estimator should be able to maintain a mean error of 5-10 per cent when working within this range.

It appears that some estimators, with no previous experience at estimating numbers of bees, are better suited for the task than others. A potential estimator can be tested using the apparatus mentioned above by allowing him to estimate two or three frames, count the

TABLE 1. Errors of observers when estimating numbers of bees on Langstroth frames

Number of bees per frame side	Group A* N**	Group A* Percentage Error Mean	Group A* Percentage Error Range	Group B* N**	Group B* Percentage Error Mean	Group B* Percentage Error Range	Group C* N**	Group C* Percentage Error Mean	Group C* Percentage Error Range
1 — 150	75	−20.1	−26.6 to −17.0	18	−22.5	−37.1 to − 4.8			
151 — 300	82	− 2.7	−14.3 to + 4.7	39	− 5.4	−18.5 to +14.7			
301 — 450	157	− 3.3	−16.1 to +15.4	42	− 0.3	−18.4 to + 6.1			
451 — 600	159	− 2.7	−15.1 to + 3.4	35	− 2.3	− 5.5 to + 0.8			
601 — 750	112	+ 3.4	− 1.5 to + 9.4	25	− 1.9	−24.3 to +16.4			
751 — 900	148	+ 3.5	− 2.4 to + 9.4	37	− 0.1	− 7.8 to +10.4			
901 — 1050	57	− 3.3	− 5.8 to + 0.6	12	− 1.0	−13.6 to +16.5			
1051 — 1200	15	− 1.5	−10.4 to +10.1	2	+12.9	+ 8.0 to +17.9			
1201 — 1350							43	+ 7.0	+ 3.3 to + 11.7
1351 — 1500							26	+ 1.9	− 9.3 to + 13.1
1501 — 2000							35	+ 3.8	− 5.0 to + 10.6
Total	805	− 0.4	− 8.0 to + 5.6	210	− 1.6	− 6.1 to + 0.5	104	+ 4.4	− 5.5 to + 8.0

* Group A 5 observers, 1968
Group B 4 observers, 1968
Group C 6 observers, 1969

** Number of frame sides

TABLE 2. Errors of observers when estimating numbers of adult honey bees in whole colonies

1969*			1970**		
Number of bees per colony	Percentage Error		Number of bees per colony	Percentage Error	
	Mean	Range		Mean	Range
14980	−21.0	−24.6 to −18.7	28895	−16.6	−31.7 to − 6.8
18880	− 2.1	−10.0 to + 2.0	33585	−12.0	−18.6 to − 2.7
20120	− 3.3	−11.9 to + 10.3	34545	− 1.8	− 5.6 to + 2.3
22910	+ 2.7	− 2.8 to + 10.9	34945	− 9.3	−18.5 to + 0.6
26385	−13.3	−18.5 to − 8.9	36000	+ 3.6	−13.3 to + 17.6
27940	− 9.6	−10.0 to − 9.3	37830	− 9.6	−14.6 to − 3.4
30375	+ 3.7	− 1.0 to + 7.8	39125	−22.0	−31.4 to −10.9
32710	−13.6	−18.8 to −10.1	39885	+ 2.4	− 7.4 to + 28.6
33555	−13.2	−20.2 to − 8.8	40170	−11.3	−20.7 to − 2.1
34100	−12.2	−15.5 to − 6.5	43010	− 4.9	−14.7 to + 9.1
34820	+ 2.6	− 2.1 to + 7.6	45125	− 5.0	−17.9 to + 14.1
56910	−20.0	−20.9 to −18.3			
73050	− 9.7	−15.8 to − 4.8			

* 3 observers
** 6 observers

bees, and repeat this procedure using frames with various numbers of bees. After a group of 2—5 frames have been estimated ascertain if his estimates are high or low and have him adjust accordingly in the next trials. The ability of a potential estimator can thus be judged within a day using about 10-15,000 bees for the estimations.

Considerable practice can be done in the laboratory using a large reference collection of photographs of known numbers of bees along with the graded series. In fact, one observer in the above trials, was trained entirely using photographs. It appears that after an initial training period of 4-6 hours using bees on combs, that the observers improve little in accuracy. Finally, it is suggested that an observer, who is making estimations over long periods of time, be checked periodically for accuracy with actual counts of bees so that errors may be detected and adjusted accordingly.

ACKNOWLEDGEMENTS

We thank the many students of the Department of Entomology, University of Manitoba, for their assistance in the estimation trials, Dr. E.P. Jeffree for his helpful advice, and the Canada Department of Agriculture for providing the funds for this study.

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(Received 24 March, 1973)

POPULATION GROWTH AND HONEY YIELD STUDIES OF PACKAGE BEE COLONIES IN MANITOBA. I. COLONIES INITIATED WITH TWO PACKAGE SIZES ON THREE DATES

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ABSTRACT

In 1967, 1968 and 1969 groups of colonies were initiated with two or three pounds of bees on each of three spring dates. Amount of sealed brood reared by each group and nectar flows were measured in each year; measurements in 1969 also included numbers of adults reared and honey produced by each group.

For any hiving date, colonies from three pounds of bees reared more brood during the initial 43 days than did the two pound groups; however, the two pound groups reared more brood per adult bee up to 67 days after hiving. For colonies from two or three pounds of bees hiving date influenced sealed brood numbers up to 67 days. In 1969 the colonies from three pounds of bees had a higher adult population up to 67 days.

Packages, hived on the earliest date, produced significantly more honey in 1969 but no other significant differences were observed.

INTRODUCTION

Beekeepers in the prairie region of Canada usually establish their apiaries annually with packages of honey bees ("package bees") imported from the southern U.S.A. Good honey crops have been obtained from packages containing two pounds of bees (Mitchener 1931, Kelty 1948, L'Arrivee and Geiger 1966) hived in late April or early May (Mitchener 1931, Geiger 1967, Pankiw 1968).

In this study, groups of colonies were initiated from packages, with two or three pounds of bees, on each of three spring dates in 1967, 1968, and 1969. The amount of brood, adult numbers, and honey produced by these colonies were recorded throughout the spring and summer periods.

METHODS

In 1967, 1968, and 1969 packages of bees of a yellow strain, from one shipper, were weighed into two and three pound lots upon arrival in Manitoba. In each year on each of three spring dates (about 15 April (DI), 27 April (DII), and 9 May (DIII)) 8 colonies were initiated with two pounds of bees and 8 colonies with three pounds of bees (six groups in all). These colonies were then managed throughout the season according to commercial honey production methods common to the area.

Sealed brood (i.e. capped brood cells) areas were measured by tracing, brood patterns onto glass plates ruled in square inches, and subsequently calculating the brood areas. In 1967 sealed brood was measured in two hives of each group and in 1968 and 1969 sealed brood was measured in all hives of the six groups. Measurements of sealed brood began 19 days after hiving for each group except in 1968 when measurements for all groups began 19 days after the final group had been hived. Thereafter sealed brood measurements were made at 12 day intervals.

In 1969 adult bee populations were estimated at 24 day intervals by comparing the bees on combs to a set of photographs of bees on combs in a graduated numerical series (see methods of Jeffree 1951 and Nelson 1971).

Honey flows for 1967, 1968, and 1969 were recorded by maintaining two, three, and six colonies respectively on platform scales throughout the season. In 1969 the honey produced by each colony was weighed.

RESULTS

The results are shown in Tables 1, 2 and 3 and Figures 1, 2 and 3. Figure 1 shows the mean amount of sealed brood in colonies initiated from two or three pounds of bees on three spring dates in 1967, 1968 and 1969. Because of the low number of hives used in the preliminary study in 1967 no statistical analyses were done; trends however, can be deduced from Figure 1. The date of hiving for a two or three pound package in 1968 significantly affected the amount of sealed brood at 43 days ($P<0.01$), and in 1969 at 19 and 31 days ($P<0.05$) and at 43, 55 and 67 days ($P<0.01$). In 1968 colonies from two pounds of bees produced more sealed brood at 79 and 91 days ($P<0.01$ and $P<0.05$ respectively) than did those from three pounds; the reverse was true in 1969 at 19, 31, and 43 days ($P<0.01$ in each case). For each hiving date in 1969 adult bees in colonies, from two pounds of bees, supported a higher number of cells of sealed brood for at least 79 days after hiving than did those in colonies from three pounds of bees (Figure 2).

Table 1 shows the total quantity of sealed brood reared in 1968 and 1969 by each group during June, July, and the period 31 May to 8 August. Total sealed brood produced in June was similar for colonies from two or three pound packages in 1968 but higher for colonies from three pound packages in 1969 ($P<0.01$). The earlier a group was hived the greater the quantity of sealed brood produced in June of 1968 or 1969 ($P<0.01$). The quantity of sealed brood produced during July by a group was not affected by package size or hiving date. For the period 31 May to 8 August total sealed brood quantities were similar in all groups in 1968 regardless of package size or hiving date but in 1969 the groups hived on DI produced more sealed brood ($P<0.01$). The two pound DI group produced more sealed brood than the three pound DI group in June 1969 and between 31 May and 8 August 1969 ($P<0.01$ and $P<0.05$ respectively).

Figure 3 shows the adult populations at various dates in 1969 and Table 2 shows the sealed brood and adult bee populations at the beginning of the nectar flow (4 July) and during the main nectar flow (17 July). All six groups increased adult populations from the time of hiving to mid August when measurements were terminated. On 4 July the DI groups had higher populations than the DII and DIII ones ($P<0.01$) but colonies from three pounds of bees only had significantly higher populations than the two pound ones at DIII ($P<0.01$). At mid nectar flow (17 July) the population pattern between hiving dates was similar to that of 4 July (see above, $P<0.01$) but colonies from three pounds of bees had larger populations than two pound ones in DII and in DIII ($P<0.05$ in both cases).

The 1969 nectar flow is shown in Figure 3 and the honey production of each group is shown in Table 3. Colonies hived from two or three pounds of bees on DI produced more honey than did those hived on DII or DIII ($P<0.01$). However, for any date of hiving there was no significant difference in honey production between the two and three pound groups. Also, no definitive relationship was found to exist between the quantity of sealed brood produced by a colony in June or July and its honey production.

DISCUSSION AND CONCLUSIONS

Cold spring weather, resulting in poor foraging conditions and reduced brood nest temperature, markedly affects brood production. This was particularly evident in the DII and DIII groups where sealed brood production in 1969 (compared to 1967 and 1968) was depressed due to poor foraging conditions in early spring followed by a cold June.

The difference in numbers of adults in the colonies hived from two and three pound packages on DI was less than that of similar groups hived on DIII; this shows the high brood rearing efficiency of the individual bees in the two pound groups.

TABLE 1

Sealed brood produced by two and three pound packages hived on three spring dates (1968, 1969)

Time Periods	Size - Date Combinations						Significant Values		
	DI (ca. 15 April)		DII (ca. 27 April)		DIII (ca. 9 May)				
	2 lb.	3 lb.	2 lb.	3 lb.	2 lb.	3 lb.	Size	Date	Size X Date
1968									
June	1756+	1815	1597	1712	1118	1316	NS	**	NS
July	1567	1538	1597	1277	1477	1421	NS	NS	NS
31 May — 8 August	4490	4878	4836	4356	4123	4046	NS	NS	NS
1969									
June	1648	1574	1152	1356	878	1224	**	**	**
July	1101	1005	969	1017	980	873	NS	NS	NS
31 May — 8 August	3844	3663	3172	3504	2835	3121	NS	**	*

+ — in square inches; NS — no significant difference; * — $P \leq 0.05$; ** — $P \leq 0.01$.

TABLE 2

Quantity of sealed brood and numbers of adults produced by the experimental colonies prior to, and during the nectar flow (1969)

Time Periods	Measurements	Size-Date Combinations					
		DI		DII		DIII	
		2 lb.	3 lb.	2 lb.	3 lb.	2 lb.	3 lb.
Prior to	Adults	35700 +(NS)+	36900	26100 +(NS)+	30200	18900 +(**)+	26200
honey flow (4 July)	Sealed brood/in.2	540	473	431	468	413	378
During	Adults	39500 +(NS)+	43000	28200 +(*)+	34100	26500 +(*)+	33600
Nectar flow (17 July)	Sealed brood	548	529	577	554	569	495

NS — no significant difference; * — $P \leq 0.05$; ** — $P \leq 0.01$.

TABLE 3.

Mean and standard error of honey production (lb.) in the experimental colonies (1969)

Weight of bees when colony hived (lb.)	Hiving Dates		
	DI	DII	DIII
2	143 ± 4.7	93 ± 5.3	93 ± 10.9
3	119 ± 11.9	98 ± 19.7	95 ± 10.2

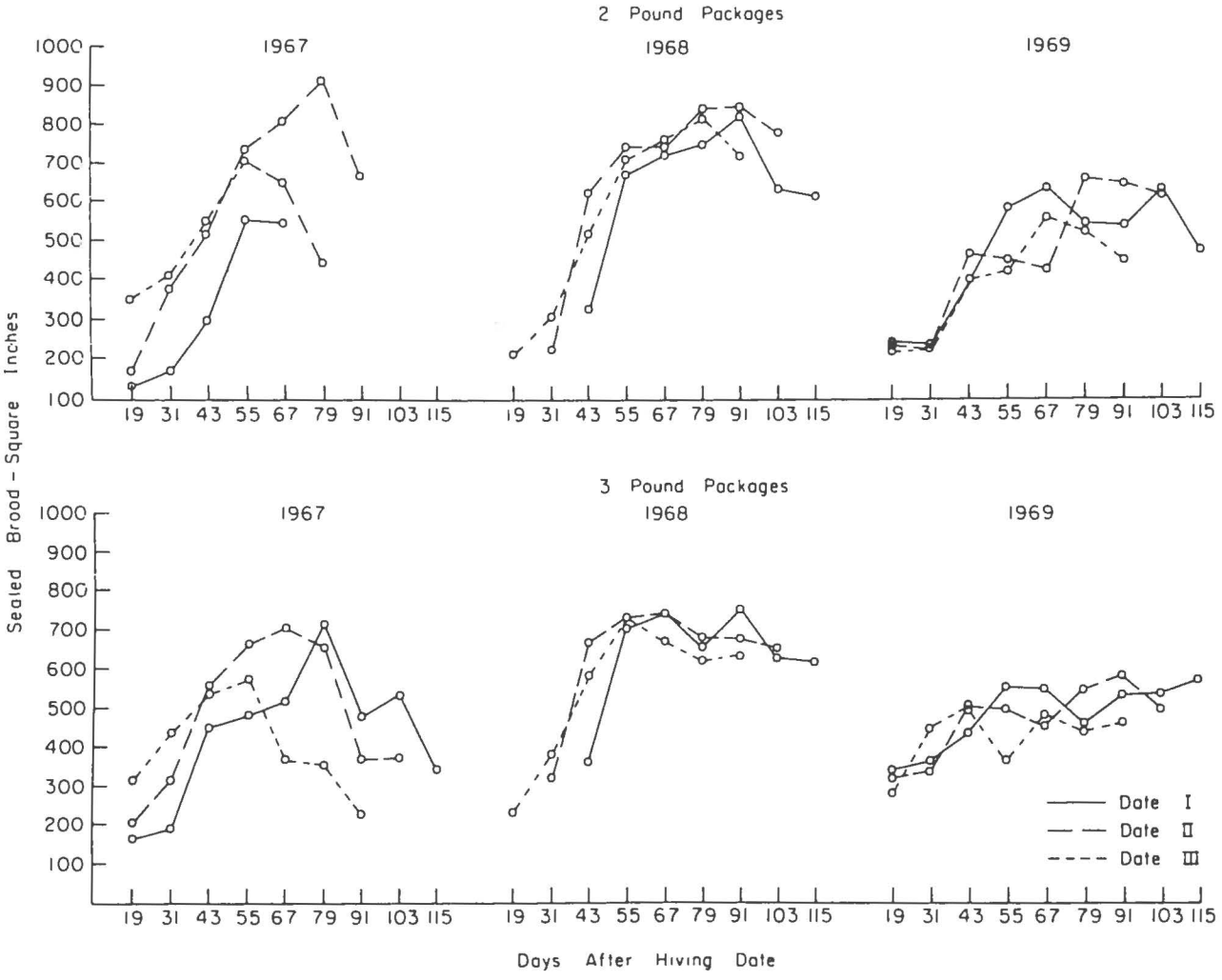

FIGURE 1

Sealed brood produced by two and three pounds of bees hived on three spring dates (1967-1969).

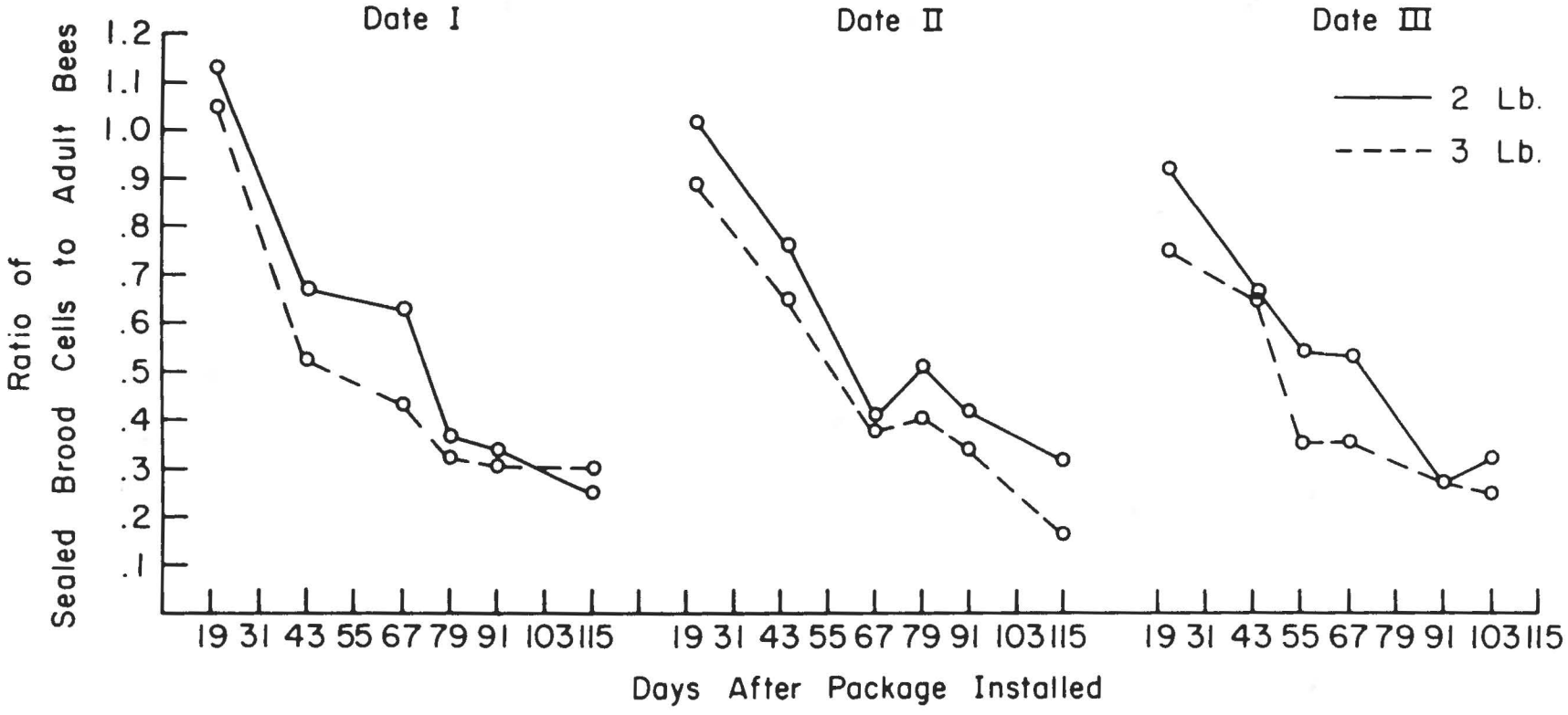

FIGURE 2

Ratio of sealed brood cells to adult bees for two and three pounds of bees hived on three spring dates (1969).

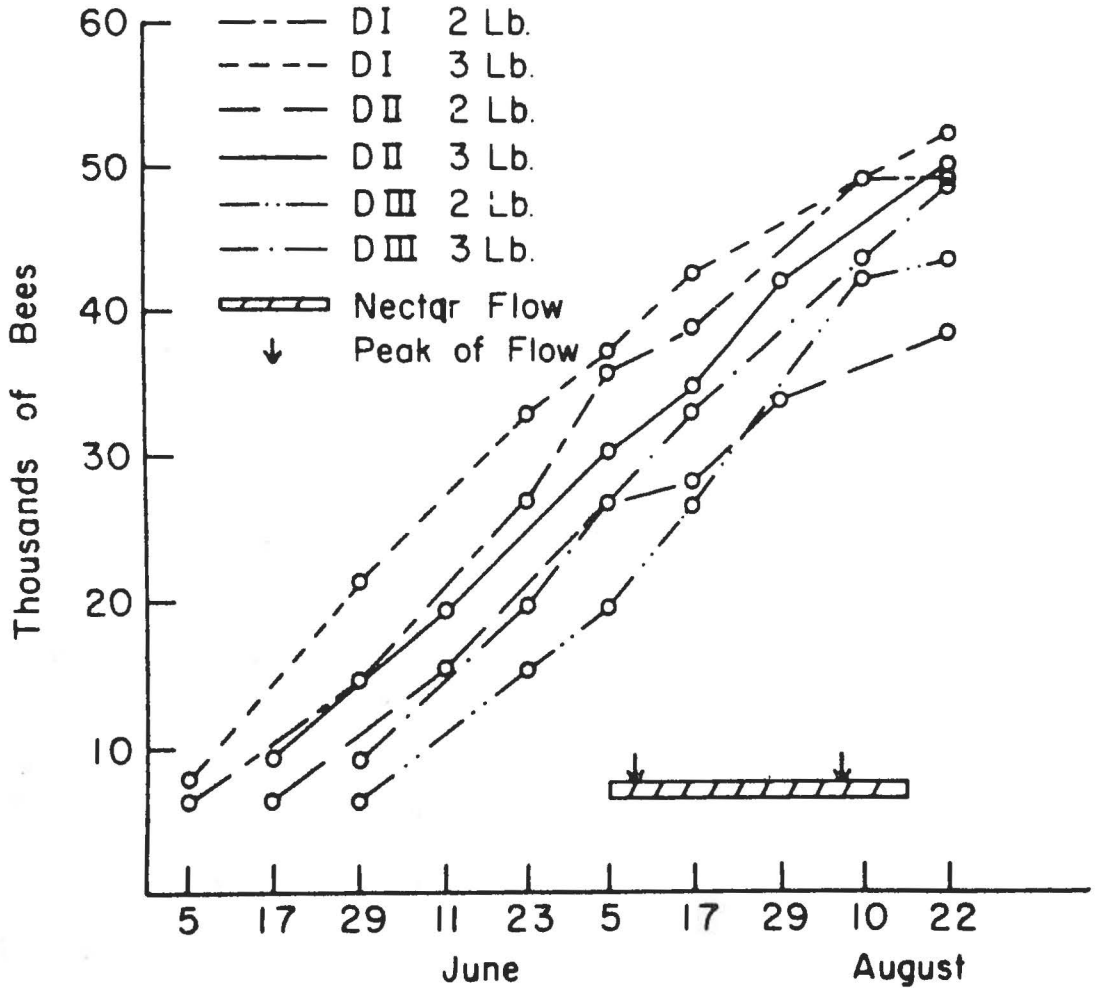

FIGURE 3

Adult bee populations of colonies hived with two and three pounds of bees on three spring dates (1969).

In 1969, the only year when adult populations were measured, the two and three pound groups of DI, and the three pound groups of DII and DIII were the only groups able to produce large adult populations in time for the nectar flow in mid-July.

It appears that nectar flows stimulate brood rearing because in all years and in all groups sealed brood reached maximum levels sometime during the main nectar flow. When a peak in brood production occurs in early July the spring foraging condition is usually excellent (e.g. 1967).

During the 1968 nectar flow more sealed brood was produced in the colonies than in those of 1969; this is attributed to the inclement weather in July 1968 which confined large numbers of foragers to their hives who might have directly or indirectly assisted in brood rearing (see Merrill 1925).

The highest adult populations in 1969 probably occurred late in August for all groups when it was too late to take advantage of nectar flows; the two and three pound groups of DI had the highest adult populations at the beginning of the nectar flows and thus had the largest honey crops. However, some factor other than population also appears to be affecting honey production because each of the colonies from three pound packages had higher populations at nectar flow but produced less honey than the two pound group at DI or produced similar amounts (DII or DIII). Perhaps because the 1969 honey crop was produced from diverse floral sources located at varying distances from the apiary, recruitment by colonies of their foragers to these sources was unequal and affected yields (see Moeller 1958).

The intensive study in 1969 showed no advantage, in terms of honey production, for the colonies hived with three pounds of bees regardless of hiving date. The two pound groups produced good honey crops when compared to the three pound ones. If adverse spring weather and foraging conditions exist then groups hived on DII or DIII require intensive management if they are to compare in honey production to those hived on DI. If good conditions prevail in May and June and adequate forage is available then probably colonies from two and three pound packages hived on DII and DIII would produce crops similar to the DI groups.

ACKNOWLEDGEMENTS

We thank the many students of the Department of Entomology (University of Manitoba) for their assistance and the Canada Department of Agriculture for providing the funds to conduct this study.

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(Received 15 March 1973)

POPULATION GROWTH AND HONEY YIELD STUDIES OF PACKAGE BEE COLONIES IN MANITOBA. II. COLONIES INITIATED WITH FOUR PACKAGE SIZES ON ONE DATE

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ABSTRACT

In 1969 and 1970 groups of colonies were initiated with one, two, three, or four pounds of bees. Amount of sealed brood, numbers of adults reared, nectar flows, and honey produced by each group were measured.

The colonies from the larger packages produced more sealed brood up to 50 days after hiving but the smaller colonies were more efficient in rearing brood; this was also true for the rearing of adults. Brood and honey production appears to be affected more by package size in a year with cold spring weather and poor foraging conditions than when good conditions prevail.

INTRODUCTION

The commercial beekeeping industry of the Canadian prairies depends upon colonies initiated from "package bees" imported each spring from the southern U.S.A. These packages usually contain two pounds of bees, but can be ordered also in one, three, or four pound sizes.

Studies of package bee performance by various authors in different areas (Nolan 1932, Kelty 1948, L'Arrivee and Geiger 1966, Geiger 1967, Pankiw 1968, Smirl and Jay 1973) indicate that, in general, colonies from two and three pounds of bees give consistent results from year to year but that there is not always a positive correlation between size of package and honey production.

This study was designed to investigate the growth rates and efficiency of colonies hived from packages with one, two, three and four pounds of bees; these factors were assessed by measuring sealed brood, and adult numbers of the colonies and total honey produced by them during two seasons.

METHODS

Packages containing one, two, three, and four [2] pounds of bees (1 lb. contains ca. 3500 bees) of a yellow strain from one shipper were hived on 3 May 1969 (8 of each weight) and on 2 May 1970 (10 of each weight). These colonies were then managed throughout the season according to commercial honey production methods common to the area. If, during the first week after hiving, a colony required a replacement queen it was considered "normal"; however, any colonies with queen losses, queen failures or supersedures, or swarming thereafter were excluded from the study.

Sealed brood (i.e. capped brood cells) areas were measured in 1969 by tracing brood patterns onto glass plates ruled in square inches, and subsequently calculating the brood

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[2] The four package sizes referred to in this paper are called group No. 1, No. 2, No. 3 and No. 4 respectively.

areas. In 1970 these data were obtained by photographing the frames of sealed brood, projecting the negatives on frosted glass ruled in square inches, and subsequently calculating the brood areas. Adult populations were estimated using an adaptation of Jeffries' (1951) method in which frames of bees were compared to a graduated numerical series of photographs of bees (see Nelson 1971 for details). Measurements of sealed brood were made at 12 days after hiving and at 12-day intervals thereafter; adult numbers were estimated at 24-day intervals.

Honey flows, and their peaks, were recorded by maintaining one colony of each group on a platform scale throughout the season; total honey produced by each colony was also weighed.

RESULTS

The results are shown in Table 1 and Figures 1, 2, and 3. Maximum amounts of sealed brood was produced on 28 July 1969 (86 days after hiving) and on 4 July 1970 (63 days after hiving). Total sealed brood produced in either year by the four groups was in the order of group 4>3>2>1. Group 1 showed a significantly lower sealed brood production than the other groups; this difference lasted to 50 days after hiving in 1969 and to 40 days after hiving in 1970 ($P<0.05$ in both cases) (Figure 1).

Adult numbers were still increasing when the study was completed (ca. 100 days after hiving). In 1969 significant differences in adult numbers occurred between groups up to 87 days after hiving and in 1970 up to 75 days ($P<0.05$ in both years). The two year average of adult populations after 100 days of colony development was: group 1 — 41,250; group 2 — 42,740; group 3 — 50,860; and group 4 — 51,200 (Figure 2).

The ratio of number of sealed brood cells to adult bees was high early in the season, declined slowly at first, and then more rapidly 30 days after hiving when adult populations were at about 15 to 20,000 bees. Group 1, in both years, maintained a higher ratio, and for a longer period of time, than the other three groups (Figure 3).

In 1969 the nectar flow extended from about 4 July to 15 August with two peaks occurring between 9—13 July and 3—7 August. Honey production was in the order of group 4>2>3>1 (see Table 1). A maximum gain of 37 pounds occurred between 9—13 July by a scale colony in group 4. In 1970 the nectar flow extended from about 19 July to 18 August with two peaks occurring between 9—13 July and 24 July — 12 August. Honey production was in the order of group 2>3>4>1 (see Table 1). A maximum gain of 79 pounds occurred between 3—7 August by a scale colony in group 4.

TABLE 1

Mean honey production (lb.) of the four experimental groups (1969, 1970)

Year	Group No. 1	Group No. 2	Group No. 3	Group No. 4	Significantly different at $P<0.05$ level
1969	55.0 ± 6.7[1]	93.4 ± 5.3	86.8 ± 19.1	118.3 ± 7.8	1—2,[2] 1—4, 2—4
1970	224.6 ± 16.7	320.7 ± 1.9	289.0 ± 19.4	248.5 ± 24.3	1—2

1. Mean and standard error;
2. Group 1 compared to group 2, unlisted comparisons were not significantly different.

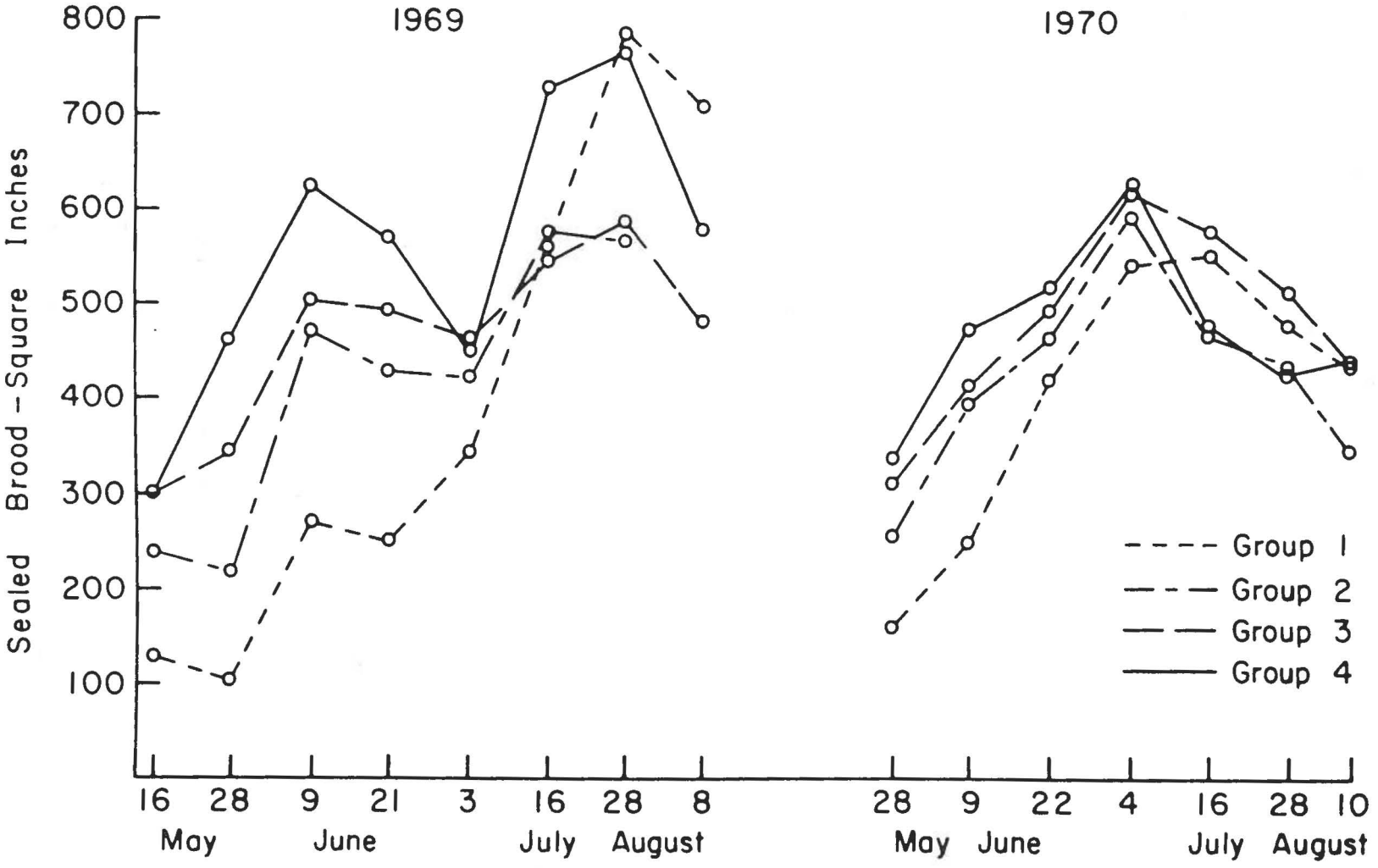

FIGURE 1

Sealed brood produced by one, two, three, and four pounds of bees (1969, 1970).

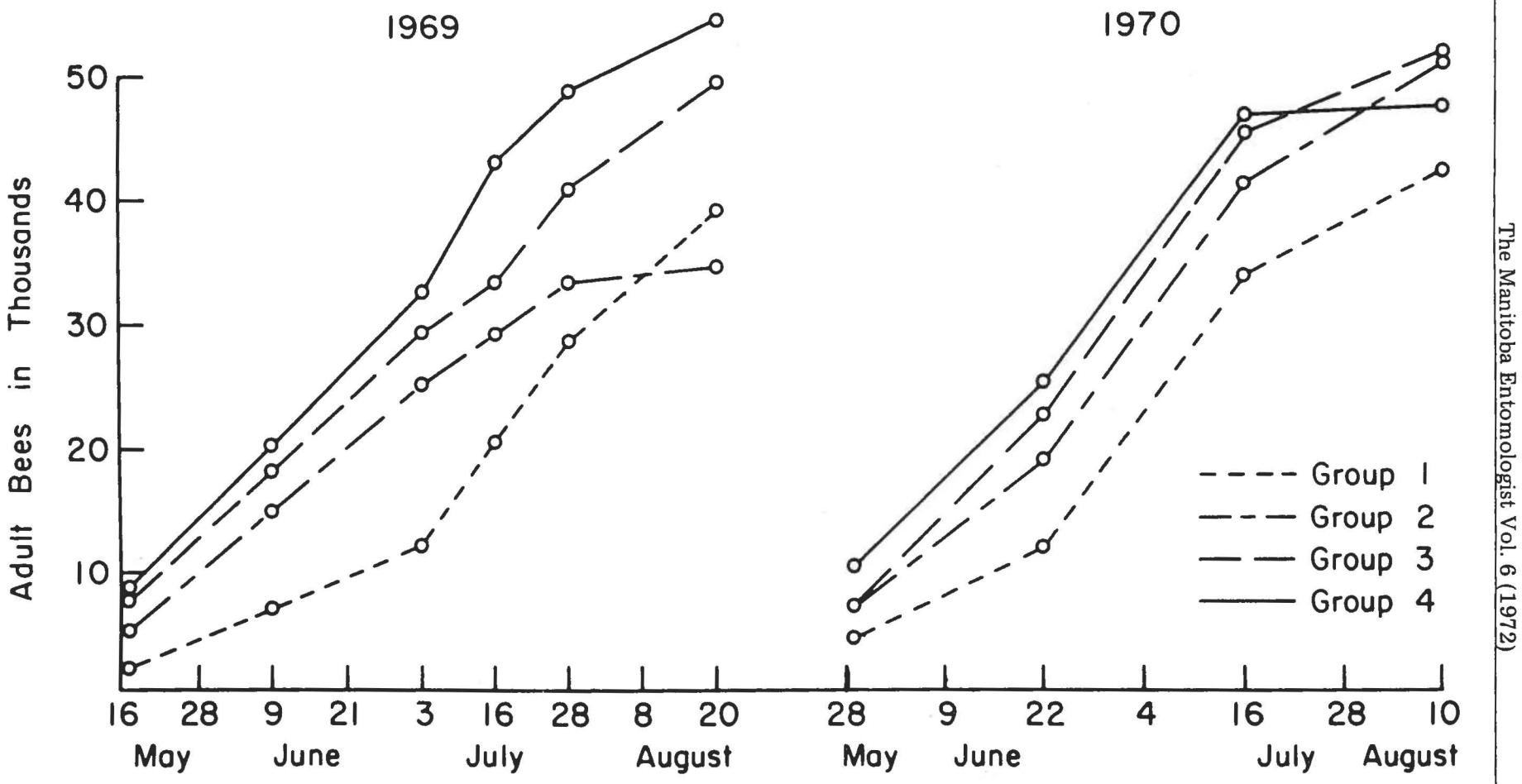

FIGURE 2

Adult bee populations of colonies hived with one, two, three, and four pounds of bees (1969, 1970).

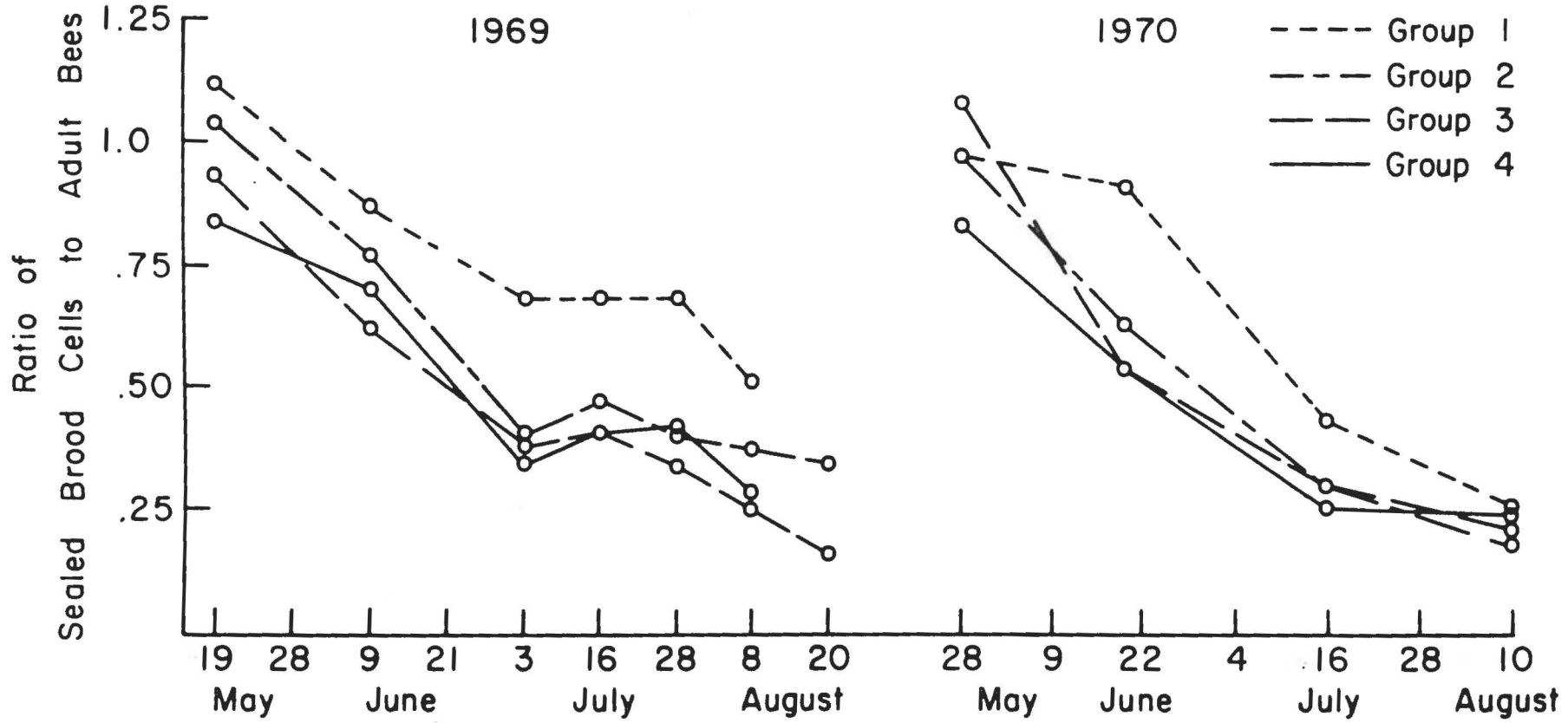

FIGURE 3

Ratio of sealed brood cells to adult bees for one, two, three, and four pounds of bees (1969, 1970).

DISCUSSION AND CONCLUSIONS

The month of June is critical for the production of the adult bees which will gather the nectar during the major nectar flows — particularly the early ones which usually occur in mid-July. A deficiency in incoming nectar and pollen in the spring (usually associated with cool or inclement weather) can cause a severe reduction in brood rearing, the reduction being most evident in the colonies with the largest brood areas (e.g. groups 3 and 4, 1969). Cool weather (e.g. June 1969) appears to affect the groups with the larger brood nests where brood mortality may be high due to chilling of brood on the outer frames and, or along the edges of individual frames.

Honey production does not appear to be greatly affected by package size in a year of good weather and foraging conditions (e.g. 1970) but is when the brood production period is hampered by cool weather and poor foraging conditions (e.g. 1969).

This study shows that maximum amounts of sealed brood are produced at about 75 days after hiving regardless of package size used. This indicates the importance of feeding pollen supplements or substitutes and sugar syrup or honey in certain years, so that brood rearing is not interrupted; otherwise peak populations occur too late for main nectar flows or for pollination. It is important to note that although Group 1 was more efficient in producing brood than the other three groups, these latter groups had a population advantage over Group 1 at the beginning of the flow.

It appears, that in this study and those of Jay (1973) and Smirl and Jay (1973), that maximum adult populations are actually attained later than 100 days (probably at about 120 days) after hiving (i.e. too late for the main nectar flows). Thus research relating to the production of maximum adult populations to occur earlier is urgently required. In addition, beekeepers should be advised to maintain scale colonies in their own areas over several years to indicate when major honey flows occur and should then manage their colonies accordingly.

ACKNOWLEDGEMENTS

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MANITOBA NECTAR FLOWS: A REVIEW OF FLOWS FROM 1924 TO 1954 WITH AN ANALYSIS OF FLOWS FROM 1955 TO 1971

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ABSTRACT

Nectar flows of 1924-1954 were compared to those of 1955-1971. Generally, the main nectar flow has been concentrated in mid-July with some variation occurring in the duration of flows from year to year. Recently, there has been a heavy nectar flow in August similar to that of the 1925-1930 period. The possible effects of various crops and agricultural practices on flow patterns is discussed.

INTRODUCTION

Manitoba is second to Alberta in Canadian honey production with 9-10 million pounds being produced annually. Mitchener (1947, 1955) kept records of nectar flows in Manitoba from 1924-1954 and showed that the major part of the honey in Manitoba is produced during a six week period in July and August. Because farming practices, and types, locations, and acreages of nectar-producing plants alter over time these records were re-examined and up-dated in this paper to 1971 with a review to assisting the beekeeping industry in Manitoba.

METHODS AND RESULTS

Data for the period 1924-1954 were taken from Mitchener's papers (1947, 1955). Data for 1955-1971 were taken from records of the Manitoba Department of Agriculture and the Department of Entomology, University of Manitoba; these records, and those of Mitchener, were supplied by various beekeepers each of whom maintained a colony of honey bees on a platform scale and noted the daily weight changes which occurred during the May to September period. Usually between 10-20 of these "scale colonies" were maintained each year.

The duration of nectar flows and the most intense flow periods are shown in Figures I and II for 1924-1971. Because few gains were made in other periods only the months of June, July and August (1924-1969) are shown in tabular form (Table 1).

DISCUSSIONS AND CONCLUSIONS

Over the years the maximum nectar flow has tended to occur in early to mid-July; thus the beekeeper obtains most of his annual honey crop during the month of July. At this time sweet clover, alfalfa, or rapeseed are in bloom. Rapeseed acreages have expanded in recent years in Manitoba giving an early summer crop of white honey. Undoubtedly the warm, sunny weather, usual at this time, contributes greatly to these nectar flows. Rainy, cool weather can delay the major flow, for example in 1971.

Except for 1969 no significant nectar flows have occurred in September during the last 15 years; in that year the flow was delayed and 7% of the honey crop was obtained in September. Although buckwheat and sunflowers frequently bloom well into September

TABLE 1

Mean monthly weight gains of scale colonies for five year periods (1924-1969), Percentage gain in brackets.

Period	Mean weight gains (lb.) by month June	July	August	Total mean weight gains (lb.)
1925-29	13.6 (5.8)	116.2 (49.4)	105.2 (44.7)	235.0
1930-34	25.9 (10.5)	140.2 (56.9)	80.4 (32.6)	246.5
1935-39	23.2 (11.3)	142.1 (69.3)	39.8 (19.4)	205.1
1940-44	27.9 (14.7)	138.1 (72.8)	23.8 (12.5)	189.8
1945-49	12.8 (6.9)	125.6 (68.1)	46.1 (25.0)	184.5
1950-54	13.1 (7.2)	120.3 (66.3)	48.2 (26.5)	181.6
1955-59	15.3 (7.0)	141.8 (64.9)	61.4 (28.1)	218.5
1960-64	23.6 (10.6)	150.9 (67.7)	48.4 (21.7)	222.9
1965-69	9.2 (4.2)	136.8 (62.9)	71.4 (32.9)	217.4

little increase in honey production appears to occur after the end of August. This was also noted by Mitchener (1955).

The heavy flows which have recently occurred in August (similar to those of the 1925-1935 period, see Table I) appear to be due to the growing of special crops (e.g. buckwheat, sunflowers) in certain areas and to the practice of not cutting alfalfa forage fields until late in August. However, in some years the August nectar flow is adversely affected by either very wet or very dry conditions.

On the basis of the above information a beekeeper should manage his bees in such a way as to produce high populations to coincide with the good nectar flows in July. This means that a beekeeper must import his bees from the U.S.A. at a time in the spring to allow the colonies to build up high populations of bees for the nectar flow. In addition, the beekeeper must continually examine his colonies to ensure that they are free of disease and that they have supplies of honey and pollen adequate to maintain high levels of brood rearing. Specific drugs are now available to assist in bee disease control and during food shortages sugar syrup and pollen substitutes, or supplements, can be fed to colonies. It is also important that ample room, to accommodate the expanding brood numbers, be provided at all times. Should the nectar flow be delayed in a particular year then measures to prevent swarming must be taken; these include the periodic removal of queen cells from brood combs, various manipulations of the brood boxes, and the provision of ventilation and adequate space for the bees to move freely within the hive.

As larger areas of specialized crops appear in various parts of Manitoba it seems advisable that separate nectar flow records be maintained in these areas in the future.

ACKNOWLEDGEMENTS

The authors thank the many beekeepers who, over the years, faithfully recorded the nectar flows of Manitoba.

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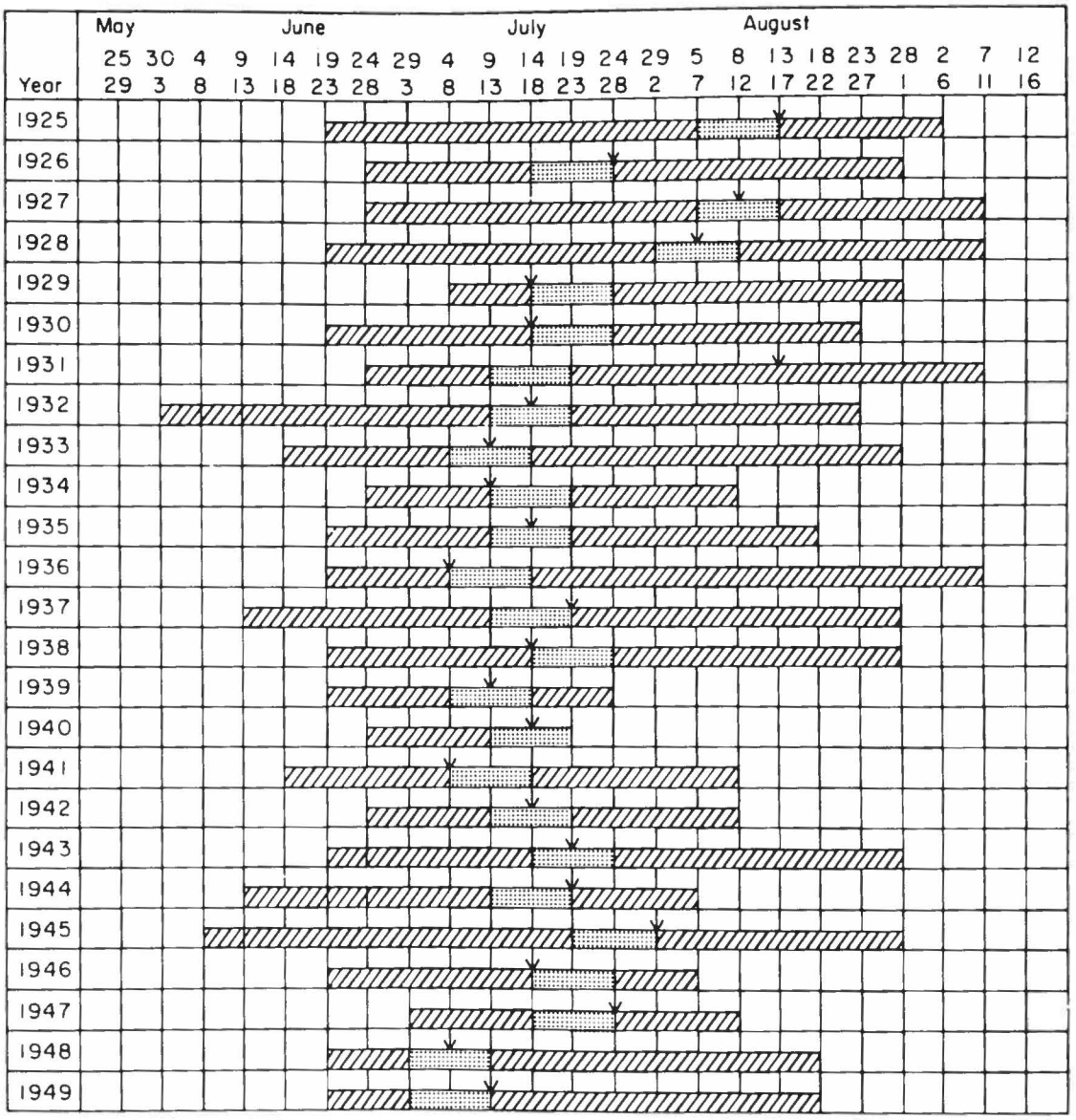

FIGURE 1

Manitoba nectar flows for the period 1925-1949.

The lined bars indicate when the mean scale colony weights showed a gain of one or more pounds during a 5 day period. The dotted bars indicate the 15 day period during which the scale colonies made the greatest gain. The arrows indicate the 5 day period during which the peaks of the nectar flows were attained annually.

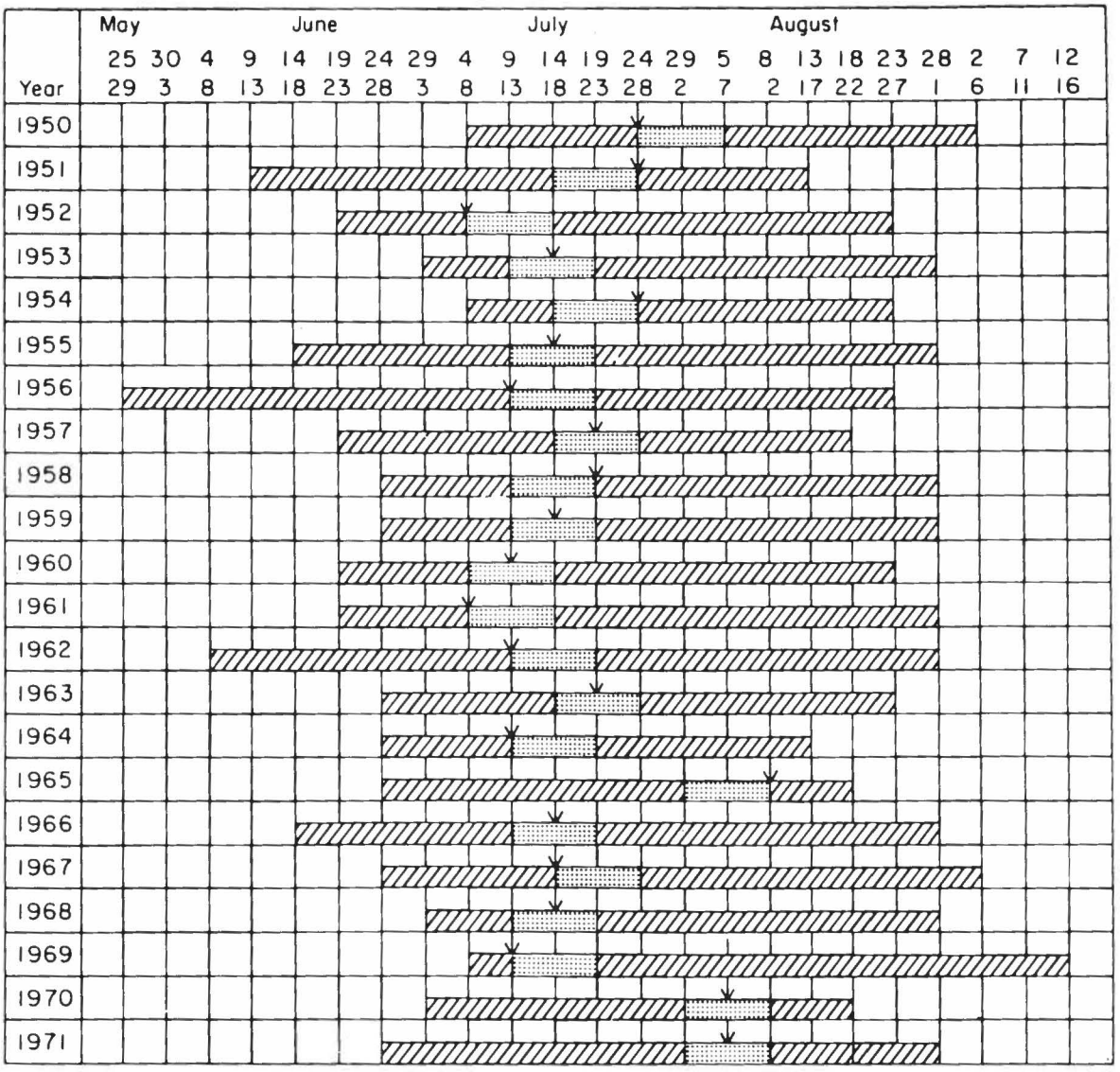

FIGURE 2

Manitoba nectar flows for the period 1950-1971.

See Figure 1 for an explanation of bars and arrows.

NUMBER OF REPLICATES REQUIRED IN EXPERIMENTS DESIGNED TO DETERMINE YIELD LOSS ON SMALL PLOTS [1]

P.A. Burnett and R.J. Baker [2]

ABSTRACT

Coefficients of variation were estimated for yield and some components of yield in cereal crops grown under a variety of conditions. High coefficients of variation were found with small plots or single plants. The replication necessary to detect, with reasonable assurance, differences of a specified magnitude is given for a range of coefficients of variation.

It is suggested that initial assessment of the effect of infestation on yield may best be accomplished by measuring kernel weight rather than yield itself. For greenhouse or growth chamber experiments, a completely random design is suggested; but, in the field, blocking is more efficient than a completely random design.

INTRODUCTION

Insects, or disease-causing agents transmitted by insects, may cause crop losses of economic significance. Resistance of plants to insects or to the disease-causing agents they transmit, is available in only a few instances so that prevention of damage to crops is usually through control of the insect by chemical or cultural means. Whether or not insect control should be undertaken obviously depends on whether or not the value of the potential crop loss is greater than the cost of control.

Studies designed to assess the effect of insect damage, or of diseases caused by agents transmitted by insects, on yield of field crops may in some cases pose problems that have important implications for the experimental design. Where insects are introduced as a treatment, it is often necessary, due to physical limitations, to use small plots or single plants; in some instances, experimental plots must be enclosed with cages for at least part of the growing season. Use of small plots may well mean that estimates of yield and of yield loss may not be very precise.

The purpose of this study was to determine the number of replicates required in experiments designed to assess yield loss due to insect damage or due to diseases caused by agents transmitted by insects.

MATERIALS AND METHODS

For this study, we have used data on yield and some of the components of yield from four sets of experiments. Set A consisted of field experiments in which wheat, oats and barley were grown separately in plots made up of four rod rows (Burnett and Robinson, 1973). The plots were arranged in blocks and six treatments, involving early and late infestations with viruliferous and non-viruliferous aphids, were applied to the plots at random. The blocks were replicated 12 times. Plot yield and average kernel weight were recorded.

Set B consisted of greenhouse experiments in which plants of wheat, oats and barley were grown singly in pots 12 cm in diameter. One of each of seven treatments, involving infestation with various levels of viruliferous and non-viruliferous aphids, was applied to each of 40 to 100 plants of each crop. Within each crop, the plants were arranged

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completely at random on the benches in the greenhouse compartment used. The number of seeds and yield for the main culm were determined as well as the number of seeds, yield and average kernel weight for the whole plant.

Set C was made up of growth chamber experiments with wheat and barley grown in 12 cm pots. For wheat, 12 cultivars were grown in each of eight replicates of a randomized block experiment. Yield per plant and number of seeds per culm were determined. Similarly, a randomized block design with 20 cultivars and seven replicates was used for barley. In this experiment, the number of seeds and yield of the main culm, and the number of seeds, yield and average kernel weight for the whole plant were determined.

Set D was a greenhouse experiment in which plants of wheat were grown singly in 12 cm pots. One pot of each of 12 cultivars was placed at random within a block. The blocks were replicated 21 times. Yields of the main culms and of the entire plants were recorded.

A coefficient of variation was calculated for yield and the component(s) of yield determined in each experiment. This was done by expressing the square root of the error mean square as a percent of the experiment mean. The coefficient of variation is the same as 'the standard error per unit as percent of the mean' used by Cochran and Cox (1957).

The method of Cochran and Cox (Section 2.21) was used to estimate the number of replicates that would be required to have an 80 percent probability of detecting a specified difference between treatments if a specified coefficient of variation were to occur in the experiment. We have assumed that there would be four treatments in the proposed experiment so that there would be 3(r-1) error degrees of freedom if r replicates were used. The method is based on the assumption that the treatment differences would be tested by a one-tailed t-test and judged significant if the t value exceeded the tabular value for the 5 percent level of probability.

The efficiency of the randomized block design relative to a completely randomized design was determined for the randomized block experiments by the methods of Cochran and Cox (1957). In this method, the block and error mean squares were used to estimate the error mean square for a completely randomized design with the same experimental material. The estimated error mean square, expressed as a percent of the observed randomized block error mean square, provided the measure of relative efficiency.

RESULTS AND DISCUSSION

Coefficients of variation for yield of wheat, oats and barley in field plots ranged from 11.6 to 15.5 percent (Table 1). In the greenhouse and growth chambers, the coefficients of variation for yields of the main culm or for yields per plant ranged from 22.1 to 51.2 percent. The latter estimates are two to three times larger than those for field data. It is evident that more replication is needed to detect a given difference with single plants than with rod-row plots.

The coefficients of variation for kernel weights were also higher for single plants grown under artificial conditions than in field plots. However, the coefficients of variation for kernel weights were generally lower than for yields. It should thus be easier to detect differences in kernel weight than in yield itself.

Coefficients of variation for number of seeds per culm or per plant were similar to those for yield. In several cases, the coefficients of variation for yield and seed number per plant were higher than those for yield and seed number on the main culm. This may be due to differences in tillering caused by environmental variation.

The relationship between the number of replicates relative to the coefficient of variation required to detect a difference (as a percent of the mean) between treatments is shown in Figure 1. This figure, in conjunction with the data in Table 1, can be used in two ways. Firstly, for example, let us consider that an investigator wishes to be able to detect, with reasonable assurance, a difference of 10 percent between treatment means of wheat grown in rod row plots. From Table 1, it is noted that the coefficient of variation for yield of wheat measured under such conditions has been estimated as 11.9 percent. From Figure 1, it will be noted that a line, drawn parallel to the horizontal axis from a point at which a

TABLE 1

Estimates of coefficients of variation for yield and some components of yield in cereal crops

Experiment	Crop	Trait measured	Coefficient of variation (%)
Field (Set A)	Wheat	Plot yield	11.9
		Kernel weight	3.4
	Oats	Plot yield	11.6
		Kernel weight	4.0
	Barley	Plot yield	15.5
		Kernel weight	3.6
Greenhouse (Set B)	Wheat	Seeds per main culm	29.6
		Seeds per plant	25.6
		Yield of main culm	29.9
		Yield of plant	26.8
		Kernel weight	13.8
	Oats	Seeds per main culm	32.2
		Seeds per plant	35.5
		Yield of main culm	32.6
		Yield of plant	37.4
		Kernel weight	13.7
	Barley	Seeds per main culm	18.6
		Seeds per plant	34.7
		Yield of main culm	22.1
		Yield of plant	35.0
		Kernel weight	12.0
Growth chamber (Set C)	Wheat	Yield of plant	51.1
		Seeds per culm	79.7
	Barley	Seeds per main culm	25.0
		Seeds per plant	53.4
		Yield of main culm	25.7
		Yield of plant	51.2
		Kernel weight	18.5

TABLE 2

Efficiencies of randomized block designs relative to completely randomized designs

Experiment	Crop	Trait measured	Efficiency (%)
Field (Set A)	Wheat	Plot yield	165
		Kernel weight	162
	Oats	Plot yield	143
		Kernel weight	117
	Barley	Plot yield	324
		Kernel weight	174
Growth chamber (Set C)	Wheat	Yield per plant	103
		Seeds per culm	100
	Barley	Seeds per main culm	101
		Seeds per plant	102
		Yield of main culm	106
		Yield of plant	101
		Kernel weight	104
Greenhouse (Set D)	Wheat	Yield of main culm	109
		Yield of plant	119

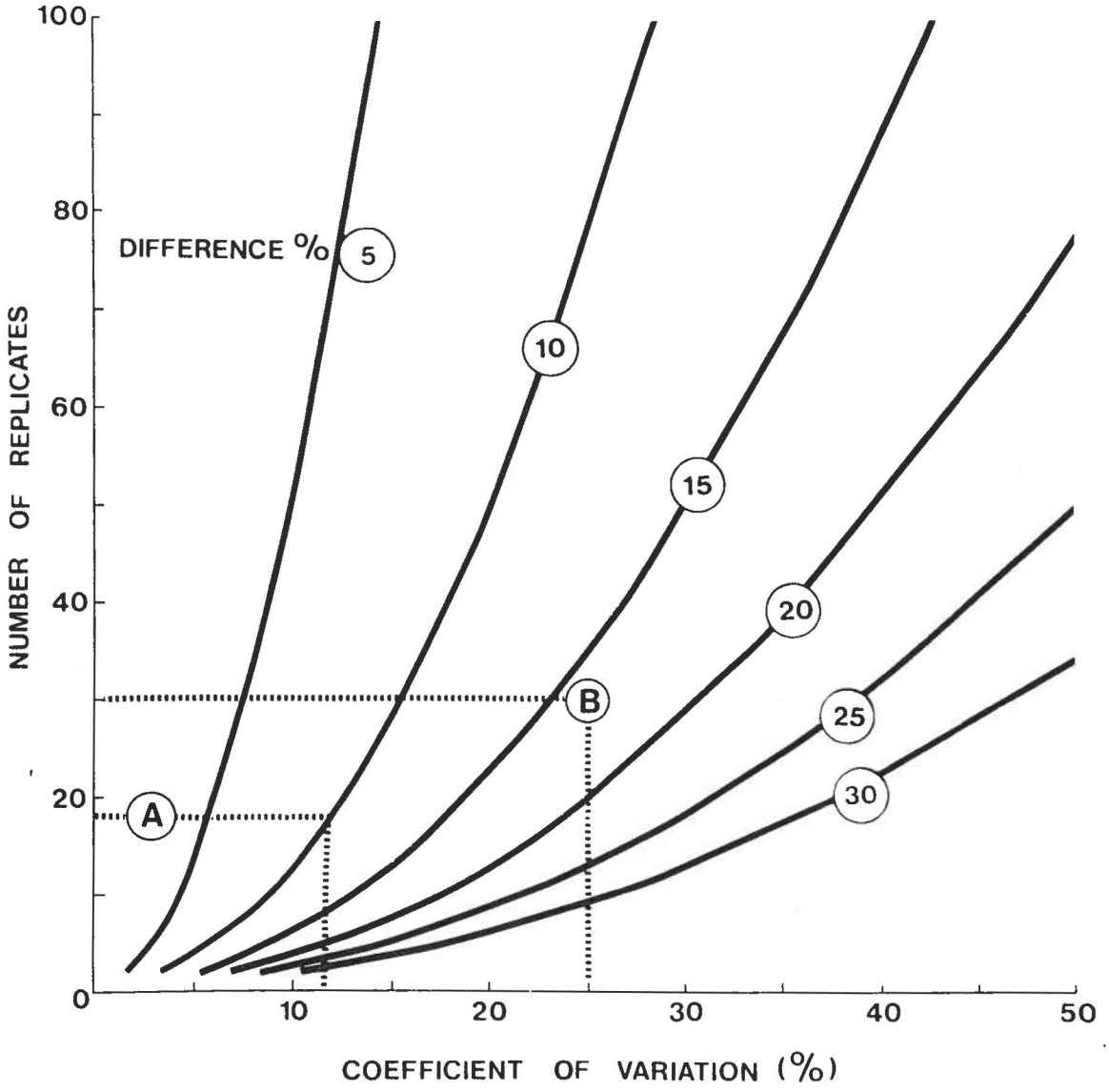

FIGURE 1. Number of replicates required to give an 80 percent probability of detecting treatment differences for various coefficients of variation.

line drawn parallel to the vertical axis and through the 11.9 percent coefficient of variation intersects the curve for a 10 percent difference (line A), indicates that 18 replicates are required for the proposed experiment.

Secondly, let us assume that an investigator wishes to assess, in a growth chamber experiment, the effect of a certain insect-transmitted virus, and let us further assume that, due to physical limitations, the maximum number of plants per treatment is 30. From Table 1 it is noted that the coefficient of variation is 25.0 percent, and from Figure 1 that the line for 30 replicates intersects the line for a coefficient of variation of 25.0 percent at a point (B) between the curves for differences of 15 and 20 percent. This level of precision may be entirely unsatisfactory for the purpose of the investigation. Perhaps the investigator should choose to abandon the experiment or to alter it in such a way as to substantially increase replication.

The information of Table 1 and Figure 1 suggests that much replication will be necessary to detect differences of 10 percent or less if small plots or single plants are used. However, many studies do not have as many replicates as would appear to be necessary and yet significant differences are found. In our experiment on barley in set C, significant differences between cultivars were obtained with only seven replicates. In that experiment, the difference between the highest and lowest yielding cultivars was 79.4 percent of the experiment mean and the coefficient of variation was 25.7 percent. With a coefficient of variation of 25.7 percent, one would require at least 20 replicates to be reasonably sure of detecting differences as small as 20 percent of the mean and about 85 replicates to detect differences of 10 percent. Burnett and Robinson (1973), on the other hand, found no significant differences in yield of wheat infected with barley yellow dwarf virus. They used 12 replicates and observed a coefficient of variation of 11.9 percent. From Figure 1, it can be seen that a difference of 12 to 13 percent may have gone undetected with 12 replicates and a coefficient of variation of 11.9 percent. For kernel weight, with a coefficient of variation of 3.4 percent, significant differences due to virus infection were observed. With such a low coefficient of variation, 12 replicates should be sufficient to detect differences as small as five percent of the mean (Figure 1).

The generally lower coefficient of variation for kernel weight suggests the possibility of using this particular component of yield as an indicator of yield loss. Certainly, in experiments where treatments do not affect the number of kernels, any loss of yield should be due solely to loss in kernel weight. For our field experiments (Set A), the correlations between kernel weight and yield per plot were 0.70 for wheat, 0.60 for barley, and 0.73 for oats.

Estimates of the efficiencies of randomized block designs relative to completely random designs are presented in Table 2. Blocking was quite effective under field conditions where there was soil heterogeneity and where there were patterns of environmental variation for which blocking could correct. With single plants grown in the greenhouse or growth chamber, on the other hand, the randomized block design was not much more efficient than the completely random design. Since the latter design presents fewer problems in the presence of missing plots, it is to be recommended for greenhouse and growth chamber studies.

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EFFECT OF BARLEY YELLOW DWARF VIRUS ON YIELD OF CEREALS IN FIELD PLOTS IN MANITOBA, 1971-72

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ABSTRACT

The yields of wheat, oats and barley were measured in plots treated with insecticide, viruliferous English grain aphids, nonviruliferous English grain aphids and in plots infested with naturally occurring aphids. There were no sigificant differences in yields of grain or weights of 1000 kernels for barley. Wheat and oats showed no significant differences in yields of grain but the weights of 1000 kernels were significantly lower in one of the two years in which the tests were carried out. The reductions were: oats — 4% by early infestation (28 days after seeding) with viruliferous aphids; wheat — 3% by natural aphid infestations or infestations with nonviruliferous aphids, 4% by late infestation (41 days after seeding) with viruliferous aphids and by 8% by early infestations with viruliferous aphids. In these trials, late infestations of viruliferous aphids did not cause economic crop loss.

INTRODUCTION

Oswald and Houston (1951) described barley yellow dwarf (BYD) as a new disease of cereals and noted that the causal agent, barley yellow dwarf virus (BYDV) was transmitted by aphids. Since then, several workers have reported yield losses in cereals attributed to infections of this virus (Endo and Brown 1957, 1963, Palmer and Sill 1966, Smith 1963, Smith and Wright 1964, Suneson and Ramage 1957). In Manitoba, studies on yield losses due to BYDV in small field plots have been reported by Gill (1967) for common wheat *[Triticum aestivum* L. em. Thell. (aestivum group)] and durum wheat *[T. turgidum* L. (durum group)], by Gill, Westdal and Richardson (1969) for wheat and oats *(Avena sativa* L.) and by Gill, Buchannon and Westdal (1969) for barley *(Hordeum vulgare* L.). These authors recorded losses varying from 20-90%, depending on crop, variety or year. In these tests, viruliferous aphids, at a rate of at least 5 aphids per plant, were placed in the plots, 20-30 days after seeding.

In the summers of 1971 and 1972, further studies were made in field plots in Manitoba, using small numbers of aphids in an attempt to more closely represent actual field infestations. In addition to the effect of BYDV on grain yield, an attempt was made to determine whether or not, in the absence of BYDV, aphid feeding affected some parameter of yield.

METHODS

The English grain aphid, *Macrosiphum (Sitobion) avenae* (Fabricius) was used for artificial infestations since it is not only a vector of BYDV, but also may cause feeding damage to kernels in developing heads of grain.

Virus-free aphids were reared on caged barley plants in a growth cabinet. Viruliferous aphids were obtained by feeding virus-free aphids on plants infected with isolate Y6407 of BYDV, maintained by C.C. Gill on oats in a greenhouse at Canada Agriculture Research Station, Winnipeg.

Field plots were at the University of Manitoba, Research Station, Glenlea, Manitoba. In 1971, Conquest barley and Harmon oats were seeded in plots, consisting of 4 rod rows, arranged in blocks that were replicated 6 times. Each block was composed of 8 plots — 4 for

each of barley and oats — arranged in a line. The crops were seeded on June 14. There were 4 treatments, as follows, allotted at random to the plots in each block: metasystox R spray, at the rate of 0.45 lb per acre, at 6 weekly intervals beginning 32 days after seeding; untreated to allow a natural infestation of aphids; viruliferous aphids distributed along the middle 2 rows of a plot at the rate of about 2 aphids per 3 plants; and nonviruliferous aphids similarly distributed. The aphids were distributed when most plants in the plots were beginning to head, about 50 days after seeding.

In 1972, the experiment differed from that of 1971 in that Manitou wheat was added and the seeding date was May 31. The blocks were composed of 8 plots of the same variety, arranged in a line and each block was replicated 12 times. Viruliferous and nonviruliferous aphids were placed in the appropriate plots at 2 stages of plant growth — June 28 and July 11, 28 and 41 days, respectively, after seeding. Two plots in every block were sprayed with metasystox R and 2 were untreated to allow natural infestation of aphids.

RESULTS

In 1971, there were no aphid colonies in the sprayed plots and only a few colonies in the naturally infested plots. In the two artificially-infested plots, the introduced aphids survived, but did not produce large numbers of young.

The barley was harvested on 4 September, and the oats on 16 September. Weights were taken for the grain from the middle 2 rows, the 4 rows and 1000 kernels for each plot (Table 1). An analysis of variance showed no significant differences between treatments for any of the weights. It appeared that the plants were too mature to be suitable for establishment of new aphid colonies and too far advanced to be affected by BYDV.

TABLE 1

Mean weights of grain harvested from field plots of Conquest barley and Harmon oats, 1971

Treatment	Weight (gm) Middle 2 rows		Whole plots		1000 kernels	
	Barley	Oats	Barley	Oats	Barley	Oats
Metasystox R.	1493	1029	3054	999	35.26	24.39
Untreated	1373	1066	2877	1010	35.48	25.28
Viruliferous aphids	1434	958	2883	1015	35.01	24.82
Nonviruliferous aphids	1407	1047	2915	1042	35.01	24.63

In 1972, aphid colonies developed on all plots except those which were sprayed with metasystox R. Symptoms of BYDV were observed only in plots which had been artificially infested with viruliferous aphids at 28 days after seeding.

Barley was harvested on 25 August, wheat on 30 August and oats on 8 September. Weights were taken for the grain from the middle 2 rows and 1000 kernels for each plot (Table 2).

An analysis of variance showed no significant differences between treatments for barley weights. For wheat, there were no significant differences among treatments for grain weights of the middle two rows but there were significant differences for 1000 kernel weights (Table 2). Weights were significantly higher in the plots of the metasystox R treatment than in plots of any other treatment. Weights were significantly lower in plots treated with viruliferous aphids than in the unsprayed plots. 1000 kernel weights were significantly lower in the plots treated with viruliferous aphids 28 days after seeding, than at 41 days after seeding.

For oats there were no significant differences among treatments for grain weights of the middle 2 rows. Analysis of variance showed that 1000 kernel weights for oats were significantly lower on plots treated with viruliferous aphids at 28 days after seeding than plots in any other treatment.

TABLE 2

Mean weights of grain harvested from field plots of Conquest barley, Manitou wheat and Harmon oats, 1972

Treatment	Weight (gm) Middle 2 rows			1000 kernels		
	Barley	Wheat	Oats	Barley	Wheat	Oats
Metasystox R.	525[a]	560[a]	494[a]	35.75[a]	29.39	34.97[a]
Untreated	501[a]	539[a]	481[a]	35.23[a]	28.50[a]	34.40[a]
Viruliferous aphids at 28 days after seeding	483[a]	512[a]	442[a]	34.92[a]	27.03	33.10
Nonviruliferous aphids at 28 days after seeding	559[a]	546[a]	488[a]	35.39[a]	28.26[a]	34.48[a]
Viruliferous aphids at 41 days after seeding	507[a]	548[a]	477[a]	35.13[a]	28.10	34.39[a]
Nonviruliferous aphids at 41 days after seeding	518[a]	544[a]	515[a]	35.16[a]	28.43[a]	34.29[a]

[a] Numbers followed by the same letter are not significantly different from one another at the 5% level (analysis of variance). Read vertically.

The results of these experiments indicate that if crops are infested with a small number of viruliferous aphids at a late stage of plant growth, no economic crop loss is experienced. With earlier infestation, such as in 1972, there may be a reduction in 1000 kernel weight. This may indicate that losses in grain yields cannot be detected because of limitations imposed by experiment size.

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OBSERVATIONS ON THE BIOLOGY OF THE FLEA BEETLE, PHYLLOTRETA CRUCIFERAE (COLEOPTERA: CHRYSOMELIDAE) [1]

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ABSTRACT

Phyllotreta cruciferae (Goeze) was introduced on the west coast of North America in the early 1920's and possibly on the east coast shortly thereafter. It quickly spread across the continent and soon became the predominant species of flea beetle on Cruciferae, to which it is largely restricted. By the late 1930's and early 1940's, it had become a serious pest of cultivated crucifers on the Prairies, and similarly, a decade later in Ontario and some eastern states.

P. cruciferae overwinters as an adult and emerges with the first extended period of warm weather in the spring. Oviposition begins shortly after emergence. The eggs, which hatch in about two weeks, are laid in moist soil near the roots of host plants. The larvae feed on the roots and develop in three to four weeks; there are three instars. There is a prepupal period of three to six days and the pupal period is seven to nine days. The period from egg to adult is six to eight weeks. Plants are most vulnerable to injury as seedlings when overwintered adults are abundant; injury to plants may continue throughout the season and may be severe in the fall when flea beetles are frequently very abundant.

A brief description of the life stages of the insect is presented. The external anatomy of the third-instar larva is described in detail.

INTRODUCTION

Phyllotreta cruciferae (Goeze), an important pest of cultivated crucifers, is widely distributed, occurring in Europe, Asia, Africa and North America (Milliron 1953, MacNay 1956, Jourdheuil 1960, Narayanan *et al.*1960, El-Sawaf *et al.*1965). Its host range is limited mainly to the Cruciferae, but it has been reported to feed on plants of other families (Westdal 1950, Feeny *et al.*1970).

The taxonomy of some of the unicolorous species of flea beetles that occur in Canada has been uncertain. Specific determination of the most common species of flea beetle, *P. cruciferae*, attacking crucifers in Manitoba was until recently unavailable. The insect has been referred to as *P. pusilla* Horn (Arnason *et al.* 1946, Westdal 1950) and *P. lewisii* (Crotch), which it closely resembles.

The main purpose of this paper is to establish that *P. cruciferae* is the species that occurs most commonly on cultivated crucifers in Manitoba. Descriptions of the life stages of the insect and observations on its life cycle and habits are also presented.

MATERIALS AND METHODS

The life cycle of the flea beetle was studied in the laboratory and in the field. For laboratory studies, flea beetles were collected in the spring from a field plot of radishes and placed in 2-l glass jars with bolting cloth over the open ends. Pots containing seedlings of radish and turnip were placed in the jars daily to provide food and oviposition sites for the beetles. The pots, together with the seedlings, were removed after a 24-hr exposure and held at room temperature (21 to 25°C) for nine days. Eggs were removed from the soil in the

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1 Based largely on a thesis presented to the Dept. of Zoology, University of Manitoba, by the senior author. 1950.

pots by floatation and held on moist blotting paper in petri dishes until they hatched. Eggs, floated from soil around seedlings exposed to flea beetles 11 days previously in outdoor cages were similarly placed in petri dishes and observed for larval emergence. Eggs deposited on the walls of the cages or on the surface of the soil were removed with a brush and placed in "cells" made of celluloid tubing (Searls 1928). The cells were 25 mm in diameter and 25 mm long, and were stoppered at one end with 3 to 4 mm of plaster of paris. The cells were pressed onto moist sand, and the date of larval emergence recorded. Larvae were reared on the roots of radish or turnip seedlings on a moist layer of plaster of paris in petri dishes (Searls 1928). The roots were covered with moist blotting paper, and the leaves allowed to protrude over the side of the dish. The dish was then covered with glass to limit evaporation. Observations were made daily to determine the duration of the larval period. Prepupae and pupae were held in these dishes until adults emerged.

In the field, flea beetles were confined for 24 hr in screen cages over seedlings of radish, cabbage and turnip. The development of the insect was then followed by examining the life stages of the insect, recovered from the soil in the cages, at known intervals of time after oviposition. Samples of the insects recovered were preserved in KAAD* for further examination.

For floatation of eggs, small quantities of soil were agitated in a saturated solution of sugar in water, or a solution of NaCl (Sp.gr.1.2.). The solution was filtered in a Buchner funnel and the eggs recovered from the filter paper.

Larvae, prepupae and pupae were separated from soil samples with a probe.

Surveys were made in several areas of Manitoba to determine the prevalence of flea beetles on rapeseed and cruciferous garden crops. During these surveys, the beetles were collected with an insect sweep net and preserved in 70 per cent ethanol. In the rapeseed survey, 50 sweeps were taken in each field visited; in the gardens, the number of sweeps varied, depending on the size of the plot. Observations on flea beetle emergence and abundance over several years were used to establish periods of flea beetle activity.

RESULTS AND DISCUSSION

Identity of *Phyllotreta cruciferae* (Goeze)

According to Milliron (1953), *P. cruciferae* was introduced on the west coast of North America in the early 1920's, but was incorrectly identified as *P. columbiana* Chittenden, from specimens collected at Agassiz, British Columbia, in 1923. The species was collected in abundance as *P. columbiana* in Minnesota in 1947, but was subsequently correctly identified as *P. cruciferae*, a well known European species (Milliron 1953). The species was taken in Philadelphia in 1943 and Milliron (1953) suggested that in view of its abundance in Delaware by 1951, it was probably "introduced also somewhere on the East Coast within the past 10 to 15 years".

In surveys of insect pests of vegetables in Manitoba in 1946 to 1949, this flea beetle was found to be very abundant on crucifers (Westdal 1946, 1947, Stephen 1948, Cole 1949). Attempts at species determination at that time were not successful, although specimens were tentatively identified as *Phyllotreta* sp. probably *pusilla* Horn. The taxonomy of the group remained uncertain for a number of years and further attempts to obtain identification were fruitless. In 1965, in response to a suggestion that the identity of the flea beetle might be resolved, 42 specimens, some from each of four insect collections in Manitoba, were forwarded to Mr. W.J. Brown, Taxonomy Section, Entomology Research Institute, Ottawa. The earliest specimen in the group was collected at Winnipeg, Manitoba, in 1936. "All the specimens", according to Mr. Brown, were "the European import *Phyllotreta cruciferae* (Goeze)".

Records in the Canadian Insect Pest Review indicate that flea beetles became a serious pest of cruciferous crops on the Prairies in the late 1930's and early 1940's. *P. lewisii*, probably an incorrect identification of *P. cruciferae*, was reported as a serious pest of

* KAAD: Kerosene — 1 part; ethanol (95%) — 9 parts; glacial acetic acid — 1 part; Dioxane — 1 part.

cultivated Cruciferae in Manitoba as early as 1936 and continued so until 1943 when the predominant species of flea beetle on crucifers was referred to simply as *Phyllotreta* spp. Later it was referred to as *Phyllotreta* sp. prob. *pusilla* Horn, and in 1965 it was identified as *P. cruciferae*. In Saskatchewan, severe flea beetle damage was first reported in 1941, with the species noted as *Phyllotreta* sp. prob. *pusilla*. Subsequently, the pest was referred to as *Phyllotreta* spp., until in 1964 it was reported as *Phyllotreta* sp. prob. *cruciferae*. In Alberta, *Phyllotreta* spp. was first mentioned in the "Review" as a pest of rapeseed in 1947, and in 1965 was referred to as *Phyllotreta* sp. prob. *cruciferae*. An unknown species of flea beetle, later identified as *P. cruciferae*, was first reported from Ontario in 1954. Similarly, an unidentified species of *Phyllotreta* was listed from Quebec in 1956 and from New Brunswick in 1957.

These records suggest that the species of flea beetle involved as the pest of crucifers on the Prairies was *P. cruciferae* and as suggested by Brown (1967), probably occurred throughout the region much earlier than the reports indicate. The occurrence of the species in Ontario in 1954 and subsequently in Quebec and New Brunwsick could have been from an introduction on the east coast, but could also have resulted from a continued eastward dispersal of the insect across the continent from its initial point of introduction.

Description of life stages

Adult: The adult is elongate — oval, about 2.2 mm long and shiny, metallic blue-black. The elytra are densely punctate, the punctures without any distinct pattern; the punctation is finer and less pronounced on the head, thorax and ventral surface of the body than on the elytra. The tarsi and segments 1 to 3 of the antennae are amber to dark amber colored; the tibiae are dark amber to black and the femurs, particularly of the third pair of legs, are similar in color to that of the ventral surface of the body.

The external morphology of the adult has been studied in detail by El-Sawaf *et al* (1965).

Egg: The egg is smooth, yellow, elongate — oval, 0.38 to 0.46 mm long and 0.18 to 0.25 mm wide.

Larvae: There are three larval instars. The newly-emerged larva is dirty-white, the head and anal plate turning brown within a short time. Following the first molt the larva is white except for the head and anal plate. For 30 first-instar larvae the mean length was 0.90 mm and the mean width 0.12 mm; the head capsule width ranged from 0.12 to 0.13 mm with a mean of 0.126 mm. For 67 second-instar larvae the mean length was 4.5 mm. Head capsule widths ranged from 0.16 to 0.21 mm with a mean of 0.175 mm. For 172 third-instar larvae the mean length was 6.68 mm and the mean width 0.56 mm. The head capsule width ranged from 0.22 to 0.29 mm with a mean of 0.264 mm.

Third-instar larva: The head (Fig. 1) is small and nutant. The labrum is slightly rounded anteriorly and has 4 pairs of setae. The lateral pair of setae are long and strong and placed medially. The 2 central setae are somewhat smaller, and medially situated. The remaining 2 pairs of setae are short and weak and situated on the anterior edge of the labrum. The clypeus is transverse and bears a single row of 3 pairs of setae. The setae are uniform in size. The frons is distinct from the epicranium, the two being separated by the frontal suture (the ecdysial line and frontogenal sulcus of Duporte 1946). The frons has 3 pairs of setae located anteriorly, medially, and posteriorly. The epicranium has a number of setae. Ocelli are absent. Each antenna (Fig. 2) is 2-segmented, short and attached to the cranium by a large membrane. The basal segment of the antenna is ring-shaped and bears 3 setae, the posterior one being strong and rounded at the tip. The mandible (Fig. 3) has 5 teeth, the median one being larger than the others. The proximal tooth is small and inconspicuous. There are 2 long setae on the outer margin and 3 at the inner margin near the base of the mandible. Of these latter 3 setae the anterior 2 are very strong, while the third is short and weak. The maxilla (Fig. 4) has a large, broad lobe which on the inner margin carries a series of 5 rather strong, stiff setae and at the end 6 smaller setae in a ring around a papilla. The maxillary palpus is conical and 3-segmented and the terminal segment is longer than the two others. The second segment bears a single seta. The labium is transverse, limited posteriorly by a

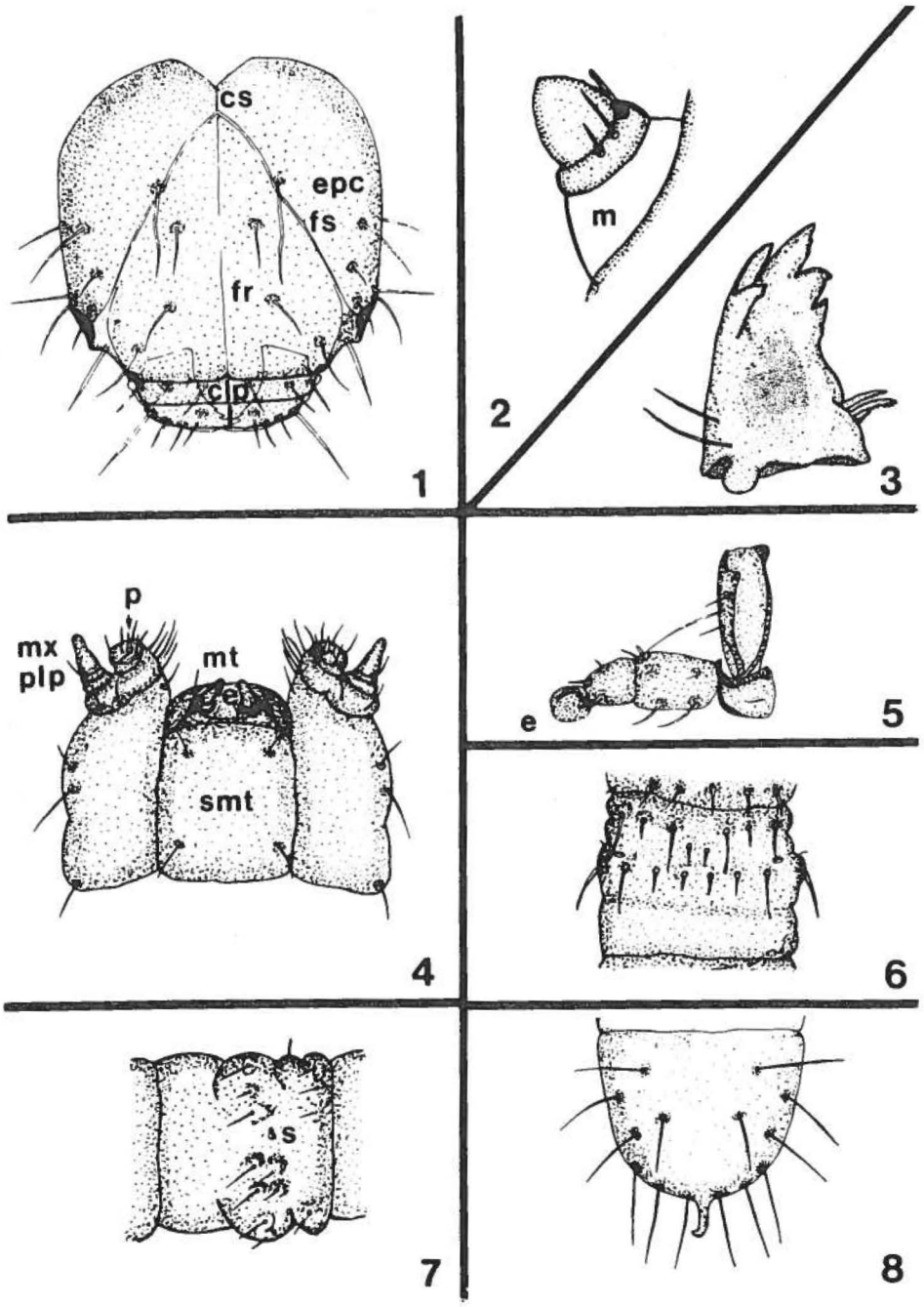

Fig. 1. Head of third-instar larva: cs — cranial suture; epc — epicranium; fs — frontal suture; fr — frons; clp — clypeus; l — labrum. Fig. 2. Antenna: m — membrane. Fig. 3. Mandible. Fig. 4. Maxilla: l — lobe; p — papilla: mxplp — maxillary palpus; e — labium; mt — mentum; smt — submentum. Fig. 5. Leg. e — empodium. Fig. 6. Dorsal view of abdominal segment. Fig. 7. Lateral view of abdominal segment: s — spiracle. Fig. 8. Anal plate.

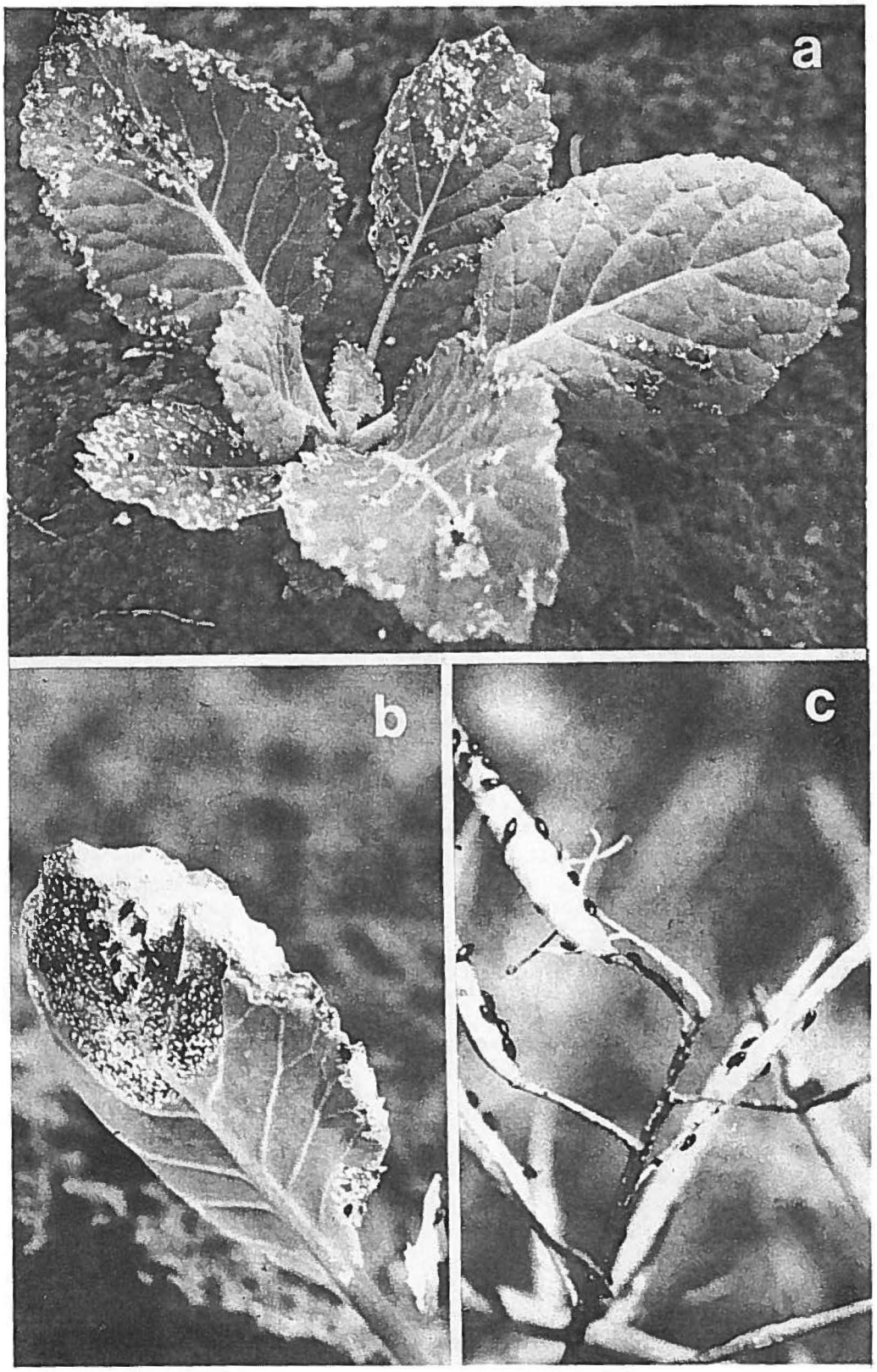

Fig. 9. Flea beetle injury to (a) cabbage, (b) cauliflower and (c) rapeseed pods.

thinly sclerotized arch and bears one pair of short setae. The labial palpus is short and 2-segmented. The basal segment of each palpus bears 2 short setae, anteriorly and posteriorly situated. The ligula is lacking. The mentum and submentun are separate. Together they form a large membranous region between the maxillae. The submentum bears an anterior and a posterior pair of setae.

The thoracic segments are distinct, each having a slightly sclerotized tergal shield. Each segment bears 4 pairs of hairs dorsally.

The legs (Fig. 5) are 5-segmented, and short. The fifth segment or "claw" is hook-shaped, moderately curved, and pointed. There is a large membranous empodium present. Segments 1, 3 and 4 each bear several strong setae. The second segment bears a single weak seta.

There are 13 abdominal segments. The first to eleventh segments (Fig. 6) are cylindrical and separated by intersegmental membranes. Dorsally each segment is divided into 3 folds, the anterior bearing 3 pairs of short setae, the second, one pair, and the third, 3 pairs. The pleural area (Fig. 7) bears 2 sets of 2 setae. Ventrally, each segment has 2 transverse folds. The anterior fold bears one pair of setae and the posterior bears 2 pairs. At the base of each of the setae there is a very inconspicuous, smooth, shiny, rounded, thinly sclerotized plate. The twelfth abdominal segment (anal plate) (Fig. 8) is spatulate and rounded posteriorly. The posterior tip continues into a small pointed outgrowth, which is sharply curved dorsally. This segment has 2 pairs of long setae on its dorsal surface, one pair anteriorly and the other pair posteriorly placed; laterally and posteriorly there are 5 pairs of setae. The thirteenth abdominal segment is retractile, cylindrical and long, with an appendage which appears to have a locomotory function.

The spiracles are small and ring-shaped (Fig. 7). There is one mesothoracic pair and there are 11 abdominal pairs.

Prepupa: The prepupa is white with a brown head and anal plate. The body is short and thick, about 3.27 mm long and 0.72 mm wide.

Pupa: The pupa is uniformly white, 2.41 mm long and 0.96 mm wide.

Life History

Adult: *P. crucifereae* overwinters as an adult in soil and trash cover. Emergence begins with the first extended period of warm weather, usually by mid May. In warm, sheltered areas, such as vegetable gardens, sweep-net collections over 3 years showed that the overwintering population reached a peak of abundance (up to 550 per 5 sweeps) in late May or early June, about 3 to 4 weeks after the first emergence. Few beetles were collected in late June and early July, but by mid July they were again abundant (up to 375 per 5 sweeps). There was a second downward trend in population size in late July or early August, followed by a large increase in population size (up to 2200 per 5 sweeps) in late August or early September.

The increase in population size of *P. cruciferae* in mid July may be peculiar to warm, sheltered areas, since in a subsequent survey of 25 rape fields during the third week of July only one crucifer flea beetle was collected, although leaf damage indicated that flea beetles had been prevalent earlier. In gardens, the increase in population size in mid July may result from the presence of both overwintered and early new generation adults, with the downward trend in population size in late July reflecting a rapid decline in numbers of overwintered adults. However, under favorable conditions, the possibility of 2 summer generations, with adults of the first generation emerging about mid July and of the second in late August, should not be overlooked. As will be shown later in this paper, development from egg to adult can be completed within 7 weeks, thus enabling 2 generations to be completed in the 15 week period from mid May to late August. Milliron (1958) reported 2 complete summer generations in the state of Delaware with first-generation adults from mid June to early July and second-generation adults in early August. Feeny *et al.* (1970) and Tahvanainen (1971) reported only one generation in New York. According to Jourdheuil (1960), it is exceptional for Halticini to be polyvoltine. He reported that dissections of summer-generation *P. cruciferae* collected in July showed that less than 10% of the females

had differentiated germinal cells, thus indicating only one complete generation. In any event, it is unlikely that more than one complete generation would develop in rapeseed fields on the Canadian Prairies, because seedlings would not emerge before late May or early June and by the time flea beetles moved into the crop the season would be too far advanced to allow for the development of 2 summer generations of adults.

Oviposition: Overwintered flea beetles oviposited in cages in the laboratory throughout the month of June, and eggs were taken from the field from June 8 to July 12, the only period sampled. A pupa was taken from the field on June 23; considering the time required to reach this stage of development, oviposition must have occurred before May 15.

In cages in the laboratory, eggs were laid singly or in groups of 3 or 4 in the soil, on the soil surface, on the sides of the cages and on the leaves and stems of plants. In outdoor cages and in the field, eggs were found only in moist soil near the roots of the host plants. In several trials in the laboratory, eggs desiccated within a few hours after oviposition unless in contact with a moist surface. Chittenden and Marsh (1920) reported a similar observation from rearing experiments with *P. pusilla.* It is thus probable that in nature, flea beetle eggs are deposited only in moist soil below the dry surface area.

Incubation: The incubation period of 3 groups of eggs was as follows:

	No. of eggs	Location or source	Incubation period (Days)	
			range	mean
	27	outdoor cage	12—15	13.1
	15	indoor cage	13—15	13.8
	32	rearing cell	10—12	11.1
Total	74		10—15	
mean				12.4

In this incubation test, 120 eggs were started, but only 62.5% hatched. Most of the eggs that failed to hatch were among those in the rearing cells. Most of the unhatched eggs showed no embryological development and were infected by fungi. Most of the eggs that remained in the soil, in either outdoor or indoor cages, for most of the incubation period, hatched. The variation in the incubation periods among the 3 groups probably was due chiefly to temperature variation, since the date of first to last oviposition ranged over a 2 week period from June 12 to June 27, when mean daily temperatures ranged from 10 to 21°C. Similar temperature variations prevailed during the rearing of the subsequent immature stages.

Larvae: In rearing dishes, larvae were quiescent for a short period after emergence and then moved about the dish possibly in search of food. Evidence of feeding by second- and third-instar larvae was observed on both the root hairs and tap root of seedling plants. In a few cases, larvae burrowed into the plant near the juncture of the root and stem and tunnelled into the stem.

Exuviae were extremely difficult to locate among root hairs of the food plants during rearing studies because of the minut ness of the larval stages. Hence, it was not possible to make progressive observations on the instars. However, head capsule measurements from another series of larvae indicated that there were 3 larval instars, the last including an active feeding stage and a quiescent prepupal stage.

First-instar larvae did not become established in the rearing dishes, but second-instar larvae from outdoor cages were reared to adult. The date of oviposition was known and using the mean incubation period, the date of larval emergence was deduced. For 16 larvae, for which the pupation date was also known, the larval period, including that of the prepupal stage, was 25 to 34 days.

Prepupa: The commencement of the prepupal period was marked by a cessation of feeding, a decrease in locomotor activity and a shortening and thickening of the body of the third-instar larva. During this period, the larvae formed small earthen cells within which pupation occurred. The prepupal period for 16 individuals was 3 to 6 days.

Pupa: The pupal period, for 16 individuals ranged from 7 to 9 days. In the laboratory, newly-emerged adults were white and their punctation was evident. Slight darkening of the cuticle was noticeable after about 6 hr but it took more than 48 hr to attain the characteristic adult coloration.

Hosts

The known host plants of *P. cruciferae* in Manitoba are all within the family Cruciferae and are as follows:

Brassica campestris L.	Polish rape
B. kaber (DC) Wheeler var. *pinnatifida* (Stokes) Wheeler	Wild mustard
B. napus L.	Argentine rape
B. oleracea L. var. *capitata* L.	Cabbage
B. oleracea L. var. *botrytis* L.	Cauliflower
B. oleracea L. var. *italica* Plenck.	Broccoli
B. oleracea L. var. *gemmifera* Zenker	Brussel sprouts
B. caulorapa Pasq.	Kohlrabi
B. rapa L.	Turnip
Armoracia lapathifolia Gilib.	Horseradish
Cardaria draba (L.)	Hoary cress
Descurainia sp.	Tansy mustard
Lobularia maritima (L.) Desb.	Sweet alyssum
Raphanus sativus L.	Radish
Thlaspi arvense L.	Stinkweed

Injury, attributed to this species, has also been noted on beets, *Beta vulgaris* L., lamb's quarters, *Chenopodium album* L. and common buckwheat, *Fagopyrum esculentum* Moench. Scott (1929) reported that *P. cruciferae*, among other species of flea beetles, seriously damaged beet crops in Kurdistan, whereas Schrier (1967), in Austria, indicated that *Phyllotreta* spp. did not injure sugar beets. Feeny *et al.* (1970), in an extensive study, and others (Chittenden 1927, Newton 1928, Milliron 1953) have indicated that *P. cruciferae* has a narrow host range limited almost exclusively to the Cruciferae and closely related families. Reports of *P. cruciferae* feeding on plants of other families may be in error, in that this species may have been feeding on cruciferous weeds among crop plants observed, as suggested by Chittenden (1927), or plant injury may have been caused by species of flea beetles other than *P. cruciferae*. Indeed, collections of flea beetles on various crops in Manitoba indicate that damage to beets is not caused by *P. cruciferae* (Table 1), but by *Psylliodes punctulata* Melsh., a species that is not prevalent on Crucifers (Tables 1 and 2 and Westdal unpublished). Similar observations were noted by Dorst (1938) and Frost (1949).

Flea Beetle abundance and nature of injury

In Manitoba, flea beetles emerge from hibernation with the first warm weather in the spring. The species usually collected earliest is *P. punctulata* followed shortly by *Phyllotreta striolata* (F.). *P. cruciferae* usually does not appear in collections until 1 to 4 weeks later (Westdal 1947, Tahvanainen 1971); it is the predominant species on cultivated crucifers (Tables 1 and 2, Westdal 1946, 1947, Feeny *et al.* 1970, Tahvanainen 1971). Extremely large populations may develop during the season as evidenced by collections of 2200 specimens in 5 sweeps (Cole 1949).

The characteristic type of injury to plants consists of small holes or pits in the epidermis of leaves (Fig. 9). Although the feeding injury does not penetrate the leaf completely, the tissues below the injury eventually dry up and break or fall out giving a shot-hole appearance. Plants are most vulnerable to injury as seedlings, when heavy infestations of flea beetles may severely damage the cotyledons and first leaves, or destroy

TABLE 1

Relative abundance * of three species of flea beetles collected throughout the season on some garden crops in Manitoba, 1946

Crop	*Phyllotreta cruciferae*	*Psylliodes punctulata*	*Phyllotreta striolata*
Cabbage	176	1	1
Turnip	383	1	2
Radish	213	7	4
Cauliflower	634	0	0
Beet (table)	1	4	0

* Mean per 25 sweeps.

TABLE 2

Relative abundance * of three species of flea beetles collected in rapeseed fields in Manitoba during the period June 19 to 23, 1956

Field Location	*Phyllotreta cruciferae*	*Psylliodes punctulata*	*Phyllotreta striolata*
Morden (field 1)	173	2	0
Morden (field 2)	423	0	1
Altona (field 1)	39	0	1
Altona (field 2)	13	2	0
Grosse Isle	9	1	0
Balmoral (field 1)	54	0	4
Balmoral (field 2)	39	1	1
Teulon (field 1)	1	1	2
Teulon (field 2)	21	0	1
Gunton	51	9	0
Fisher Branch	0	0	0
Framnes	0	1	0
Arborg	0	0	0
Winnipeg Beach	1	1	0

* Mean per 50 sweeps.

the plants (Dorst 1938, Westdal 1946, MacNay 1956, Weiss 1955, and Milliron 1958). Older plants may also suffer considerable flea beetle damage. With light infestations, injury is often restricted to the edges of leaves, resulting in the leaf margins drying and curling. With heavy infestations, leaves, petioles, seed pods and stems may be attacked, leading to complete shrivelling of tissues and shattering of pods.

No information is available on the effect of larval feeding on plants.

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DISTRIBUTION OF TERRESTRIAL SLUG SPECIES IN MANITOBA

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ABSTRACT

Three species of slugs were identified during a survey of gardens in the agricultural areas of Manitoba. *Agriolimax laeve* (Müller), a native species, was widely distributed; while *Agriolimax reticulatus* (Müller), an introduced species, occurred in many localities in Manitoba. Another introduced species, *Lehmania valentiana* (Férussac), has so far been restricted to greenhouses in the Winnipeg area.

INTRODUCTION

Slugs have not been a significant economic pest in Manitoba, and neither the species nor their distribution is known. There were very few reports of slugs in the province prior to 1946. However, in recent years slug damage in market and home gardens has become more frequent. With the increasing importance of market gardens and greenhouses in Manitoba, information on the distribution and abundance of these pests is important.

METHODS

A survey was conducted in August, 1972 in 19 towns in southern Manitoba (Fig. 1) to determine the distribution of slug species and their population densities. Four separate gardens were sampled in each of 15 smaller towns and 8 sites were sampled in Brandon, Portage la Prairie, Swan River and Winnipeg. Population densities were determined by counting the number of slugs on the surface of the ground in 5 ft. squares, chosen at random, in each garden. Two squares were counted in small gardens and 4 squares were counted in large home gardens and market gardens. Slug species in greenhouses were identified but no attempt was made to determine population densities in these restricted areas. The density classification in each town was determined by averaging all the sites sampled in that town.

Species were identified using the keys of Pilsbury (1948) and Barnes and Weil (1944). The identification of *Agriolimax reticulatus* (Müller) and *Lehmannia valentiana* (Férussac) was confirmed by L. Chichester, University of Connecticut.

RESULTS

Agriolimax laeve has a wide distribution in southern Manitoba (Table 1). This species was absent from only 1 of the 19 locations checked (Melita), where it was too dry for slugs to be found on the surface of the ground. Some may have been present in moister situations, such as cracks in the soil. *A. laeve* was most commonly found in the moister parts of gardens and along the edges of cultivated fields. In all localities, population densities were relatively low and little or no plant damage could be attributed to this slug.

Agriolimax reticulatus has a scattered distribution in Manitoba (Table 1), being found in 10 of the areas sampled. Although this species has been present in the Winnipeg area for approximately 20 years, it has been found in the Swan River area for less than 6 years. This would imply that this species is still extending its range in Manitoba, most likely benefiting from the transfer of plant material by gardeners. In all areas where this species was observed, it was causing aesthetic concern to home gardeners and economic loss to market gardeners.

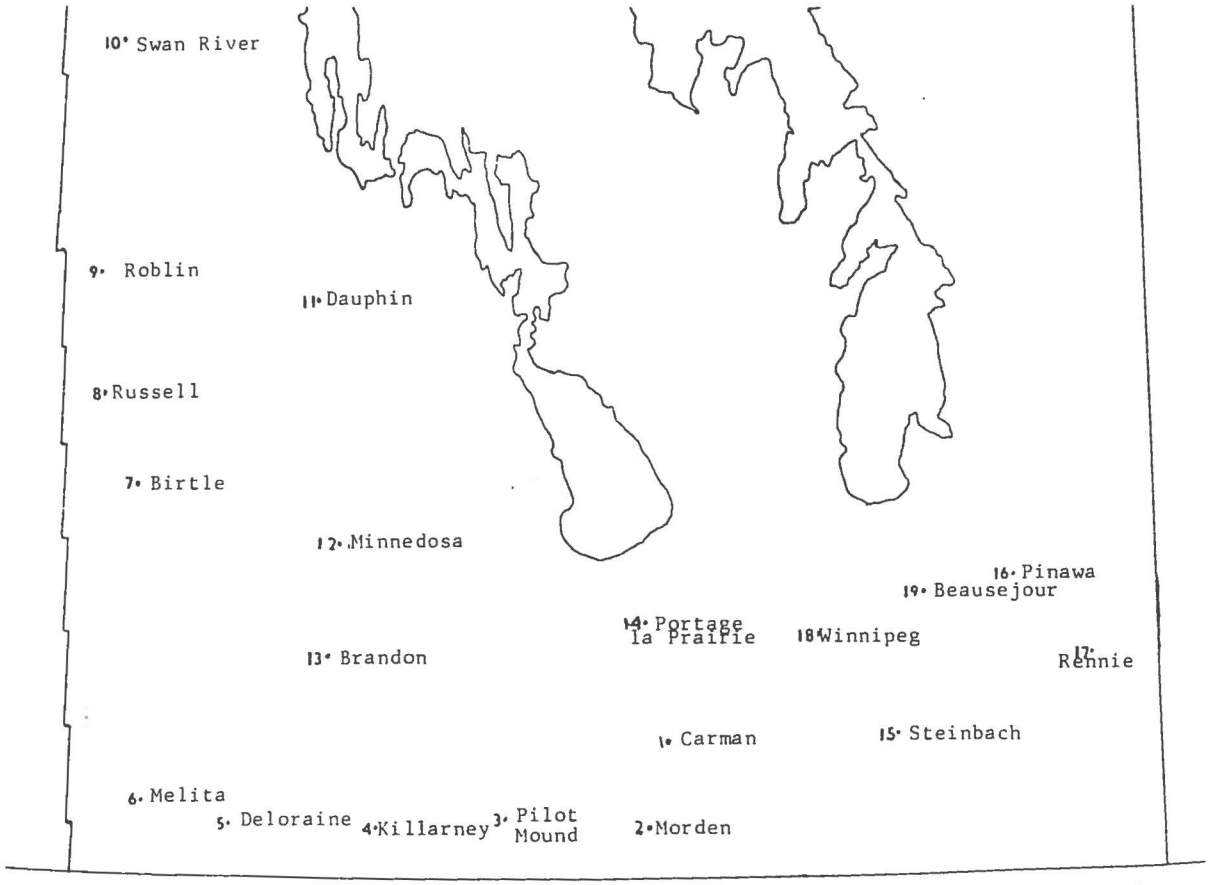

Figure 1. Towns sampled for slug distribution in southern Manitoba.

Lehmannia valentiana has a very limited distribution at present, being found only in greenhouses in the Winnipeg area, where it does little damage. It has undoubtedly been introduced into Manitoba with imported plant material. Due to the severe climatic conditions in Manitoba, *L. valentiana* does not overwinter in the field (Howe 1972) and therefore should not become a pest in gardens.

TABLE 1

Distribution of Slugs in Southern Manitoba

Town	Species Found(1)	Population Densities(2)
Carman	Al.	low
Morden	Al. Ar.	low, moderate
Pilot Mound	Al.	low
Killarney	Al. Ar.	low, low
Deloraine	Al. Ar.	low, moderate
Melita	none	—
Birtle	Al.	low
Russell	Al.	low
Roblin	Al.	low
Swan River	Al. Ar.	low, high
Dauphin	Al. Ar.	low, low
Minnedosa	Al.	low
Brandon	Al. Ar.	low, low
Portage la Prairie	Al. Ar.	low, low
Steinbach	Al. Ar.	low, low
Pinawa	Al.	low
Rennie	Al.	low
Winnipeg	Al. Ar. Lv.	low, high, low
Beausejour	Al. Ar.	low, low

(1) Species: Al. = *Agriolimax laeve;* Ar. = *Agriolimax reticulatus;* Lv. =*Lehmannia valentiana.*
(2) Population densities: low = <2/grid square; moderate = 3-4/grid square; high = >4/grid square.

DISCUSSION

L. valentiana is unlikely to become a pest in greenhouses and gardens in this province. *A. laeve*, although widely distributed in Manitoba, cannot be considered a pest species, because of its low population density and preference for uncultivated land. Although all slug species may be aesthetically displeasing, only *A. reticulatus* can be considered a pest species in Manitoba gardens. *A. reticulatus* appears to be extending its range to all cultivated parts of the province and often attains high population densities.

Chemical control may be needed occasionally, with metaldehyde pellets being effective. Normally slug populations are below pest proportions when all plant and material refuse is eliminated from the garden area. Removal of such refuse eliminates the moist habitat needed for slug survival. Since slugs are spread with transported plant material and soil, it is important that plant nursery and greenhouse owners prevent the further spread of slugs by practising stringent slug control.

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CHARACTERISTICS OF *BESSA HARVEYI* (DIPTERA: TACHINIDAE) SUGGESTING THE HISTORIC INTRODUCTION OF THE LARCH SAWFLY TO NORTH AMERICA[1]

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ABSTRACT

The North American *Bessa harveyi* (Townsend) is closely related to the two Eurasian species of *Bessa,* resembling *B. fugax* Rond. more closely in its morphological characteristics and *B. selecta* (Meigen) in its host preferences. It seems likely that a common ancestor of these three species, or perhaps two of them, had a Holarctic distribution prior to the Pleistocene with evolution into separate species occurring following geographical isolation that occurred during the Pleistocene. In terms of numbers attacked, the larch sawfly, *Pristiphora erichsonii* (Hartig) is by far the major host of *B. harveyi* in North America at present. In spite of this, *B. harveyi* is not well adapted to the larch sawfly, suggesting that the parasite switched from Nearctic hosts to the larch sawfly quite recently. This is consistent with the hypothesis that the larch sawfly is a Palaearctic species that was introduced to North America in historic times.

The larch sawfly is a holarctic defoliator of *Larix* spp. The question of its origin, natural range, and method of introduction to North America have been debated with inconclusive results (Coppel and Leius 1955, Nairn *et al* 1962). Historical and morphological evidence has been cited in support of theories that the larch sawfly entered North America by way of a Bering land bridge during the Tertiary or was introduced to the eastern United States during historical times. A third theory, that the parthenogenetic larch sawfly spread into boreal North America from the Bering refugium in post glacial times, unaccompanied by its bisexual parasites, was advanced by Pschorn-Walcher and Eichhorn (1963). An acceptable hypothesis for the origin of the larch sawfly must account for the fact that the parasite complex of the larch sawfly in North America is much poorer in species than in Europe and those which have been reported regularly are either introduced species such as *Mesoleius tenthredinis* Morley or are of doubtful geographic status (Pschorn-Walcher 1961). The reference to species of doubtful geographic status undoubtedly includes *B. harveyi*, which is the only common parasite of the larch sawfly in North America and which, in 1961, was regarded by some authors as a race of the European *B. selecta* Meigen (Herting 1960) and as a separate species by others (Mesnil 1960).

Dr. Herting, however, following the examination of an extensive series of North American specimens, changed his initial opinion and concluded, in a statement quoted by Turnock and Melvin (1963), that *B. harveyi* is certainly a distinct species differing from both of the European species, *B. selecta* and *B. fugax*.

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The relationships of the four known species of the genus *Bessa* can best be shown by the following key, reproduced from Mesnil (1960) with modifications following Hertig (1960) and the comments of Dr. Hertig in Turnock and Melvin (1963):

1. Scutellum with ± flattened pilosity and two rather fine, horizontal crossed apical setae. Distal 1/2 of palpi yellow. Inner side of front coxae covered with very thick hairs. Abdomen lacking discal setae. Burma, India, Malaysia, Fiji. Host: Lepidoptera: ..... *B. remota*

— Scutellum with erect pilosity, and without a spur on apical setae.
Palpi black 2

2. Front claws and pulvilli of ♂ very small; the last (fifth) tarsal joint hardly longer than the third joint and the claws distinctly shorter than the last joint. Discal setae lacking on third tergite and weak and rather close to the marginals on the fourth segment. N. America.
Host: sawflies, rarely Lepidoptera ..... *B. harveyi*

— Front claws and pulvilli of ♂ as long as the last tarsal joint which is distinctly longer than the third joint. Two discal setae on each of the third and fourth tergite. 3

3. Discal setae indistinct or only small ones on the fourth tergite present. Eurasia. Host: Lepidoptera ..... *B. fugax*

— Two distinct discal setae on both third and fourth tergites. Eurasia.
Host: sawflies ..... *B. selecta*

B. harveyi shows a closer resemblance to *B. fugax* in morphological characteristics and to *B. selecta* in host preference, which suggests that it is descended from an Eurasian ancestor which entered North America before the three species developed their characteristic morphological differences and host preferences.

B. harveyi is a polyphagous parasite which attacks a wide range of forest sawflies and, rarely, forest Lepidoptera. It has, however, one major host; the larch sawfly. In terms of reports of attack, only 24 per cent of the 1,624 reports of *B. harveyi* received by Turnock and Melvin (1963) were from hosts other than larch sawfly. The records of percentage parasitism also indicate that the larch sawfly is the major host of *B. harveyi:* reports of cocoon parasitism up to 59 per cent (Lejeune and Hildahl 1954, Ives and Prentice 1959) and of parasitism of fully-fed larvae up to 70 per cent (Ives 1967) are representative while reports from other hosts indicate levels of parasitism under 10 per cent (i.e. Bradly 1951, Nash 1939, Turnock and Melvin 1963).

Hawboldt (1947) recorded from 0.9 to 25 per cent parasitism (mean value 5.4%) of the European spruce sawfly *Gilpinia hercyniae* (Hartig) and noted occasionally fairly high percentages of parasitism: "From casual observations these appeared to occur most noticeably in spruce stands adjacent to larch or mixed with larch in which the larch sawfly was present in greater than normal numbers. This is taken as indicating that *Bessa selecta [=harveyi]*, being more numerous under such conditions, was attracted to *Gilpinia hercyniae* from *Pristiphora erichsonii* and that probably the parasite does make a better showing on *P. erichsonii* than it does on *G. hercyniae.*"

This strong association between *B. harveyi* and the larch sawfly could be taken as evidence of a long association between the species and,therefore, that the host species was a Holarctic species and not a Palaearctic one introduced by European settlers into North America. There is, however, evidence that *B. harveyi* is not well adapted to the larch sawfly, despite its abundance on this host. *B. harveyi* maggots in over-wintering host cocoons are much less tolerant of inundation than their hosts (Heron 1960), and under such conditions parasitized hosts commonly succumb while unparasitized hosts survive. A high proportion of the tamarack stands in the boreal forest zone (Rowe 1972) occur on poorly drained sites which are subject to periodic flooding. In addition, *B. harveyi* has a strong tendency toward bivoltinism, which leads to heavy parasite mortality in many areas where the larch sawfly is abundant and alternate hosts, fall-feeding sawflies, are rare. In Manitoba, a variable proportion of the *B. harveyi* population shows a bivoltine type of development and these individuals die without leaving progeny (Turnock 1973). In this situation, bivoltine development is minimized when parasite oviposition takes place under relatively short day lengths (mid-July to mid-August), when subsequent temperatures are low and when winter

comes early; and are maximized when oviposition occurs under long day length (late June to early July), subsequent temperatures are high and the autumn is long and warm. In some warmer climates, *B. harveyi* is less abundant on larch sawfly than it is in the boreal forest zone e.g. the parasite is scarce in south central British Columbia (Hopping *et al* 1943, Turnock 1972), and rare or apparently absent from larch plantations in Illinois, New York and Pennsylvania (Drooz 1973). The climate of these areas is normally of the type that would lead to a high proportion of fall development and abundant alternate hosts are absent.

The indications that *B. harveyi* is poorly adapted to the larch sawfly are consistent with the hypothesis that the larch sawfly was introduced into North America following European settlement of the continent. As the larch sawfly is the preponderant host of *B. harveyi* it seems highly likely that the parasite would be better adapted to the host had the association been of long duration.

This conclusion, however, leaves unanswered the question of why the larch sawfly has become the major host of the *B. harveyi*. If the association between these species is of recent origin (say 120 years), then *B. harveyi* should be better adapted to native hosts than to the larch sawfly. Prior to the appearance of the larch sawfly, *B. harveyi* could have been either a bivoltine species adapted to bivoltine hosts or a very flexible species, attacking uni, bi, or multivoltine hosts depending on their availability. The host records given by Turnock and Melvin (1963), ranked by the number of records of attack and with the hosts identified as to origin and voltinism (Table 1) provide some evidence concerning this. All but five of the Nearctic hosts are univoltine, and therefore it seems unlikely that *B. harveyi* was previously adapted primarily to bi— or multivoltine hosts.

TABLE 1. Records of hosts of *Bessa harveyi* in North America (from Turnock and Melvin 1963) arranged in order of frequency and identified as to voltinism (U = univoltine, B = bivoltine, M = multivoltine) and origin of the host species

Number of Records	Nearctic	Exotic
1235		Pristiphora erichsonii U
125	Pikonema alaskensis U	
45		Gilpinia hercyniae U—B
13-26	Neodiprion abietis U Neodiprion n. nanulus U	Pristiphora geniculata U—B Hemichroa crocea B
9	N. pratti banksianae U Neodiprion spp. U Anoplonyx spp. U Nematus limbatus U	Trichiocampus viminalis U—B
6	Neodiprion virginianus complex U—B	
5	Anoplonyx luteipes U Croesus latitarsus M Nematus spp. U—M	
4	Neodiprion lecontei U—M Trichiocampus irregularis U Nematus ventralis U—M Amauronematus spp. U Macremphytus varianus U	Nematus ribesii B—M
3	Neodiprion swainei U Pikonema dimmockii U Macremphytus spp. U	
2	Arge pectoratis U Neodiprion maurus U Platycampus spp. U Pristiphora leechi U Eupethecia luteata U	
1	Ten sawfly spp. U Four lepidopterous spp. U	Priophorus morio B—M

The alternate hypothesis, that *B. harveyi* was a flexible, polyphagous parasite seems more reasonable. Partial bivoltinism in *B. harveyi* is more likely to be related to the phenology of development of various univoltine hosts than to adaptation to bi— or multivoltine host species. For example, in Manitoba, larvae of six host species; *Hemichroa crocea* (Four), *Pikonema alaskensis* (Roh.), *P. dimmockii* (Cress.), *Nematus limbatus* Cress., *Amauronematus* spp. and *Macremphytus varianus* (Nort.) are present in late summer when second generation adults of *B. harveyi* emerge (Turnock and Melvin (1963). These species are not abundant enough to provide hosts for a significant proportion of *B. harveyi* adults produced from first generation attacks on the very abundant larch sawfly but may be abundant enough to have given the characteristic of partial bivoltinism a positive survival value in pre larch sawfly times.

The present predominance of the larch sawfly as a host for *B. harveyi* is consistent with the tendency of flexible polyphagous parasites to switch their attacks to the most abundant prey (see review by Murdoch 1969). The larch sawfly—*B. harveyi* situation appears to be an example of a polyphagous parasite greatly increasing its population density by exploiting the food resource made available by the appearance of an exotic species within its range. Examples of native parasites and predators "switching" to exotic prey, and the converse, the switching of exotic parasites to native phytophages are not uncommon in biological control literature, e.g. Griffiths *et al* (1971) note that 28 indigenous parasites attack the exotic phytophage *Neodiprion sertifer* (Geoff.) in Canada; while the exotic polyphagous parasite, *Compsilura concinnata* Meigen, is recorded as attacking 16 indigenous phytophages in Canada (from McGugan and Coppel 1962, Appendix II). The switching of *B. harveyi* to the larch sawfly differs from these examples in the marked degree that this host species has become the major host for the parasite. This has probably occurred because the larch sawfly has persisted at high levels of abundance over a large area for a comparatively long period (Turnock 1972).

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SEMIOTHISA SPECIES (LEPIDOPTERA: GEOMETRIDAE) IN SOUTHERN MANITOBA BOG FORESTS

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ABSTRACT

Three, *Semiothisa* species, *S. sexmaculata* Packard, *S. signaria dispuncta* (Walker) and *S. oweni* (Swett.), normally occur on tamarack, *Larix laricina* (Du Roi) K. Koch, in the bog forests of southern Manitoba. A fourth species, *S. bicolorata* Fabre, normally found on pines, occurred in small numbers in one year. Life histories are described and annual larval population estimates are given for three species for an 8-year period. Larval abundance of these species were significantly correlated with the larval abundance of the larch sawfly, *Pristiphora erichsonii* (Hartig), in many of the study areas.

INTRODUCTION

The *Semiothisa* complex in southern Manitoba bog forests includes three species: *S. sexmaculata* Packard, *S. signaria dispuncta* (Walker), *S. oweni* Swett. These species cohabit the bog forests with the larch sawfly *Pristiphora erichsonii* (Hartig), an abundant defoliator of *Larix* spp. across North America (Turnock 1972). The intensive study of the population dynamics of the larch sawfly by a group of investigators of the Canadian Forestry Service, Winnipeg, offered the opportunity for a study of the abundance of the *Semiothisa* complex and the mortality factors affecting it. This paper describes the life history and ecology of the *Semiothisa* species in the light of the field data collected.

In the bog forests, these *Semiothisa* species, and the larch sawfly, feed on tamarack, *Larix laricina* (Du Roi) K. Koch. *S. sexmaculata* and *S. oweni* are reported to feed on tamarack and western larch, *Larix occidentalis* Nutt. while *S. signaria dispuncta* is an extremely polyphagous feeder on forest trees (Prentice 1963). A fourth species, *S. bicolorata* Fabr., reported as feeding on pines (McGuffin 1972), was found in small numbers on tamarack in one year of this study.

These three *Semiothisa* species occur widely in the coniferous forests of North America (McGuffin 1972, Prentice 1963, Forbes 1948) and are usually found in every tamarack stand in these regions (Prentice 1963). *S. sexmaculata* occurs from eastern British Columbia to Newfoundland, north to Fort McPherson, N.W.T. and to South Massachusetts, New York and Oregon; *S. signaria dispuncta* from Newfoundland to the Queen Charlotte Islands and *S. oweni* from Newfoundland and Nova Scotia to western Alberta.

Very little information is available on the bionomics of the genus *Semiothisa* or other members of the subfamily Ennominae. Herrebout (1967) described the habitat selection of *Eucarcelia rutilla* Vill. (Diptera, Tachinidae) which parasitize larch looper populations while Turnock and Melvin (1963) reported that *(Bessa harveyi* (Townsend), a common parasite of sawfly larvae, occasionally attacked *S. Granitata.*

STUDY AREA AND PLOT DESCRIPTIONS

Larch looper populations were studied in the 7 permanent investigations plots of the Larch Sawfly Team of Manitoba. The plots were situated as follows:

Rennie — 10 miles north of Rennie Town
Telford — 7 miles east of Rennie Town
Seddon's Corner — 3 miles east of Seddon's Corner
Pine Falls — 9 miles north of the Power Dam
Riverton — 23 miles north of Riverton
Darwin — 5 miles north of the Fireguard Road

A description of these plots in terms of tamarack trees and moisture conditions of the forest floor is given in Table 1.

Buckner (1957, 1959) described in detail the vegetation of two typical tamarack bogs (Rennie and Telford plots). Tamarack stands are often mixed with black spruce *(Picea mariana* (Mill.) BSP) or swamp birch *(Betula glandulifera* (Reg.) Butler) or trembling aspen *(Populus tremuloides* Michx.) depending on the site of the plot. The understory comprises

TABLE 1

A Summary Description of the Sampling Plots

Plot	No. of living larch trees/acre (1970)	Moisture Conditions	Remarks
Rennie	267	Dry	Understory; sphagnum moss and Labrador tea
Telford	236	Very Wet	Few balsam firs; understory; sphagnum moss, Labrador tea, pitcher plants, grasses and sedges
Seddon's Corner	491	Wet	Understory; sphagnum moss
Pine Falls	551	Dry	Understory; sphagnum moss and Labrador tea
Riverton	268	Very Wet	Understory; sphagnum moss, pitcher plants, grasses and sedges
Darwin	178	Wet	Understory; sphagnum moss, grasses and sedges
Hodgson	338	Dry	Sand

TABLE 2

The Seasonal Occurrence of *S. sexmaculata* (Green Larch Looper) Larvae

Month	Year 1962	1963	1964	1965	1966	1967	1968	1969	Total
June	0	0	0	1	0	0	1	0	2
July	28	0	77	16	41	22	13	4	201
August	212	169	456	329	315	219	46	249	1,995
September	103	92	90	117	42	445	30	40	959
October	0	0	0	0	0	24	13	0	37
Total	343	261	623	463	398	710	103	293	3,194

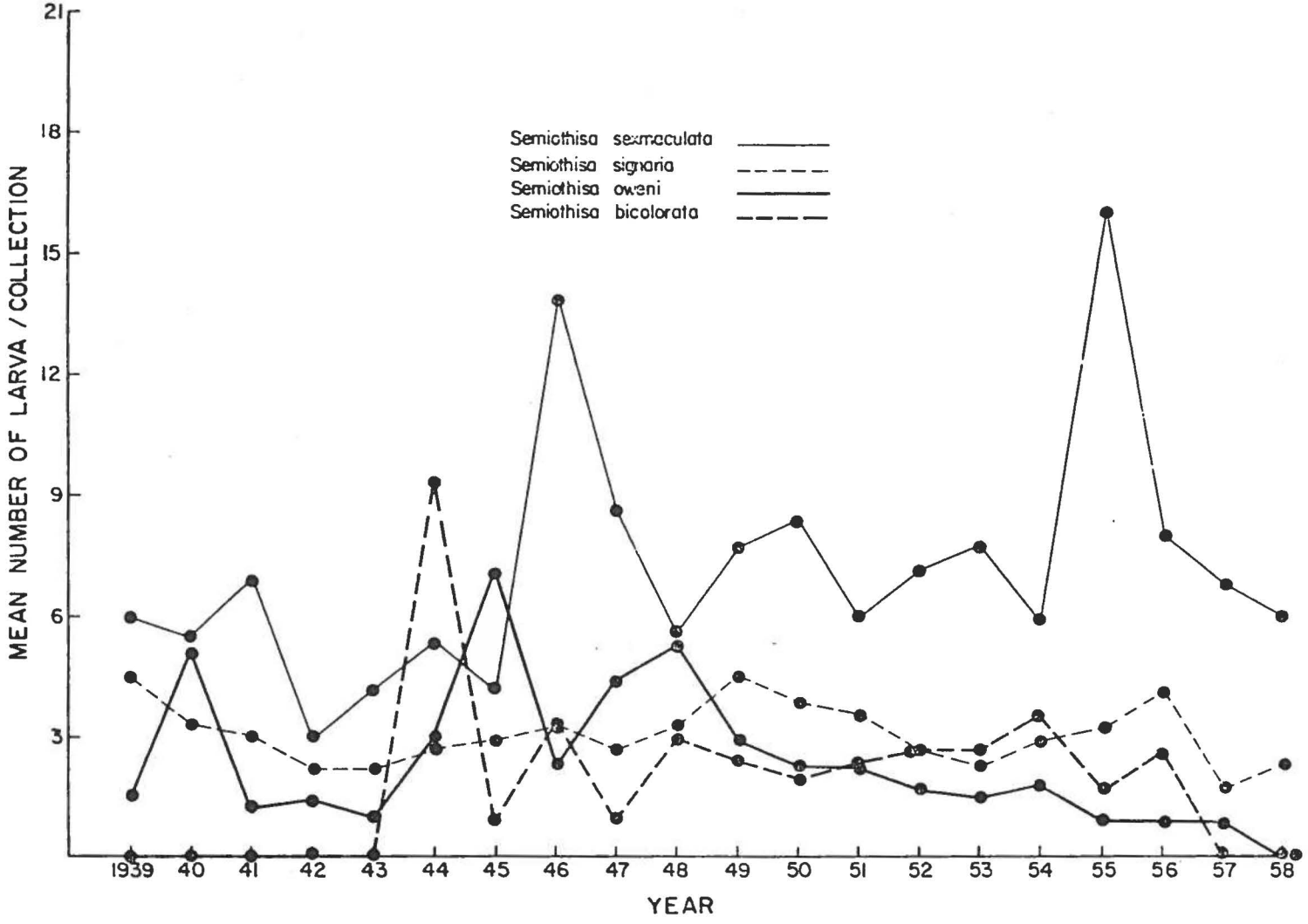

FIGURE 1. Numbers of *Semiothisa* larvae collected in Canada during a period of 20 years (from data in Prentice 1963).

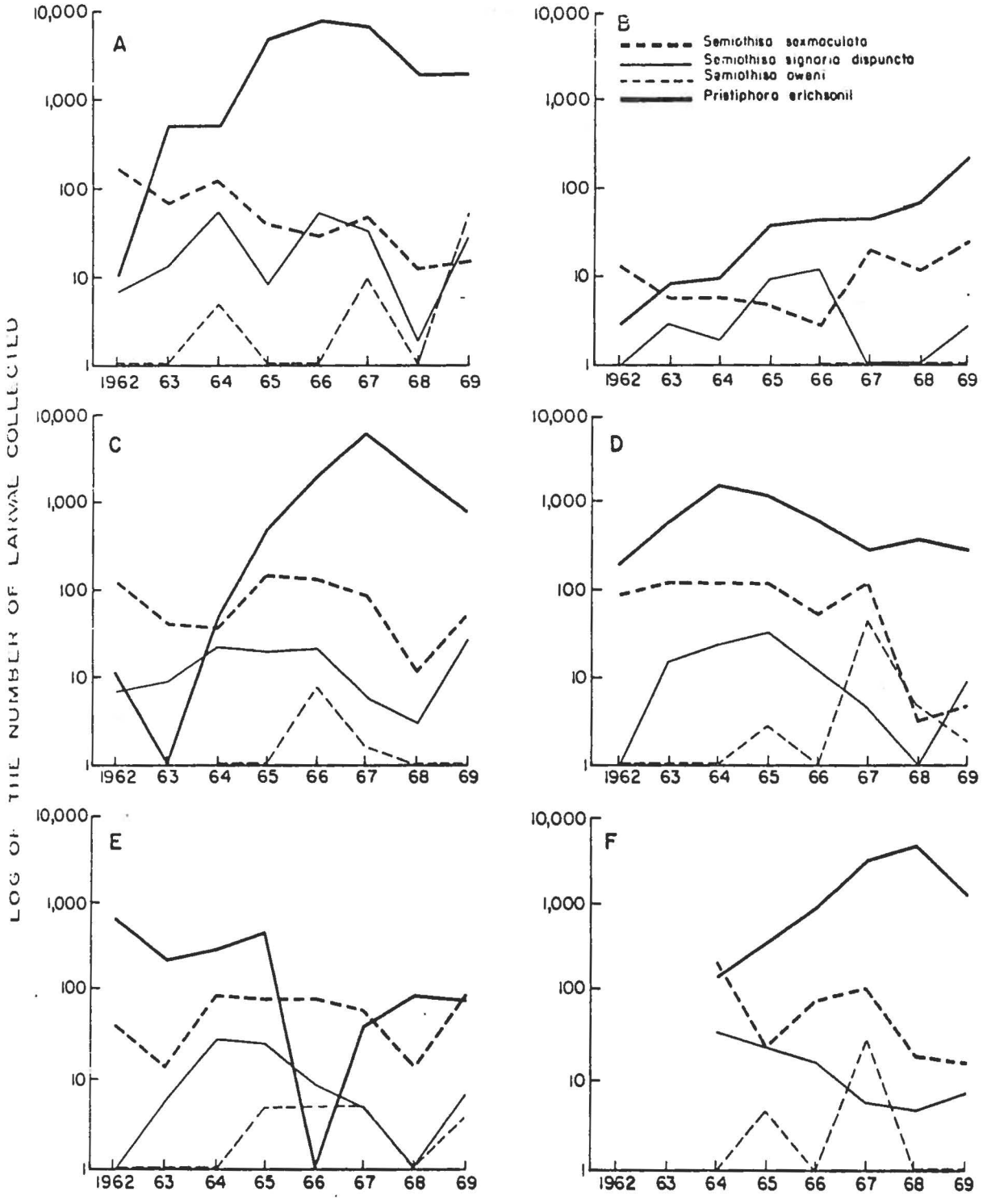

FIGURE 2. Annual variations in the numbers of *Semiothisa* larvae collected in larval drop funnels in six tamarack bogs of southeastern Manitoba, 1962-69. (A = Rennie, B = Telford, C = Seddon's Corner, D = Pine Falls, E = Riverton, F = Darwin).

different combinations of the following herbaceous plants and mosses: sphagnum and peat mosses, Labrador tea *(Ledum groenlandicum* Oeder), pitcher plants *(Sarracenia purpura* L.), grasses and sedges. Surface water may also occur, especially in wet plots such as Telford and Darwin.

CENSUS TECHNIQUES

Techniques for the study of the larch sawfly populations have also proved to be useful for measuring *Semiothisa* populations. In the case of the larch sawfly investigations, population 'fixes' were made at three points in their life cycle: egg, larval and adult stages (Ives *et al.*, 1968). Ives (1967b) used oil drop funnels to measure populations of falling larvae of the larch sawfly, a technique which has proved useful in the current study on *Semiothisa.* This technique consisted of a funnel with a two square foot collecting area directed downwards towards a trap containing a layer of light oil[1] and a fungicide[2] over water. The larvae were trapped by a strainer in the oil whereas rain water could pass through without displacing the oil (Ives *et al.*, 1968). There were 30 of these traps in each investigation plot.

RESULTS

In Manitoba, adults of the four *Semiothisa* spp. have a long emergence period, beginning in May and reaching a peak in July and August (Prentice 1963). Emergence cages in the study plots, examined every fortnight, showed emergence of *Semiothisa* adults, to be: 27 June, 2; 11 July, 14; 25 July, 12; 8 August, 6. Larvae feed from July to late October (Atwood 1944, Forbes 1948) and the pupae, which are formed after 20 to 50 days of development from the egg stage, are probably present in the bogs from July to mid-summer of the following year.

All four species tend to exhibit population peaks (Fig. 1), those of *S. sexmaculata* being particularly noticeable while those of the other species are less variable. The population trends of *S. sexmaculata, S. signaria dispuncta,* and *S. oweni* in the study plots tended to have similar peaks and dips (Fig. 2), especially in the Rennie plot where the species had a very similar pattern of fluctuation. Pine Falls and Darwin plots illustrate the same trends.

According to the number of larvae collected in larval sampling traps (oil drop funnels), the majority of larvae of *S. sexmaculata* drop from the trees in August and September (Table 2), although recoveries were made from June and until November. This confirms the year-round presence of their pupae in the Manitoba bogs, which was suggested by dates of adult emergence.

The second most numerous species of the larch looper group, *S. signaria dispuncta,* the brown larch looper, shows a similar pattern; the collection of larvae occured mainly in July and August (Table 3), a little earlier than *S. sexmaculata.* These pupae then would be present in the plot from early August and September to the next emerging time for adults.

The third species of the group, *S. oweni* (Table 4), follows closely the pattern for the green larch loopers with most recoveries occurring in August and September. In five of the plots, larval drops occurred slightly later than that of *S. sexmaculata* but the other, Seddon's Corner, showed mainly July and August recoveries.

A fourth species of larch looper, *S. bicolorata* appeared only once in the plots. In 1963, a total of 19 larvae were collected in Rennie (12) and Seddon's Corner (6) plots in August, and in Riverton (1) plot in late July. This species has not previously been reported to feed on larches (Prentice 1963).

Correlation coefficients were calculated to show the relationship between the larval numbers of each species in consecutive years, and between pairs of species in the same year and the following year (Table 5). A significant positive correlation between numbers in year

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1 Carnea pale oil 21, Shell Canada Limited.

2 Dyrene, Chemagro Corporation (¼ lb per 25 gal oil).

TABLE 3

The Seasonal Occurrence of *S. signaria dispuncta* (Brown Larch Looper) Larvae

Month	Year 1962	1963	1964	1965	1966	1967	1968	1969	Total
June	0	0	0	0	2	3	0	0	5
July	0	15	25	17	57	20	3	0	137
August	11	29	144	78	54	8	2	65	391
September	0	0	0	28	0	12	0	5	45
October	0	0	0	0	0	0	0	0	0
Total	11	44	169	123	113	43	5	70	578

TABLE 4

The Seasonal Occurrence of *S. oweni* Larvae

Month	Year 1962	1963	1964	1965	1966	1967	1968	1969	Total
June	0	0	0	0	0	0	0	0	0
July	0	0	0	4	2	3	0	0	9
August	0	0	1	7	8	26	1	3	46
September	0	0	0	0	0	38	3	0	41
October	0	0	0	0	0	1	3	0	4
Total	0	0	1	11	10	68	7	3	100

TABLE 5
Relationships between the species of larch looper larvae as analyzed by the correlation method (with larvae collected by sampling traps)

Type of Analysis	r values						
	Rennie	Telford	Seddon's Corner	Pine Falls	Riverton	Darwin	Hodgson
S. sexmaculata (n) vs S. sexmaculata (n+1)	0.232	0.003	0.155	0.005	−0.077	−0.314	----
S. signaria dispuncta (n)	0.487	−0.496	0.176	0.562	0.638	0.693	0.881
S. signaria dispuncta (n+1)	−0.191	−0.363	−0.583	0.449	−0.176	0.455	----
S. oweni (n)	0.007	0.128	0.442	0.237	0.478	0.212	0.299
S. oweni (n+1)	−0.413	0.091	0.683+	−0.456	0.771	−0.001	----
S. signaria dispuncta (n) vs S. signaria dispuncta (n+1)	−0.205	0.013	0.030	0.469	0.439	0.890*	----
S. oweni (n)	0.221	0.280	−0.027	−0.354	0.113	−0.317	−0.189
S. oweni (n+1)	0.407	0.593	0.723+	−0.104	0.816*	0.028	----
S. oweni (n) vs S. oweni (n+1)	−0.241	0.416	0.500	−0.024	0.480	−0.299	----

* Probability > 95% level.

\+ Probability > 90% level.

TABLE 6

Relationships between the larch looper and larch sawfly larvae as analyzed by the correlation method (with larvae collected by sampling traps)

Type of analysis	r values						
	Rennie	Telford	Seddon's Corner	Pine Falls	Riverton	Darwin	Hodgson
P. erichsonii (n) vs							
S. sexmaculata (n)	−0.344	0.631+	0.080	0.497	−0.047	−0.270	0.325
S. sexmaculata (n+1)	−0.347	0.818*	−0.507	0.150	−0.150	−0.467	————
S. signaria dispuncta (n)	0.479	−0.002	−0.372	0.905*	0.265	−0.844*	−0.162
S. signaria dispuncta (n+1)	−0.306	0	−0.568++	0.564++	0.182	−0.676	————
S. oweni (n)	0.558++	−0.047	0.697+	−0.339	−0.336	0.369	0.999*
S. oweni (n+1)	0.655++	0.420	0.103	−0.076	−0.081	−0.319	————

* Probability > 95% level.
\+ Probability > 90% level.
++ Probability > 85% level.

n and year n + 1, was found for only one of the three species, *S. signaria dispuncta*, in only one of the plots. The numbers of *S. oweni* in year n + 1 showed a significant positive correlation with the numbers of the other two *Semiothisa* species in year n in four of the comparisons. This suggests that *S. oweni*, the least common species, may compete with the more abundant *Semiothisa* species but that the effects of this competion are not expressed in the same larval generation. A later paper will examine the means by which these effects may be expressed in subsequent developmental stages of the insects.

Because the larch sawfly is the most abundant defoliator of tamarack in these bog forests, it could be a major competitor for the less numerous *Semiothisa* species. Evidence of relationships are shown by both graphical and correlation analysis (Fig. 2 and Table 6). Comparisons with the same year show that *S. oweni*, the least numerous larch looper species, shows a high positive correlation in three plots while *S. sexmaculata*, the most numerous, shows it in only one plot. *S. signaria dispuncta* shows a high positive correlation in the Pine Falls plot, but a high negative correlation in the Darwin plot. Comparisons with larch sawfly in year n and each of the larch looper species in year n + 1, show significant positive correlations for *S. sexmaculata* and *S. oweni* in one plot each, while *S. signaria dispuncta* shows a significant negative correlation in one plot.

The relationship between these defoliators of tamarack is obviously complex and varies between plots where biotic and abiotic factors differ. Small mammals have been shown to be important predators of the larch sawfly (Buckner 1959) and larch loopers (Bergeron 1972) and their role in the determination of population density of larch loopers will be examined in a subsequent paper.

ACKNOWLEDGEMENTS

This study was supported jointly by the Canadian Forestry Service and the Zoology Department of the University of Manitoba. Financial support was also provided by National Research Council grants 311-1749-11 and 311-1749-05. Critical analysis of both the experimental procedures and the manuscript were provided by C.H. Buckner, Chemical Control Research Institute, Ottawa, W.G.H. Ives, Canadian Forestry Service, Edmonton; J.A. Drouin and D.G.H. Ray made available valuable field assistance.

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W.R. ALLEN – 1913-1973

Willard Ross Allen died suddenly at Winnipeg, Manitoba, on June 10, 1973, at the age of 60.

Willard was born in Toronto on January 10, 1913, and as a child lived briefly in Ottawa and Charlottetown where he completed his primary education. The family later moved to Winnipeg where Willard completed his secondary education in 1932. In that year he entered the University of Manitoba, Faculty of Agriculture, where during his undergraduate years he was awarded an Isbister Scholarship. Willard specialized in entomology and upon graduation with a B.S.A. in 1936, was awarded the University of Manitoba Gold Medal for general proficiency Willard received his M.Sc. degree from the University of Manitoba, in 1939, where he studied under Prof. R.A. Wardle and the late Prof. A.V. Mitchener. The masters thesis was on the ecology of grasshoppers. He later continued graduate work under Prof. A. Glen Richards, at the University of Minnesota where, in 1952, he was awarded a Ph.D. degree with a major in insect physiology and a minor in biochemistry. The doctoral dissertation was on the enzyme systems of insect muscle.

In his undergraduate years, Willard worked with his father, the late Dr. J.A. Allen, Provincial Pathologist, Manitoba Game and Fisheries Branch; the Entomology Department of the University of Manitoba; and the Dominion Entomological Laboratory, Brandon, Manitoba.

After batchelor's graduation, Willard joined the staff of the Dominion Entomological Laboratory where, until 1942, he was engaged in research on the ecology of grasshoppers. At this point his interests led him to the field of chemical control of insects and, in 1946, he was seconded, for a year, to the Entomology Section, Defence Research Board, Ralston (Suffield), Alberta, to evaluate and select new insecticidal agents. On his return to Brandon he was made responsible for the planning and direction of research on the chemical control of field crop and vegetable insects. In 1957, he was transferred to the C.D.A. Research Station, Winnipeg, as toxicologist, a position he held until his death. In recent years, his main interest was in soil insecticides.

Willard was the author of numerous research and technical papers which attest to his stature as a scientist. However, the most lasting impression to colleagues, students, and the general agricultural community will be his generous off-the-record assistance. Although Willard was a member of the much maligned "spray and count" tribe of entomologists, he was acutely aware of the impact of insecticides on society. Indeed he objected strenuously to the registration of some of the "hot" compounds long before some of the sensational biologists began to worry about "ecology".

In his early years, Willard was active in sports, particularly hockey and golf, dramatics and debating; latterly, he took a keen interest in art and took up painting as a hobby. He always had a great zest for life and the tales he told and embellished with each retelling will always bring pleasure to those who knew him.

Willard was a member of the Kinsmen Club of Brandon, the K-40 Club of Winnipeg, and the Society of Sigma Xi. He was a charter member and past president of the Entomological Society of Manitoba, a member and former director of the Entomological Society of Canada, and a member of the Entomological Society of America. He had many friends in the insecticide development industry and in research institutions in North America.

Willard was married in 1940 to Phyllis Parry. Two sons, Richard and Gregory also survive. The family resides at 120 Linacre Road, Winnipeg.

Askew-Westdal

BOOK REVIEW

SWAN, Lester A. and Charles S. Papp. The Common Insects of North America. 750 pp. Harper & Row, New York, 1972. $15.00

A student of living things — whether he is a biologist or a layman interested in or exasperated by a particular insect in his home, garden or cottage — often has difficulty in finding a handy reference book from which he can learn about the identity, distribution, and food habits of a particular insect. Books currently available to fill this need are of two types: a) those of a natural history type that contain only a few common or conspicuous insect species, mainly to develop appreciation of the insect world; and b) those of the technical category, usually taxonomic books or monographs on various orders, families or genera of insects. Whereas the first type of book contains far too inadequate coverage of the numerous species that make the insect world, the second type is too technical for those not professionally trained in insect taxonomy. This book partly fills the need of a source book that falls somewhere between the two extremes.

The book describes — with the aid of well-drawn illustrations — the appearance, habits, and habitats of more than 2,000 common species of insects representing both the western and eastern parts of America, north of Mexico. Whenever available, both common and scientific names of the species recognized by the Entomological Societies of America and Canada, are given. In the introductory 35 pages of the book, the authors briefly present the morphology, physiology and interrelations of insects as a class. This section also includes a simple pictorial key to all insect orders. Some species from each insect order are described in 23 chapters of the book — each chapter representing one order. In addition to accurate illustrations of adult and often immature forms of each species (including the actual length of specimens), species description includes information on range of distribution, conspicuous taxonomic characters of adult and immature stages, and food. Appendices of the book include a table of geologic eras and periods in which various groups of insects evolved, a list of orders and families along with their common names, a 15-page glossary, and a bibliography of general as well as technical publications on insects. The book ends with a comprehensive index of subjects and common names.

From a technical point of view the book has several drawbacks. Scientific names of genera and species are not followed by names of authorities. Scales for measurement of insects are given in inches instead of centimeters, thus ignoring the almost universally-accepted current practice of using the metric system in technical literature. The style of writing often is not uniform. Although illustrations have added to the usefulness of the book, they hardly replace taxonomic keys which must be used to separate economically important species from other superficially similar (at least to a non-entomologist) species occupying the same niche. However, considering what a major undertaking it is to compile a book of this nature — the authors took eight years to prepare this volume — these drawbacks can be regarded as minor. Professor Swan and Mr. Papp have written an excellent source book of North American entomology. The book will be useful to students of zoology and entomology, entomology technicians and extension entomologists, in addition to all biology-oriented laymen who are curious about insects.

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BOOK REVIEW

R.W. Campbell *et. al.* "Toward Integrated Control". Proceedings of the Third Annual Northeastern Forest Insect Work Conference. New Haven, Conn., 17-19 February, 1970.

During the past few years forest insect work conferences in North America have emphasized reviews of specific themes of current importance in insect control and pest management. The above Proceedings, published as USDA Forest Service Research Paper NE - 194, 1971, documents up-to-date concepts and some specific information on integrated control, that complex and time consuming but potentially effective method of controlling forest insect pests. The work is lucid enough to be understood by biologists outside the entomological specialization and is of real value to practising insect pest control researchers and managers.

The initial impression from reading the contribution was that the whole proceedings was a valiant attempt to define the integrated control concept. This may well have been the participants' intention since this approach to the control of forest insect pests has only recently been imported into North America from Europe. Be that as it may, the sections on population quality, vertebrate and invertebrate predators, pathogens and parasites, and insecticides all effectively focused attention on some of the more important component methodologies which can be used harmoniously in forest pest control. The section on insecticides which included discussions on cost effectiveness, associated ecological problems, desirable characteristics and the role of pesticides in integrated control should be of special interest to toxicologists.

A weakness of the report was a lack of any real attempt to draw together the various components into an applicable harmonious methodology. Little was made of such important questions as spread and persistence, selectivity and safety, and evaluation of mortality data in microbial control, of autocidal control, of insect hormones and repellents and of methods of minimizing side effects of chemical insecticides. However, on the whole, the report makes for interesting and informative reading in an age of turning toward the ecological approach to pest management.

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1. The Manitoba Entomologist is printed annually and publishes articles on all phases of entomology. Each paper should contain the results of original research or review, in depth, some aspect of entomology. While the primary aims are to publish material of regional interest, papers of interest to other geographic areas or of general interest will be accepted.

2. Manuscripts should be prepared according to instructions described in the **CBE Style Manual Third Edition**, published by the American Institute of Biological Sciences, 3900 Wisconsin Ave., N.W., Washington, D.C. 20016, U.S.A.

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4. Tables and illustrations should be clear and concise, kept within reasonable limits, and should not repeat material presented in the text. Notations identifying the author and title should be made lightly in pencil on the back of each illustration. Tables should be typed separately, one to a page at the end of the manuscript.

5. Each manuscript is reviewed by at least one external referee, who will check for scientific content, originality, and clarity of presentation.