THE INFLUENCE OF THE SPRAY PROGRAM ON THE NATURAL CONTROL OF OYSTERSHELL SCALE, *Lepidosaphes ulmi* (L).

by

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I. INTRODUCTION.

The control of apple pests in Nova Scotia has developed into an arduous and expensive process so that, with six to nine sprays, it is not uncommon for a farmer to have a high percentage of cull apples. Some pests which were formally of minor importance have now developed to threatening proportions. Among these the oystershell scale, *Lepidosaphes ulmi* (L.), which had for years been of minor importance, began to emerge as one of our major pests during the 1930's. Instead of attacking isolated orchards and particularly isolated trees as appears to have been the case fifty years ago we now find, in many cases, that it is a serious pest over whole orchards. It can be controlled by applying dormant oil sprays every three or four years; it does, however, seem to be the general impression among entomologists and growers that the over-all pest situation is aggravated by the use of oils. Moreover, it is often difficult to get a sprayer on many orchards early enough to apply the spray, if cost alone were not enough to make it desirable to eliminate an extra spray application. In 1941 and 1942 large blocks of orchards at Berwick, formerly the property of the late S.B. Chute which had become heavily infested with scale, were left unsprayed. In these blocks oystershell scale disappeared and observation showed that the same thing happened in several other orchards similarly neglected. Scales from these orchards were examined in the laboratory in the early spring of 1943 by Messrs. Pickett, Stultz and Patterson. They found that, while most of the scales were dead, in some of the living scales parasites or mites were present. These proved to be the chalcid parasite, *Aphelinus mytilaspidis* LeB. and the mite *Hemisarcoptes malus* (Shimer). In a commercial orchard at Berwick, owned by A. Palmer, a light scattering of *H. malus* and *A. mytilaspidis* were also found, so in 1943 a number of materials were tested there for the control of oystershell scale as well as for their effect against the natural control agents. The results of the 1943 test combined with the fact that natural control of scale had been proven by winter examinations to be of minor importance in sprayed orchards led to the setting up of experiments designed to test the effects of the more commonly used fungicides on oystershell scale and its parasites and predators.

To digress somewhat at this point, it is worth recalling that ecologists have on numerous occasions flung the challenge to economic entomologists that they must become ecologists. At the Dominion Entomological Laboratory in Nova Scotia an attempt has been made to apply ecological concepts to the problem of apple pest control. As a result, for several years now, a study has been under way on as much as possible of the whole orchard fauna, and fundamental to this has been the need to consider the spray program as an ecological factor in a complex environment.

The study of the effects of the spray program on the natural control of oystershell scale which forms the basis of this thesis is in turn a part of the whole general ecological approach to the study of orchard pests in Nova Scotia. During the course of these experiments it became very evident that time and space are two very important factors to be considered in the investigation of orchard insect problems. The spray program which has been followed in an orchard in the years before an experiment is started has an important conditioning effect on the experiment. This can only be overcome by using the experimental materials on the same trees for several years in succession. Single row plots are limited in long term studies by the differential ability of the various species to migrate from one plot to another. The importance of the failure to consider the over-all effect of a spray program is illustrated by the advocation of elemental sulphur sprays for commercial orchards on the sole basis of their fungicidal value without relation to their effects on all other organisms. As a result of these investigations it is now known that sulphur sprays inhibit natural control of oystershell scale while bordeaux mixture, Fermate or no spray at all will allow natural control agents to eliminate oystershell scale.

II. HISTORY AND BIOLOGY OF OYSTERSHELL SCALE.

A. Origin and Distribution of Oystershell Scale.

Caesar (1914) and Quaintance (1916) state that oystershell scale is very widespread over the world and that it has been on this continent for over 150 years. Griswold (1925) gives the most complete account of the history of oystershell scale and the following summary is based on her work. Réaumur in 1738 made careful observations on the insect, his account of it being given in his "Memoires des Insectes." An interesting description of the scale and suggested remedies were found by Miss Griswold in a copy of a letter from Enoch Perley of Bridgetown, Maine to Oliver Smith in December 1794. This appeared as the first description of the scale in America in 1796 in the Rules and Regulations of the Massachusetts Society for Promoting Agriculture. Fitch in 1856 made counts of the eggs and was the first to notice parasite larvae. Walsh in 1868, Shimer in 1868 and LeBaron in 1870, and 1871 made detailed studies of oystershell scale. Riley also in 1869 and 1873 made detailed observations on its life history and development. Comstock in 1881 seems to have been the first to have noticed the two races of Lepidosaphes ulmi(L)

In the Review of Applied Entomology Series A. there are a large number of references to oystershell scale, the great bulk of them dealing with control measures or listing it as a pest from almost every place where apples are grown in Canada and the United States.

B. Historical Record of the Occurrance of Oystershell Scale in Nova Scotia.

James Fletcher, Dominion Entomologist, said in 1893 "The Oyster-shell, Bark-louse (<u>Mytilaspidis pomorum</u> Bouché) is probably the worst pest of the apple trees, concerning which this year as every other year there has been much enquiry from every province of the Dominion."

It is worth pointing out here that these outbreaks must have occurred on unsprayed trees to a very large degree. To-day in any unsprayed orchard isolated trees can be found heavily coated with scales but the heavy general infestations in the 1930's occurred in well cared for orchards even though this is not stated in the records. Mention is made of the fact here to draw attention to it in studying the table below and will be referred to in some detail after a description of the experimental results has been given. The history of the recorded occurrance of oyster shell scale in Nova Scotia is as follows:

Fletcher	1885	Few orchards were exempt from its ravages.
"	1893	Worst pest of apple trees in the Dominion.
"	1896	Berwick, N.S. - "bark louse gains ground on trees that are not in good cultivation."
"	1897	About as previous year.
"	1901	About as earlier years.
"	1903	First reference by Fletcher to <u>Aphelinus mytilaspidis</u> (in Ont.) - "Sometimes so abundant that it destroys more than half the scales which are formed."

Fletcher	1906	Listed as a pest.
"	1908	" " " "
Hewitt	1912	Dormant lime sulphur reported to be controlling scale.
"	1915	G.E. Sanders - (Annapolis Royal) reporting on insect pests did not mention oystershell scale.
Brittain	1915	Dormant lime sulphur and summer sprays for apple scab controlled scale.
"	1916	"The oyster-shell scale, if not a native has been with us so long as to be practically acclimatized. Where lime sulphur is used scale is not a problem."
Hewitt	1917	Work by Tothill indicated that the mite <u>Hemisarcoptes</u> <u>malus</u> (Shimer) was the most important single factor in control.
Spittall	1924	Slowly increasing generally in the Annapolis Valley.
"	1925	Outbreaks discovered at Berwick & Canard.
"	1925	Found everywhere but not a serious pest except in untreated orchards. "Two years ago we were under the impression that it was generally on the increase. However many orchardists have gone back to lime sulphur sprays, and this insect usually begins decreasing when subjected to treatment by that material."

Spittall	1927	No appreciable change.
Anon.	1928	Parasites found in winter scales. Scales less numerous.
Spittall	1930	Injury negligable.
"	1931	No mention in Nova Scotia.
"	1932	No mention in Nova Scotia.
Gilliat	1934	Was numerous in 1933 and appeared to have wintered well and contributed to winter injury where the insect was plentiful.
Pickett	1935	First mention at a Nova Scotia Fruit Growers Meeting of oystershell scale as an insect needing special control measures (in well cared-for orchards.)
"	1936	"The oyster-shell scale has been steadily increasing in numbers during the last few years until it may now be considered a pest of major importance. (in well cared-for orchards.)
"	1937	About same as 1936 statement.
"	1938	Continued to increase in many districts.
"	1939	First reference in Report of Insecticide Investigations to an experiment designed specifically for oystershell scale control (Except for one small experiment in 1924.)
Cameron & Pickett	1940	Better control measures prevented a general increase but it was heavy in many orchards. (Well cared for orchards.)

Pickett & Patterson	1940	Paper on control of oystershell scale by means of dormant oils presented to Nova Scotia Fruit Growers Association.
Cameron	1940	"This pest is at present probably one of the major problems in the Valley."
Pickett & Patterson	1941	Paper on control of oystershell scale by means of dormant oils presented to Nova Scotia Fruit Growers Association.
Neary	1941	Oystershell scale increased seriously.
"	1942	" " still a major pest.
Pickett	1942	Paper on control of oystershell scale by means of dormant oils presented to the Nova Scotia Fruit Growers Association.
Neary	1944	At about the same level.
"	1945	About the same as the past few years.

C. Notes on the Biology of Oystershell Scale in Nova Scotia.

In Nova Scotia, as elsewhere, there is only one generation of oystershell scale each year. A very thorough description of all stages is given in Miss Griswold's admirable bulletin (1925). Only sufficient details of it's biology in Nova Scotia need be given to integrate it's bionomics with that of Aphelinus mytilaspidis LeB. and of Hemisarcoptes malus (Shimer) which are it's most important natural control agents.

The scale has three instars, the last ovipositing when full grown i.e. in the latter part of August and into September.

After oviposition the adult female dies and the eggs overwinter under the protection of the scaly covering formed the previous summer. In Nova Scotia the overwintering scales were found by Brittain (1916) to contain an average of 28.71 eggs with a maximum of 50. During the course of the investigations described in this paper a number of scales were counted at various times and found to contain about 30 eggs. Miss Griswold found, in New York State, that the average number of eggs per scale was 61.73, but also states that the usual range on the continent varies from 30 to 50 per scale. In 1944, at Berwick, the "crawlers" were most abundant from May 30 to June 10. In 1945 when the spring was backward, the "crawlers" were not found in abundance until June 16. It was noteworthy that in 1945 there were more than the usual number of scales on the apples in the fall. When the scales first hatched the young larvae remained under the parent scale for several days, the length of time apparently having been influenced by the temperature. During this period newly hatched protonymphs of the mite H. malus frequently attached themselves to the young scales and it is probable that many of the mites were transported in this way. The first instar scale is oval, whitish amber in color and as soon as it settles on the bark becomes covered with a white fibrous waxy secretion. This stage lasted for almost a month and then the second instar was formed. The second instar assumes the characteristic "mussel" shape; the scaly covering consisting of two sections, one oval and light colored and the other fan shaped and darker. Predacious mites attacked all stages of the scale and apparently migrated after killing a scale, but the chalcid parasites emerged from the overwintering scales in time to oviposit in the earliest second instar scales. The parasite larvae are found outside of the host but under the waxy covering and are unable to move from one host to another. The third instar began to form early in August and had three portions to the scaly protection, the third section being about the same color as the second section. Full grown third instar scales began to oviposit in the latter part of August. Reproduction is parthenogenic according to Miss Griswold and males are extremely rare, she herself never having seen one.

III. NOTES ON THE BIOLOGY OF *Hemisarcoptes malus* (Shimer) (ACARI) AND *Aphelinus mytilaspidis* LeB. (CHALCIDIDAE).

A. General Notes on *Hemisarcoptes malus*.

The following summary is largely based on the work of Tothill (1919). *H. malus* was apparently of European origin but was discovered in Ohio in 1868 and described by Shimer as *Acarus malus*. He studied its habits and recognized it's importance istic "mussel" shape; the scaly covering consisting of two sections, one oval and light colored and the other fan shaped and darker. Predacious mites attacked all stages of the scale and apparently migrated after killing a scale, but the chalcid parasites emerged from the overwintering scales in time to oviposit in the earliest second instar scales. The parasite larvae are found outside of the host but under the waxy covering and are unable to move from one host to another. The third instar began to form early in August and had three portions to the scaly protection, the third section being about the same color as the second section. Full grown third instar scales began to oviposit in the latter part of August. Reproduction is parthenogenic according to Miss Griswold and males are extremely rare, she herself never having seen one.

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A. General Notes on *Hemisarcoptes malus*.

The following summary is largely based on the work of Tothill (1919). *H. malus* was apparently of European origin but was discovered in Ohio in 1868 and described by Shimer as *Acarus malus*. He studied its habits and recognized it's importance in the control of oystershell scale. In 1868 Walsh also mentioned its usefulness, and Le Baron in 1870 noticed them in Illinois. Riley in his Fifth Report (1873) figured the mite from material collected in Missouri. Hubbard in 1885 in his "Insects Affecting the Orange", mentioned these mites checking bark lice. Lignières, working on oystershell scale in France, found the mite in 1893 and called it Hemisarcoptes coccisugus. Jarvis in 1910 found it attacking scale near St. Catherines Ont. Ewing & Webster (1912) found H. malus to be very important in the control of oystershell scale in Iowa. Tothill (1919) gives a table showing it to be present in Nova Scotia, New Brunswick, Prince Edward Island, Quebec and Ontario but not in British Columbia. Glendenning (1931) states that the mite was introduced into British Columbia in 1917 and, under certain conditions effected very efficient control of oystershell scale. Buckell (1931) found that in British Columbia it exerted little control of scale on apple trees because of its susceptibility to sprays applied for scale. However he found that it controlled the scale quite well on wild bushes.

B. Notes on the Biology of Hemisarcoptes malus (Shimer) in Nova Scotia.

Only sufficient details of the biology of this mite were worked out in Nova Scotia for proper evaluation of the effects of the spray materials on the natural control of oystershell scale. Observations were made whenever time permitted rather than by any method of rearing in the laboratory or by daily observations. Twigs were selected at random from a tree which had been sprayed with Fermate in 1943 and which was known to have a large population of H. malus. The results of these observations have been summarized in Table I.

About the last two weeks in May, 1944 gravid females, much larger than any seen during the winter, were laying eggs in greatest abundance. These eggs were pearly white, cylindrical in shape, more shiny than oystershell scale eggs and much smaller. In the spring, oviposition took place under the old scales among the scale eggs or among the debris of destroyed eggs. Frequently the female mite may be found with a cluster of eggs around her, 20-25 eggs not being uncommon. As a rule there is only one such female to a scale even though other smaller mites may also be present. Eggs may be found occasionally during the winter but these were probably laid the previous autumn. About the middle of May and toward the end of that month protonymphs began to hatch. The start of hatching of mites seemed to precede by a few days the hatching of oystershell scale eggs (which occurred during the last week of May or just before full bloom of the variety Stark).

The scales, as they hatched,remained under the parent scale for a few days and during this period tiny mites often attached themselves to the ventral side of the scale larvae.When the scales migrated (May 31-June 7) in abundance many of the young mites were probably carried in this way. Whatever the means of migration for the mites may have been, large numbers of scales were found infested with mites as soon as they settled down on the wood. Oviposition, hatching and migration of Hemisarcoptes malus overlap considerably and eggs may be found at all times throughout the year, but the greatest abundance of eggs and young mites coincides very closely, in the spring, with the hatching and migration of the scales.

A few eggs were found outside of, and adjoining, first instar scales but the numbers were small and this characteristic appeared to be true for second instar scales as well. Bloated females and masses of mite eggs, however, again became common under third instar scales just before and during the beginning of oviposition by the scales. This would be about the middle to latter part of August and at this period of egg laying there was usually only one gravid female mite per scale though immature mites were also found. During the winter mites were found in all stages of development, except very young and in the egg laying stage. If either of these occurred during the winter they were never noticed during winter examinations. Most commonly occurring in the winter were well developed mites and these were found under mature 1943 scales in the winter in numbers varying up to 20 per scale. In the autumn of 1944 they were found varying up to 17 under mature scales. First instar scales usually had only one mite per scale but two, three or even four occurred occasionally. With second instar scales the same was true but two, three and four occurred more often.

With third stage scales the number of mites varied according to the size of the scale up to the beginning of oviposition. In May, during the first period of abundance of mite eggs, the numbers per 1943 scale varied up to 30 and in August during the second period of mite egg abundance, up to 45 per 1944 scale.

It would be difficult to say at what stage of scale development most damage is done by Hemisarcoptes malus, as that would depend so greatly on the stage at which the mite reached greatest concentration of numbers. On the Stark, upon which these observations were made, a great deal of damage was done to 1st., 2nd. and early 3rd. stage scales. On other trees where the mite built up later in the season the scales had reached advanced stages of development before the mite reached damaging proportions. When the mite attack occurs early in the year after having been well established the previous autumn and winter, there may be little evidence of the mite itself by autumn of the second year. On the Stark in question, there were, by September of 1944, very few mites but there were a great number of dead scales in all stages of development up to the egg laying stage (but very few of these.) The parasite, Aphelinus mytilaspidis also attacks second instar scales, often without leaving any evidence of having done so, but does not attack first instar scales. When this parasite attacks third instar scales, it is present the following winter, or there is an exit hole if it was present during its second generation.

Results of periodical observations to study the biology of *Hemisarcoptes malus* infesting oystershell scale on a Stark tree in the Fermate plot in the Palmer orchard during the summer of 1944.

Date exam.	*H. malus* UNDER MATURE 1943 SCALES EXAMINED IN THE SPRING OF 1944: Average *H. malus* per infested scale: mature mites	mite eggs	proto-nymphs	*H. malus* FOUND UNDER 1944 SCALES EXAMINED IN 1944: Total 1944 scales examined in 1944: 1st stage total	1st stage % dead	2nd stage total	2nd stage % dead	3rd stage: early total	3rd stage: early % dead	3rd stage: egg stage total	3rd stage: egg stage % dead	Average *H. malus* per infested 1944 scale: mites	eggs
April 6	3.7	2.7											
" 17	5.5	1.5											
" 27	3.2	3.0											
May 20	2.7	11.0											
" 27	2.0	17.5	1.7										
June 5	1.5	15.8	2.2	200								1.0	
" 13	1.9	8.7	2.0	400								1.2	
" 16	3.1	9.0	1.7	-								-	
" 26	1.7	1.3	1.0	200								1.5	
July 5		-		197	79.1	103	19.4					2.0	
" 11		4.0		128	84.4	295	14.0					1.2	2.3
" 17				210	99.1	290	15.9					2.0	6.3
" 25				96	100.0	300	20.0	4	0.0			1.8	3.5
Aug. 3				144	100.0	90	44.5	169	7.7			1.8	4.2
" 15				135	100.0	20	70.0	97	27.8			1.4	11.9
" 23				115	100.0	92	98.9	91	67.0	2	0.0	1.9	14.7
" 29				65	100.0	87	100.0	125	88.8	23	30.4	3.6	8.0
Sept 14				124	100.0	51	100.0	119	98.3	22	40.9	2.3	2.6
" 28				153	100.0	95	100.0	134	100.0	21	85.7		3.8

C. Notes on the Biology of *Aphelinus mytilaspidis* LeB. with Particular Reference to Nova Scotia.

An account of the life history of this chalcid parasite was worked out in some detail by Griswold (1925) Part II) so only a brief summary need be given here. In Nova Scotia only sufficient details of its life history were worked out to facilitate measurement of the effect of spray materials upon the parasite as was done for the predator mite *Hemisarcoptes malus*.

According to Miss Griswold the parasite is both predacious and parasitic. The first generation develops on the second instar scales. The second generation develops in third instar scale before oviposition begins. The third generation of parasites develops on the scale during the period of egg laying. Miss Griswold states that the parasite is predacious on the eggs of scale and while this is true to a certain degree in Nova Scotia, control by this means is unimportant. Most of the control is exercised by the attack on the scale insect itself durir_ the summer and fall.

Observations were made in the A.S. Palmer orchard at Berwick in Kings County, N.S. where plots were laid out to measure the effect of fungicide sprays upon the natural control of scale. On the Fermate block parasites became numerous in 1943 and were numerous again in 1944 thus giving a good opportunity to study the parasite under natural conditions during 1944. Twigs were collected at random from Fermate sprayed trees and the scales dissected for parasites. This was supplemented by frequent observations in the orchard to determine the periods when the adult parasites were present in numbers. The results are given in Table II.

It can be seen from Table II that *Aphelinus mytilaspidis* has three generations a year, the third overwintering as larvae. In 1944 pupation occurred about the second week in June and adults of the third generation emerged early in July in the greatest numbers, pupation in this case occurring under the 1943 scales. These adults oviposited on the second instar scales, the larvae developing on them during July. The pupae from this generation of *A. mytilaspidis* were much smaller than those of succeeding generations. Pupation of first generation larvae took place about the third week in July and the adults emerged during the first two weeks in August. During the period in which larvae of the second generation were developing (during August) the scales began oviposition. Parasitized scales sometimes laid a few eggs but usually were unable to oviposit. Pupation and emergence of the second generation of parasites was more prolonged than that of the overwintering generation or the first summer generation. Adults of the second generation were found again throughout most of September but were most numerous about the second week in the month. The third generation overwintered mostly as full grown larvae though some partly grown larvae were also found .

The natural complex of *A. mytilaspidis*, *H. malus* and *L. ulmi* has been summarized in Table III as it is important in studying the effects of spray materials to have this relationship in mind.

TABLE II.

Results of periodical observations to study the biology of A. *mytilaspidis* infesting oystershell scale in the Palmer orchard. Examined during 1944.

			No. of larvae & pupae of A. mytilaspidis			
ate exam.	Stage of scale exam.	No. of scales exam.	without cast pellets	with cast pellets	No. of pupae	No. of exit holes
p to ay 20 1943	scales		all	0	0	0
une 5 1943	"	29	1	3	0	0
une 7 1943	"	200	3	37	12	0
une 13 1943	"	1100	0	9	50	1
une 16 1943	"	926	3	2	53	2
une 21 1943	"	692	8	2	80	18
une 24 1943	"	200	1	1	33	16
une 26 1943	"	250	0	0	12	6
une 29	Adults emerging in a box in the insectary					
uly 1 1943	"	125	0	0	1	35
uly 1-9	Adults numerous on limbs and twigs					
uly 17	2nd stage '44 scales	490	62	0	4	0
uly 24-27	" "	1800	13	15	312*	?
ug 3-11	Adults numerous on limbs and twigs					
ug 14&15	3rd stage '44 scales	2400	257	46	23	0
ug 23	" "	893	16	18	46	4
ug 29	" "	1222	3	1	76	6
ept 1-	Adults becoming numerous on limbs and twigs.					

* includes emerged.

TABLE III.

Calendar summarizing the contempary developement of oystershell scale and its natural control agents in 1944.

Date	Stage of oystershell scale	Stage of A. mytil-aspidis	Stage of H. malus	Spray applied
Winter & spring	Full of eggs	Overwintering larvae	Mostly mites; a few eggs	
May 18-22	" " "	" "	Gravid ♀♀ ; many eggs	Near pink spray
May 27	Larvae hatching; some crawling	" "	Most of mite eggs hatched	
June 1-2	Moving larvae very numerous	" "	1-3 small mites per scale	Calyx spray
June 10	Most of scales settled down	Prepupal pellets formed		
June 16-19	2nd instar beginning to form	Mostly pupae	1-5 mites per scale; a few eggs	1st cover spray
July 3-4		Overwintering generation pupae		2nd cover spray
July 1-9	Mostly 2nd instar	Adults plentiful	Mites and eggs plentiful	

TABLE III. (Continued)

Date	Stage of oystershell scale	Stage of A. mytil-aspidis	Stage of H. malus	Spray applied
July 24-27	3rd instar beginning to form	1st summer generation pupae	Mites and eggs plentiful	
Aug 3-11	3rd instar pre-oviposition stage	Adults plentiful	Many mites; eggs near peak of abundance	
Aug 15-31	Starting to oviposit	2nd summer generation pupae	Eggs at 2nd peak of abundance	
Sept 1-15 & later	Oviposition taking place	Adults plentiful	All stages plentiful	
Late fall	Full of eggs; females dead	Mostly full grown larvae	Mature and partly grown mites; a few eggs	

IV. A SHORT HISTORY OF NOVA SCOTIA SPRAY PRACTICES WITH PARTICULAR REFERENCE TO THE CONTROL OF OYSTERSHELL SCALE *Lepidosaphes ulmi* (L.)

It is difficult at this date to assess the causes of the developement of a problem such as the present oystershell scale problem in the Annapolis Valley. It has been customary in insecticide research to conduct field tests usually on small plots and then to measure the changes in the pest populations after a few weeks or months. These tests were usually not repeated on the same trees nor was any measure made of the changes in the total arthropod fauna of the trees, particularly the latent effects. In this way both time, space and interaction tended to be ignored except by general experience with sprays in commercial use year after year over whole areas. Pressure on economic entomologists to find relief for growers from a number of pests has tended to lead them into the practice of advocating the most successful immediate results of rather small scale tests without assessing the long term effect on the whole arthropod fauna. In other words the spray program as an ecological factor was largely ignored.

The delayed effect of the spray program is the subject of a fundamental study by Nicholson (1938). In this article he states -

"Briefly the situation is this. When an efficient insecticide is applied in a previously unsprayed area, the immediate effect is a great reduction in the density of the pest. This causes the state of balance which previously existed between the pest and its environment to be violently disturbed.

original state of balance and abundance within a few generations. On the other hand, if spraying is continued as a routine, the pest will ultimately attain a new state of balance, and the spray program becomes one of the environmental factors with which the pest population is balanced. It by no means follows, however, that the density of the pest will then be lower than it was in the original unsprayed environment - it may be unchanged, or even higher than before. These effects can be produced even though the spray does not destroy the pest's natural enemies. They are also independent of any question of the developement of a strain of the pest which is resistant to the spray."

In the same article Nicholson also states, - "Before showing how these conclusions are reached, I must briefly discuss the question of balance, for many people seem to find it difficult to believe that animal populations do in fact exist in a state of balance with their environments. They claim, quite rightly that populations do not remain constant in density, but fluctuate continually as the favourableness or otherwise of the environment fluctuates. But mere increase in density under favourable conditions, and decrease under unfavourable ones, by no means gives a complete explanation of the observed facts."

....

"A favourable environment merely permits a pest to increase progressively in density, while an unfavourable one causes a progressive decrease. These progressive density changes would continue indefinitely were it not for the density dependent action of competition, which first slows, and finally arrests, the changes. It is quite evident, therefore, that it is competition, and not the favourableness or otherwise of the environment, which really determines the abundance of a pest."

The evidence presented in this paper serves to strongly confirm Nicholson's theories. The oystershell scale problem, as will be shown later, arose from the use of sprays which were applied for the control of apple scab, Venturia inequalia Wint. Flotation sulphur was found to be an efficient fungicide which did not greatly mar the finish of the fruit. For these reasons it came to be widely used, particularly in the pink, calyx and first cover sprays. In many cases it was used even more often but in either case the latent effect did not immediately become apparent. Under natural conditions biological competition usually causes the oystershell scale population to fluctuate about a point at a sufficiently low level to cause no appreciable damage. The population level in orchards treated consistently with either copper sprays or with Fermate usually remains at much the same point as in unsprayed orchards. Lime sulphur and flotation sulphur destroy the two important biological control agents, thus creating a condition where competition fails to function. When flotation sulphur is used, the limits to the scale's increase are overcrowding of the scales, and the amount of scale the trees can support. Lime sulphur has some toxic action on the scales themselves, so that, although biological competition is eliminated, there is usually no great increase in the scale population. In the past, oystershell scale outbreaks have been reported from orchards where lime sulphur had been used consistently.

Flotation sulphur began to be used on a commercial scale in the Annapolis Valley about 1933 and experience has shown that oystershell scale has risen since then from a minor problem affecting isolated trees or orchards to the stage where it affects large acreages as a major pest requiring chemical control measures every three or four years.

According to Kelsall (1938) by 1908 many of the more progressive growers were applying sprays but shortly after that spraying became a general practice for most of the growers in the Annapolis Valley. The spray then used was a bordeaux mixture consisting of equal parts of copper sulphate and lime combined with an arsenical. After 1910 lime sulphur was used for a time as a fungicide and Brittain (1915) reported dormant lime sulphur and the summer sprays as having controlled oystershell scale. No mention was made of the influence on natural control by either of these materials but Tothill in 1919 published a paper showing _Hemisarcoptes malus_ as a very important natural control agent for oystershell scale. Tothill, however, does not say, except in a few cases, whether the scales were collected from sprayed or unsprayed trees. In a few cases he does say they came from unsprayed trees and one would surmise that most of the samples must have been from unsprayed trees or from bordeaux sprayed trees in the cases where he found mite. In any case it must be borne in mind that previous to 1919 many orchards in New Brunswick and Nova Scotia were unsprayed and the rest were rather lightly sprayed with hand sprayers or relatively inefficient power sprayers. From 1918 to 1924, according to Kelsall(1938), the practice of dusting orchards was quite prevalent but declined after the latter date due to severe outbreaks of the eye-spotted bud moth (Spilonota ocellana (D & S)) and the European red mite (Metatetranychus ulmi (Koch) - (Paratetranychus pilosus C & F). Better quality power sprayers also contributed to the decline of dusting.

Kelsall's (1938) paper continues with a description of the sprays in use until 1938. About the latter part of the 1920's dormant oils came into use for the control of red mite but these were found also to be valuable against oystershell scale, apple mealy bug (Phenacoccus aceris Sig.) and the Buffalo tree hopper (Ceresa bubalus (F)). During the 1930's a mixture of lime sulphur and iron sulphate combined with calcium arsenate came into general use. The program for the season consisted of two excess-lime bordeaux mixture sprays, three intermediate sprays, of lime sulphur - iron sulphate mixture and ending with two bordeaux sprays, calcium arsenate being used in both mixtures as the insecticide.

Some flotation sulphur was used in the early 1930's and toward the end of that period this material began to be used quite extensively. It was used either as a six spray program or in a bordeaux-flotation sulphur calendar. Since 1940 most of the growers have used a bordeaux-flotation sulphur program with lead arsenate as the insecticide. It is notable that oystershell scale became a general and severe problem during the period in which the precipitated or mild sulphurs have been used.

Recommendations for the control of oystershell scale previous to 1911 were based largely on the reports of the Dominion Entomologist. Later they were based on the joint recommendations of the Provincial Entomologist, the Officer-in-charge of the Dominion Plant Pathology Laboratory and the Officer-in-charge of the Dominion Entomological Laboratory. In the Reports of the Dominion Entomologist, J.S. Fletcher, measures recommended for the control of oystershell scale covered an interesting range of remedies. Many of these remedies were derived from letters received from individuals located all the way from Nova Scotia to Vancouver Island as well as some apparently derived from United States sources. These have been summarized as follows:

Year	Recommended control measures.
1885	1. Soap washes (no details).
	2. Kerosene emulsion (weak but no details given).
	3. Painting lightly in the winter with petroleum or oil paint.
	4. Alkaline washes. (no details)
	5. A solution of concentrated lye applied to the small limbs with a syringe (no details).
1893	1. Dormant kerosene emulsion and when the young scales are active.
	2. Crude carbolic acid emulsion applied to the trunk and large limbs with a cloth or a stiff brush

twenty days before the trees bloom.

3. Induce vigorous growth.

1896 1. Alkaline washes.

2. Spray with kerosene emulsion before the buds burst and again in June.

3. Use bordeaux mixture.

4. Prune and cultivate well.

1897 1. Same as (2) 1896.

2. Apply whale oil soap in June when the young scales are active.

1900 1. Same as (2) 1896.

2. Lime whitewash applied in the late fall at the rate of 1 pound of lime to each gallon of water.

3. Prune and cultivate well.

1903 1. A lime-sulphur and salt mixture as used for a fungicide.

2. Weak kerosene emulsion in June when young scales are active.

3. Whale oil soap in June when young scales are active.

4. A lime whitewash (as in (2) 1900).

5. Good cultivation.

1906 1. Weak kerosene emulsion in June when young scales are active.

2. Whale oil soap in June when young scales are active.

3. Lime whitewash as in 1900.

4. Lime-sulphur wash as used for a fungicide.

5. Good cultivation.

In 1912 the report of the Dominion Entomologist, C.G. Hewitt, recommended lime-sulphur sprays for the control of oystershell scale. As was pointed out by Kelsall (1938) spraying was a fairly general practice in the Annapolis Valley by 1908 among progressive growers. According to the same author a number of growers had changed from bordeaux mixture to lime-sulphur as a fungicide by 1910. Brittain in 1915 stated that the most satisfactory treatment was the dormant lime-sulphur wash for scale, but also if the regular summer fungicide sprays of lime-sulphur applied after the blossoms fall were delayed a few days it effected control of scales by destroying the emerging young of oystershell scale. Brittain also referred to miscible oils as then being on the market but did not advise their use. Sanders and Brittain (1918) pointed out that the increased use of high power sprayers and greater capacity nozzles were causing considerable damage to the foliage and began work on excess lime bordeaux mixtures. The review of the paper by Kelsall (1938) to which reference has already been made showed the changes in the spray program during the 1920's and 1930's. During the 1920's there was very little mention of oystershell scale as a pest, but from 1926 to 1936 nicotine sulphate was recommended in the Nova Scotia spray calendar for it's control. This was applied at the rate of 1 pint of nicotine sulphate to 100 gallons of spray when the scales were crawling in June. After 1928 dormant 3% mineral oil sprays were recommended for outbreaks of European red mite which started about that time. It was not until 1935 that a dormant 5% mineral oil was recommended for the control of oystershell scale. In 1941 an alternative to the dormant 5 % mineral oil was dormant $2\frac{1}{2}$% DN oil (a preparation of mineral oil with dinitro-ortho-cyclohexylphenol called Dowspray Dormant.) This was changed in 1943 to a dormant 5% mineral oil with, as an alternative, dormant 4% mineral oil to which was added $1\frac{1}{4}$ pounds of Dinitro Dry (40% sodium dinitro-ortho-cresylate). These latter recommendations continue in use at the present time.

V. LABORATORY TESTS OF SOME SPRAY MATERIALS ON THE NATURAL CONTROL AGENTS OF OYSTERSHELL SCALE.

When scales from all plots in the Palmer orchard were examined in the winter of 1943-1944 predator mites and parasites were found in numbers only on the plot which had received the Fermate program. The mites were very numerous on one Stark tree in this plot so it was from this tree that all twigs for the spray tests were selected. Some of the standard fungicides and insecticides were selected for testing to gain some leads as to the laying out of the plots in the Palmer orchard described in this paper.

On February 1, 1944, twigs were sprayed in the laboratory basement with a paint-gun sprayer and subsequently, from February 8 and 9 to March 28 and 29, six examinations of the sprayed twigs were made. A final examination of scales was made on April 11 and 12 for effect on _A. mytilaspidis_. The twigs were kept in jars of water in the basement during this period.

A test of this nature does not simulate field conditions since only one application was made with small chance of much weathering of spray residue. Also the mature scales offer considerably more protection to H. malus and A. mytilaspidis than they get in the summer while attacking immature oystershell scale. This should not, however, detract too much from the value of the results obtained in the case where H. malus or A. mytilaspidis were affected.

The following is a list of the spray materials tested:

Materials	Amount per 100 gallons
1. Lime sulphur	$2\frac{1}{2}$ gallons.
2. Flotation sulphur	15 lbs.
3. Bordeaux mixture 5-15-100	
4. Fermate plus Hydrated lime	2 lbs. 2 lbs.
5. Enarco spray oil (emulsified with blood albumin)	5 gallons.
6. Enarco spray oil (emulsified with blood albumin)	3 gallons.
7. Dinitro dry (sodium dinitro-o-cresylate 40%)	3 lbs.
8. Unsprayed check	

A summary of six examinations for H. malus and the results of the final count are given in Table (IV). The results of a final count for A. mytilaspidis are given in Table(IVa). A discussion of these tests follows.

1. Lime-sulphur. There was a consistent preponderance of scales with dead mites at each examination, with the number of dead mites increasing somewhat. The number of scales with mite eggs did not increase even after some weeks [illegible] Observation showed that only a few mite

eggs could be found under any scales. In the check, Fermate and bordeaux plots many scales had upward to fifty mite eggs by the time the scales were ready to hatch. There seemed to have been little effect on parasites under the overwintering scale. The scales were able to hatch normally in the laboratory and settle on the twigs.

2. Flotation sulphur. The results from this material were much the same as for lime-sulphur except that the action against H. malus took place more slowly.

3. Bordeaux mixture, 5-15-100. There was no important effect from bordeaux mixture on either H. malus or A. mytilaspidis. The mites were able to lay large numbers of eggs, indicating a healthy population. There may have been a slightly repressive effect on the parasite population but a considerable percentage were able to emerge.

4. Fermate. This material give much the same results as the check, thus giving no apparently adverse effect on either H. malus or A. mytilaspidis.

5. Enarco spray oil 5%. This material was disasterous to the mite and parasite population as well as to the oystershell scale population.

6. Enarco spray oil 3%. Same as plot 5.

7. Dinitro dry (40% sodium dinitro-o-cresylate.) Like the oils this material was disasterous to oystershell scale and H. malus. The results against A. mytilaspidis were somewhat inconclusive but the percentage dead was rather high.

8. Unsprayed check. The mites were able to lay large numbers of eggs, the parasite emerged in normal numbers and oystershell scale

TABLE IV A.

Results of laboratory tests with some common spray materials on *A. mytilaspidis* under overwintering oystershell scales.

Final series of observations 71 days after spray treatment.

Materials	No. scales exam	No. of *A. mytilaspidis*: Dead	Living pupated or emerged
Lime sulphur	500	6	31
Flotation sulphur	500	5	20
Bordeaux mixture	500	11	19
Fermate	500	3	25
Oil 5%	500	49	1
Oil 3%	500	24	1
Sodium dinitro-o-cresylate	500	13	23
Check	500	9	14

VI. STUDIES IN THE PALMER ORCHARD ON THE INFLUENCE OF SPRAYS ON THE OYSTERSHELL SCALE PROBLEM.

A. Discussion of the Orchard and Details of the Spray Program.

In investigating the oystershell scale problem in 1943 this orchard was sprayed with a number of oils and other materials to test their effect on oystershell scale and their natural control agents because the mite H. malus was known to be present in small numbers. The orchard was a small one and the plots consisted of one row as a rule or several at the most. In 1944 when the present project was started only one of the materials, Fermate, was continued from 1943. The orchard however was conditioned by the 1943 experiment to a considerable degree. A further drawback was found later in the size of the plots and this point will be discussed later in connection with the interpretation of the experimental results from this orchard. However even with these limitations sufficiently conclusive results were gained to make possible a change in the spray program to be used in the Annapolis Valley. The results obtained were amply supplemented in other orchards and by a survey of commercial orchards results from some of which are given in Tables and are discussed later in this paper.

The Palmer orchard has woods or waste land on three sides and a poorly sprayed orchard on the 4th side. There are thirty-five rows of trees each containing about thirteen trees.

One third was used in the experiment, the varieties being mostly Cox Orange, Stark, Northern Spy, Ben Davis and a few other scattered varieties.

The spray program followed in this orchard was as follows:-

Row	Spray program in 1943.	Spray program from 1944-46.
1&2	6 Ferm.	6 Ferm.
3.	3 L. sul.; rest owner-sprayed	6 Ferm.
4.	3 Bord; " " "	6 Ferm.
5.	Dorm. oil 3% & NaOH; rest " "	6 Ferm.
6.	" Stove oil 10% &DNC; " " "	6 L. sul.
7.	All owner sprayed	6 L. sul.
8.	" " "	3 Bord. - 3 C.O.C.S.
9.	" " "	6 Flot. sul.
10.	Dorm. L. sul.; rest owner-sprayed	6 Ferm.
11.	" DNC; " " "	6 L. sul.
12.	" oil 3% and DNC; " " "	3 Bord. - 3 C.O.C.S.
13.	" " 5%; " " "	6 Flot. sul.

Ferm.- Fermate (Ferric dimethyldithiocarbamate)

L. sul. - Lime sulphur

Bord. - Bordeaux mixture

Dorm. oil - Enarco spray oil

DNC - Niagara dinitro dry

C.O.C.S.- Copper oxychloride sulphate

Flot. sul. - Flotation sulphur

Owner-sprayed includes some sulphur sprays.

B. Details of three year experiment in the Palmer orchard.

1. Observations on the Conditioning Effect of the 1943 Experiment.

In 1943 some routine insecticide investigations were carried on in this orchard to measure the value of several spray materials for the control of oystershell scale. An examination of scales from this orchard the previous winter had shown small numbers of both the predator mite and the parasite to be present and it was therefore planned that this experiment should also give some measure of the influence of sprays on the natural control of oystershell scale. The dormant sprays and the first three sprays for those plots designed to receive them (see section VI A) were applied by the Annapolis Royal Laboratory and the rest of the spray applications were made by the owner,who followed the calendar recommendations. On the first two rows all six sprays were Fermate without an arsenical. This experiment brought about marked changes in the oystershell scale populations on the different rows. Scale was reduced on the rows receiving dormant oil, sodium dinitro-o-cresylate and dormant lime sulphur. These were rows 5,6,10,11,12 and 13 and a count on terminal wood the following autumn showed scale to be light on some of these rows (see Table XVII). An examination of scales the following winter revealed that the predator mite and parasite situation had also been altered sharply. These were very scarce over the whole block except on the first two rows which had received six Fermate sprays. On the two

Fermate rows there was a fairly high percentage of *A. mytilaspidis* and some *H. malus*. On one stark tree in these two rows a very large population of *H. malus* was found. Presumably either the experimental sprays or the sprays applied by the owner had reduced the influence of natural control factors. For the results of these examinations see Table VI.

2. Notes on the Distribution of Adult A. mytilaspidis in the Palmer Orchard.

In 1944-1945 and 1946 the spray program described in Section VI A was followed. The records in 1944 were rather general as it was first necessary to gain information on the habits of *H. malus* and *A. mytilaspidis* as was described in Section III. In 1944 a measure of the distribution of adult *A. mytilaspidis* was made by closely examining the limbs of a tree for a five minute interval and then repeating the procedure on a number of trees in each plot. No counts were made of the adults in 1944 but notes on their relative abundance were made.

a. Distribution of Adult *A. mytilaspidis* in the Palmer orchard in 1944.

Adults from the overwintering generation were most numerous on the first two Fermate rows but they were also found in moderate numbers on the third and fourth Fermate sprayed rows. The first two rows had carried over a population of parasite larvae from the previous autumn, as these rows had been sprayed with Fermate in 1943. No adults were found on the sulphur sprayed rows and none on the copper orFermate sprayed rows farther down the orchard.

The first summer generation of adults was also found only on the Fermate rows but was noticed in larger numbers than previously on the third and fourth Fermate sprayed rows. This was early in August and, as very little rain had fallen since spraying was concluded, there was presumably still considerable spray residue present. This was probably the reason why no adults were found on the other plots.

The second summer generation of adults emerged from a very large population of parasite larvae in the first two Fermate sprayed rows. By this time, living scale on these rows was getting scarce due to attack by H. malus and A. mytilaspidis. The parasite adults emerged early in September, by which time, presumably most of the spray residue had weathered off. Whatever may have been the logical reasons for it, the adult parasite could be found on all fourteen treated rows during the period of existance of the second summer generation of parasite adults.

b. Distribution of Adult A. mytilaspidis in the Palmer Orchard in 1945.

In 1945 the same method of examining the trees for adult A. mytilaspidis was followed except that a count of the number of adults seen during the five minute interval was made. It will be seen from Table V that few adults were found on the sulphur plots until the second generation emerged. During the flight of adults from the overwintering larvae, its adults were present on the copper and isolated Fermate row (row 10) where they had become established in the fall of 1944 though were not as plentiful as during the later August flight. The parasites had been found on the sulphur rows in fair numbers in the fall of 1944 but only a few were found here in July and August of 1945. As in the previous autumn, when the second generation adults emerged in the fall of 1945 they could be found on all rows including the sulphur rows since by this time the sulphur had probably weathered off. Table V shows the adults in September 1945 in larger numbers on the copper row (row 8) and the isolated Fermate row (row 10) than on the sulphur row. This examination must have been made at a time when the parasites were emerging in greatest numbers and had not yet migrated to any great extent. It is apparently that they did disperse more than Table V shows since a winter examination of scales (see Table XV) showed the overwintering larvae to be about as numerous on the sulphur rows as on the copper row (row 8) and isolated Fermate row (row 10).

c. Distribution of Adult _A_. _mytilaspidis_ in the Palmer Orchard in 1946.

There was not sufficient time in 1946 to make records on the distribution of adult _A_. _mytilaspidis_ in this orchard. During the 1946 spring season there was a great deal of windy weather which resulted in a considerable amount of spray drift from the sulphur plots contaminating the copper and Fermate rows. This is possibly the reason why the scale population on these rows was not decimated to the extent that might have been expected and why parasitism by overwintering parasite larvae in the fall of 1946 was not as high as had been expected (see Table XVI).

TABLE V.

Average number of *Aphelinus mytilaspidis* adults observed per five minute inspection per tree in 1945 in the Palmer orchard.

Row	Treatment	No. over-wintering gen. adults observed July 9/45	No. 1st. gen. adults observed Aug 6/45	No. 2nd. gen. adults observed Sept 13/45*
1&2	Fermate	0.8	none exam.	12.2
3,4&5	"	10.0	7.5	22.6
6 - 7	Lime sul.	1.0	0.2	56.1
8	Bord. & C.O.C.S.	14.0	30.7	186.0
9	Flot. sul.	2.0	0.0	85.8
10	Fermate	2.3	15.6	215.8
11	Lime sul.	0.5	none exam.	39.2
12	Bord & C.O.C.S.	0.0	none exam.	24.0
13	Flot. sul.	none exam.	none exam.	11.5

* before adults had dispersed very much through the orchard.

3. Interpretation of the Tables on the Palmer Experiment from 1943-1946.

When this experiment was started the full importance of space as a factor was not fully realized. The experiment on natural control arose out of an experiment on the control of scale in 1943 in which interference with natural control was considered a secondary factor. For this reason both the oystershell scale and it's natural control agents were unevenly distributed in the orchard when the decision was made to use this orchard to measure the influence of some fungicide sprays on the natural control of oystershell scale. The north end of the orchard and a narrow strip along the west side contained plants such as maple trees which could support oystershell scale and consequently, _H. malus_ and _A. mytilaspidis_. A complication resulting from single rows or small plots was found in the difficulty of preventing spray drift from contaminating the adjoining rows and in 1946 this proved to be a serious disadvantage to the experiment. A further complication in these small plots was found in the differential readiness with which _A. mytilaspidis_ migrates, as this is apparently governed by the amount of repellant or toxic spray residue. This weakness greatly increased the amount of record taking that was necessary but in some ways it also served to emphasize the importance of sulphur sprays as a deterrent to the parasite. Sulphur spray residue on the trees at the time the first two generations of adult parasites were present in the orchard either killed or repelled them. In consequence while the sulphur was on the trees the parasite larval population was at a very low level but by the time the second generation adult parasites appeared there was probably little spray residue to hinder their migration to all plots. It is not surprising then that there should be a much smaller difference in the parasite population under the overwintering scales on the plots than there had been the previous summer. This tendency for parasites on all plots to become somewhat equalized in the fall allows us to again measure the effect of treatment the following spring. What has been said of the parasite applies in a lesser degree to H. malus since, even though it probably relies on chance transportation it would not be able to survive if it's arrival on a sulphur plot took place before the sulphur had weathered from the trees.

The nature of the experimental set up and the consequent necessity of presenting a dynamic picture of what has occurred makes it necessary to study the Tables as a series and that the above considerations be kept in mind while doing so.

Table VI shows the degree to which the orchard was conditioned by the 1943 experiment, only the two rows treated with Fermate having any appreciable build up of the natural control agents. Thus the three extra rows adjoining these rows which were included in the fungicide experiment beginning in 1944, were much more liable to rapid infestation by parasites and predacious mites than were the bordeaux rows or the single isolated Fermate row. This shows in Table VII where rows 3,4 and 5 were found to have a small number of mites while none were found in the rows lower in the orchard regardless of treatment. It is worth mentioning here that the infestation of mites and parasites on the first two rows in 1943 may easily have come from the wild land adjoining them. At the time that this examination (Table VII) was made in 1944 A. mytilaspidis overwintering larvae were still under the old scales.

Table VIII shows the same relationships during 1944 as Table VII except that in the meantime the parasites had emerged and some of them had migrated to the three additional rows in the five row Fermate block but were not found in any of the rows lower in the orchard. It is possible that the sulphur sprayed trees acted as a barrier to their migration.

Table IX repeats the information of the preceding two Tables with some indication of mites and parasites appearing in the single bordeaux and Fermate rows (rows 8 and 10). At the time this examination was made in 1944 the spraying season was finished but it is probable that there was still considerable spray residue on the trees.

Table X summarizes the results of extensive records made in the late fall of 1944. In September of 1944 the third generation of adult A. mytilaspidis had appeared and, apparently unhindered by sulphur residue, had spread out over the orchard. This was the reason for the high percentage of A. mytilaspidis larvae overwintering under scales in the sulphur treated rows.

Both the parasite and the predator mite were found in greatest numbers on the Fermate and bordeaux rows. A large percentage of the scales had been destroyed on the first two Fermate rows. Lime-sulphur acted directly to a degree in the control of scale but the percentage surviving in all other rows was high, as would be expected from the small amount of natural control during the summer.

Table XI is a summary of an experiment during 1944 on a single tree in the second Fermate row which had a moderate number of scales with overwintering A. mytilaspidis in the spring of 1944. Fermate was applied to this tree in the pre-blossom sprays but flotation sulphur was applied in the post-blossom applications. The experiment showed the drastic effect of sulphur on A. mytilaspidis since the scales on this tree started the season with a sufficient number of A. mytilaspidis to have controlled the scale by natural means had sulphur not interfered.

Table XII shows the first two Fermate rows in the spring of 1945 to have had a small population of H. malus, the reason for this being that scale had been badly decimated in 1944. The adjoining three rows had a higher percentage of infestation by the mites since there was still a large number of scales on these rows. None were found on the sulphur rows but a few were found on the isolated bordeaux and Fermate rows. At this time the parasites had not emerged from the old scales.

Table XIII shows the same relationships with regard to H. malus as does Table XII. Parasite adults had emerged by this time in 1945 in fairly large numbers on all rows and for this reason the differences between the rows was all the more impressive. Very few *A. mytilaspidis* larvae were found on the sulphur rows and only a few were found on the bordeaux row (row 12) at the lower end of the orchard. It is possible that in the latter case, this was due to spray drift from the sulphur rows but this is not known for certain.

Table XIV gives the results for examinations made in August 1945 about the time the scales were beginning to oviposit. The numbers of *H. malus* on the Fermate and bordeaux rows contrasts sharply with their complete absence from the sulphur treated plots at this time. It will be noticed, by consulting Table XV, that this relationship was still true in December of 1945, though a few mites had by then migrated to the sulphur treated rows. There were distinct differences also in the numbers of *A. mytilaspidis* in August 1945, their numbers being much greater on the bordeaux and Fermate rows than on the sulphur rows. They were unaccountably high on the lime-sulphur rows adjoining the five row Fermate block. Most of the parasites which make up the 10.4% recorded for these lime-sulphur rows were found on a single tree out of the four trees examined, but their presence there was not accounted for. Earlier in the month when the second generation of parasite eggs were being laid there was still a lot of spray residue on the trees. On the sulphur rows this residue no doubt accounted for the small numbers of parasite larvae at the end of August.

Table XV shows that only a few living scales were left on any of the Fermate rows at the north end of the orchard by December of 1945. In these five rows practically all the scales which had survived long enough to reach the late third instar were unable to lay eggs. Due to the scarcity of living scales on this area very few H. malus could be found by December as they are found only under healthy scales. It is also apparent that the scales in the Fermate block had been killed before the third generation of parasites appeared. Had scales (which had not then oviposited,) been alive when the parasite adults of the second generation were present, the overwintering parasites would have been present in the mature scales even though no scale eggs were present. H. malus was more numerous on the isolated bordeaux and Fermate rows (rows 8,10 and 12) than they were on the sulphur rows. Some predacious mites were found on the sulphur rows at this examination and, since none had been found there in August, it would appear that H. malus may be transported fairly readily. On the rows from 6 to 13 the parasite larvae were fairly evenly distributed regardless of treatment. There was probably very little sulphur left on the trees when the adults of the second generation parasites were present in September of 1945 which would account for the even distribution of overwintering larvae. This would appear at first glance to be unexpected in view of the uneven distribution of adults shown in Table V for the observations on September 13. The September count of parasite adults however must have been made just after the parasites had emerged and before any great migration had taken place but it is very apparent, however, that such a migration did take place.

Table XVI gives the results of the single series of examinations made during 1946,as pressure of other work prevented more extensive observations in this orchard. Sufficiently conclusive results were obtained in 1944 and 1945 to make possible a reorganization of the method of taking winter counts to analyze quite well the changes which had taken place during the previous summer. Laboratory tests on the method of selecting samples and on the number of scales to be examined had shown that large samples from a few trees may be more variable than a smaller sample more representative of the whole orchard. In order to find how large the latter type of sample should be, short twigs were selected from each of fifteen or twenty trees scattered throughout the orchard. In making the microscopic examinations,about ten scales were examined per twig until one hundred scales had been examined. The data was recorded and the same twigs gone over again for the next hundred scales. Ten samples of one hundred scales each were taken in this way from the same twigs. It was found by this method that in general,there was no important change in the averages after four hundred scales had been thus examined.

In the late fall of 1946 an examination, designed to give a summary of the effect for the whole season, was made from those plots on which scales could still be found. Both *H. malus* and *A. mytilaspidis* were found to be much heavier on the non-sulphur rows. In 1945 the parasites overwintering were as heavy on the sulphur rows as they were on the bordeaux and Fermate rows. This revealed that the second generation of parasite adults had in September 1946 dispersed throughout the orchard. This apparently did not happen to the same degree in the fall of 1946. Practically all the scales in the five row Fermate block had been killed in 1945 so that in the fall of 1946 there was no large surplus of parasites over healthy scales on these rows to migrate in search of healthy scales. Possibly because, in the remaining rows, there was a surplus of scales over parasites (drift of sulphur sprays had in all probability prevented natural means from decimating the scales on the single copper and Fermate sprayed rows) the urge to migrate may have been less than when there was a surplus of parasites. At best, however, this is speculation despite it's plausibility and does nothing to disprove the adverse effect that sulphur sprays have on A. mytilaspidis.

Table XVII is a summary of the effect of the sprays as measured mostly by winter examinations which are taken at a static period in scale, mite and parasite developement. The percentage of scales surviving is influenced to a considerable degree by the ability of the September generation of parasite adults to migrate. Because of this, many scales on the sulphur plots contained parasite larvae and no scale eggs thus lowering the percentage surviving. It also serves to lower the ratio of mature scales with eggs to the number of scales with parasite larvae during the winter. The ratio of mature scales with predator mites to the number of scales with eggs is in some cases quite large. In these cases the mite had so decimated the scales that the mites apparently had difficulty in finding the widely scattered healthy scales. The winter measure of H. malus may, therefore, be a very poor measure of the effect that the mite may have had during the season and this is particularly true of the Fermate block. The number of scales on the new wood is a reliable measure of the influence of the spray program on the natural control of oystershell scale over a period of several years, except in the case of the single copper and Fermate rows in 1946. In the latter case these rows were contaminated by spray drift from the sulphur plots. From a study of this Table it is quite evident that neither bordeaux nor Fermate appreciably interfere with the developement of either H. malus or A. mytilaspidis despite the complications introduced by single row plots. Because of these complications the results with bordeaux sprays were not as clear cut as in the block with Fermate treatment, but it will be seen by a study of results on the Hiltz and South Yarmouth blocks that a bordeaux and C.O.C.S. spray program allowed for an adequate control by natural means.

Lime-sulphur used throughout the spraying season seemed to keep the scales somewhat in check but it also destroyed both H. malus and A. mytilaspidis. Flotation sulphur had very little effect on the scales but was drastic in it's effects on predacious mites and on parasites. The natural result of this was a build-up of oystershell scales with flottation sulphur.

Table XVIII is also a summary of the results of the experimen in the Palmer orchard, presenting in brief the progression of changes given in the previous Tables.

4. Summary of the Palmer experiment from 1943-1946.

In 1943 the first two rows were sprayed with Fermate with a resultant small build up of H. malus on most of the trees and one tree had a heavy population of these mites. There was also a considerable build up of A. mytilaspidis on these rows. The rest of the orchard in 1943 had various programs for the control of oystershell scale and these rows were all sprayed in the summer by the owner who used some sulphur sprays. In consequence very few mites or parasites were found on any other row.

In 1944 the plots listed in this report were laid out to test the effect of Fermate, copper and sulphur fungicides on the natural control of oystershell scale. During 1944 parasites and mites became numerous, destroyed much of the scale on the first two Fermate rows and spread some during the summer to adjoining three Fermate rows. By the fall of that year most of the scales in rows 1&2 had been destroyed and the second generation of A. mytilaspidis had scattered throughout the orchard. Predacious mites, however, were found in moderate numbers on the 3rd., 4th. and 5th. Fermate rows and a few on the copper and 10th. Fermate row.

In 1945 the parasites (and the few mites) were destroyed on the sulphur rows during the summer while scale continued to thrive. On the block of three Fermate rows the mites and parasites became very numerous and the same was true on the copper and Fermate rows (8, 10 and 12).

Spray drift due to windy weather interfered with this experiment in 1946. It may be surmised that the parasite and predator mite populations were damaged by this drift so that scale was not eliminated from the single copper and Fermate rows as might have been expected. Notice (Table XVII) that row 5 (Fermate) which lies next to a sulphur row had more scales than in 1945 and also that scale had increased on the copper treated row (row 8). Similarly on the single Fermate row (row 10) the population has been reduced only slightly. The latter two rows had sulphur treated rows on either side of them.

The essential point, however, has been proven from the experiment. That is that with Fermate or copper sprays a serious oystershell scale problem is reduced to a very minor one. On the other hand flotation sulphur allows oystershell scale to build up to formidable proportions due to interference with natural control agents while having little effect on the scale itself. Lime sulphur has been found to have the same effect as flotation sulphur on natural control but to exert a considerable restraining effect on the build-up of oystershell scale.

TABLE VI.

Number of __A__. __mytilaspidis__ and __H__. __malus__ under mature scales in the Palmer Orchard before starting the fungicide experiment. Examined in the winter of 1943-1944.

Row	Treatment in 1943	No. scales exam.	No. scales with H. malus	No. scales with A. mytilaspidis
1&2	Fermate	4248	95	682
3	L. sul.; flot. sul.; bord.	374	0	0
4	Bord.; flot. sul.	387	0	3
5	Dorm. oil, 3% &NaOH; Bord.; flot. sul.	351	0	7
6	Dorm. stove oil, 10% &DNC;Bord.; flot.sul.	121	0	2
7	Bord.; flot. sul.	380	0	2
8	Bord.; flot. sul.	385	0	1
9	Bord.; flot. sul.	372	0	3
10	Dorm. L. sul.; bord.; flot. sul.	256	0	0
11	Dorm. DNC; bord.; flot. sul.	178	0	0
12	Dorm. oil, 3% &DNC; bord.; flot. sul. (no scale)			
13	Dorm. oil, 5%; bord.; flot. sul. (no scale)			

L. sul. - Lime sulphur; Flot. sul. - Flotation sulphur; Bord. - Bordeaux

Dorm. oil - Dormant enarco spray oil; DNC -sodium dinitro-o-cresylate.

TABLE VII.

Number of _H. malus_ attacking first instar scales in the Palmer orchard on July 13, 1944.

Row	Treatment	No. scales exam.	No. scales with _H. malus_
1&2	Fermate (same as 1943)	2,168	252
3,4&5	Fermate	2,027	17
6 & 7	Lime-sulphur	497	0
8	Bordeaux & C.O.C.S.	600	0
9	Flotation sulphur	600	0
10	Fermate	600	0
11	Lime-sulphur		
12	Bordeaux & C.O.C.S.		
13	Flotation sulphur		

See section VI A for treatment of these rows in 1943.

Aphelinus mytilaspidis had not emerged from the 1943 scales at this date.

TABLE IX.

Number of _H. malus_ and _A. mytilaspidis_ attacking third instar (before oviposition) scales in the Palmer orchard on Aug. 14-23, 1944.

Row	Treatment	No. scales examined	No. scales with _H. malus_	No. scales with _A. mytilaspidis_
1&2	Fermate (same as 1943)	597	158	261
3,4 & 5	"	800	47	49
6 & 7	Lime sulphur	400	0	1
8	Bordeaux	200	1	1
9	Flotation sulphur	200	0	0
10	Fermate	400	3	1
11	Lime sulphur			
12	Bordeaux & C.O.C.S.			
13	Flotation sulphur			

TABLE X.

Percentage of scales found in the Palmer orchard by examination in the winter of 1944-1945 to be infested with H. malus and A. mytilaspidis.

Row	Treatment	No. mature scales exam.	% of 3rd instar scales with A. mytilaspidis: 2nd generation exit holes	% of 3rd instar scales with A. mytilaspidis: over wintering larvae	H. malus	Percentage of total scales immature	Percentage of 1944 surviving i.e. with eggs
1 & 2	Fermate	1071	43.8	23.5	5.1	64.6	9.8
3 & 4	"	5574	7.2	32.5	6.8	15.5	54.8
7	Lime sulphur	1858	0.6	19.9	0.2	41.3	44.8
8	Bord.&C.O.C.S.	3113	3.7	25.5	1.1	5.7	77.9
9	Flot. sul.	3093	0.3	8.6	0.03	6.3	87.7
10	Fermate	2817	0.4	11.3	1.8	6.1	86.0
11	Lime sulphur	1983	0.4	14.6	0.9	29.0	61.3
12	Bord.&C.O.C.S.	2115	3.4	30.6	2.8	3.9	79.8
13	Flot. sul.	1224	0.3	10.2	0.1	15.3	77.6

TABLE XI.

Influence of flotation sulphur on the natural control agents of oystershell scale on a tree with a high population of A. mytilaspidis and surrounded by trees with a similar population (Gravenstein in 2nd position in 2nd row).

Date exam.	No. exam.	No. scales with H. malus	No. scales with A. mytilaspidis
Jan. 29	461	4	74
July 3	3rd generation adult A. mytilaspidis abundant on adjacent trees, none on this tree.		
July 13	300	1	0
July 25	400	0	8
July 25	400	0	1
Aug. 4	1st generation adult A. mytilaspidis abundant on adjacent trees, none on this tree.		
Aug. 14	100	0	1
Aug. 14	100	0	0
Sept.13	Some 2nd generation adult A. mytilaspidis seen on this tree.		
Dec.	300	0	9

This tree received 3 applications of fermate before bloom. After the bloom two sprays of flotation sulphur were applied. This tree in the fermate plot due to treatment with fermate in 1943 had quite a large population overwintering A. mytilaspidis larvae. All adjacent trees sprayed with fermate also held numerous overwintering larvae.

TABLE XII.

Average number of *H. malus* per 100 first instar scales in the Palmer orchard on June 26-29, 1945.

Row	Treatment	No. scales exam.	Percentage of scales attacked by with *H. malus*	Average No. of *H. malus* per 100 scales
1&2	Fermate	1614	6.8	8.5
3,4&5	"	5446	13.9	16.4
6 &7	Lime-sulphur	2988	0.0	0.0
8	Bordeaux & C.O.C.S	2028	2.2	2.5
9	Flotation sulphur	2015	0.0	0.0
10	Fermate	2400	1.8	2.2
11	Lime-sulphur	763	0.0	0.0
12	Bordeaux & C.O.C.S.	781	1.2	1.4
13	Flotation sulphur	795	0.0	0.0

TABLE XIII.

Average number of H. malus and A. mytilaspidis per 100 second instar scales in the Palmer orchard on July 24 - 26, 1945.

Row	Treatment	No. scales exam.	% of scales alive	% of scales dead	% of scales infested with A. mytilaspidis	% of scales infested with H. malus	Average No. H. malus per 100 scales mites	Average No. H. malus per 100 scales eggs
1&2	Fermate	677	52.9	47.1	13.4	2.4	0.4	12.1
3,4&5	"	4662	56.3	43.7	23.4	9.5	9.6	28.4
6 & 7	Lime-sul.	2589	87.6	12.4	3.2	0.0	0.0	0.0
8	Bord.& C.O.C.S.	1527	74.5	25.5	17.3	2.2	1.8	7.8
9	Flot. sul.	1513	95.7	4.3	1.3	0.0	0.0	0.0
10	Fermate	2119	84.5	15.5	9.3	1.3	.7	3.8
11	Lime-sul.	1200	95.0	5.0	0.1	0.1	0.1	0.0
12	Bord.& C.O.C.S.	1200	74.5	25.4	1.4	1.0	1.5	2.4
13	Flot. sul.	1200	95.6	3.5	.4	0.0	0.0	0.0

TABLE XIV.

Average number of H. malus and A. mytilaspidis per 100 third instar scales (before oviposition) in the Palmer orchard on August 30-31, 1945.

Row	Treatment	No. scales exam	% of 3rd instar scales: % dead	% of 3rd instar scales: % alive clean	% of 3rd instar scales: % alive infested	% with H. malus	% with A. mytilaspidis	No. H. malus per 100 scales: mites	No. H. malus per 100 scales: eggs
1&2	Fermate	160	77.5	14.4	8.1	3.8	21.9	1.3	30.0
3,4&5	"	2607	83.6	6.8	9.4	11.7	19.7	21.1	44.8
6 & 7	Lime-sul.	1335	26.9	65.9	7.5	0.0	10.4	0.0	0.0
8	Bord.&C.O.C.S.	1349	60.2	32.7	7.1	5.2	34.9	10.2	18.4
9	Flot. sul.	1010	7.7	91.8	0.5	0.0	1.4	0.0	0.0
1 0	Fermate	1440	42.4	39.3	18.3	9.9	36.6	31.5	62.3
11	Lime-sul.	800	6.5	91.9	1.6	0.0	2.8	0.0	0.0
12	Bord.&C.O.C.S.	729	34.4	57.8	7.8	5.4	22.5	17.2	24.7
13	Flot. sul.	800	3.3	96.4	0.3	0.0	0.8	0.0	0.0

TABLE XV.

Average number of _H. malus_ and _A. mytilaspidis_ per 100 third instar scales (after oviposition) in the Palmer orchard in December 1945.

Row	Treatment	No. exam.	% of mature scales			% of mature scales attacked by		% of all 1945 scales surviving (with eggs)	Average mature scales per 100 twigs
			without eggs	with eggs		A. mytilaspidis	H. malus		
				clean	infested				
1&2	Fermate	43	95.3	4.7	0.0	7.0	0.0	0.2	0.8
3,4&5	"	165	93.9	4.8	1.2	6.7	0.0	0.4	3.3
6 & 7	Lime -sulphur	852	57.5	27.3	15.1	26.4	2.0	16.6	35.0
8	Bord.& C.O.C.S	948	50.0	40.5	9.5	25.2	3.0	11.9	41.0
9	Flot. sul.	1000	14.5	69.3	16.2	22.4	0.5	73.0	633.0
10	Fermate	1400	61.6	27.6	10.7	28.9	4.2	17.3	256.0
11	Lime -sulphur	800	25.1	53.6	21.3	30.5	2.3	47.2	203.0
12	Bord.& C.O.C.S.	750	49.5	39.5	11.0	26.9	3.6	31.1	37.0
13	Flot. sul.	800	10.1	76.2	13.6	18.5	0.4	76.5	194.0

TABLE XVI.

Average number of *H. malus* and *A. mytilaspidis* per 100 third instar scales (after oviposition) in the Palmer orchard late in October, 1946. (Only one examination made in 1946.)

Row	Treatment	No. exam.	% of mature scales without eggs	% of mature scales with eggs	% of mature scales attacked by *A. mytilaspidis*	% of mature scales attacked by *H. malus*	% of all 1946 scales surviving (with eggs)	Average mature scales per 100 twigs
7	Lime-sul.	400	32.2	67.8	2.8	0.0	48.5	150
8	Bord.&C.O.C.S.	400	50.7	49.3	24.5	1.4	34.2	472
9	Flot. sul.	400	18.8	81.2	3.2	0.0	68.0	1036
10	Fermate	400	59.0	41.0	24.4	6.4	27.3	210
11	Lime-sul.	400	33.6	66.4	5.4	0.0	49.5	127
12	Bord.&C.O.C.S.	400	49.0	51.0	20.6	1.6	40.3	111
13	Flot. sul.	400	4.7	95.3	.8	0.0	86.7	1329

TABLE XVII

Summary of winter examinations of oystershell scale from 1943 to 1946

Row	Treat-ment	% of scales surviving				Ratio of mature scales with parasite larvae to scales with healthy eggs				Ratio of mature scales with *H.malus* to scales with healthy eggs				Average no. of scales per 100 twigs			
		1943	1944	1945	1946	1943	1944	1945	1946	1943	1944	1945	1946	1943	1944	1945	1946
1&2	Ferm.	66	10	.2		1:4	1:1	1:1		1:31	1:5	0:2		724	58	1	2
3	"	88	55			0:352	1:2	1:2		0:352	1:10	0:3		148	328	2	1
4	"	92		.4		1:123	1:2	1:1		0:369	1:9	0:1		553	1234	4	4
5	"	84				1:48		1:1		0:338		0:6		37	126	4	12
6	L.s.	67				1:50		1:1		0:100		0:74		299	51	22	127
7	"	91	45	17	49	1:182	1:4	1:1	1:24	0:364	1:355	1:144	1:194	827	182	49	150
8	Copper	93	78	12	34	1:370	1:3	1:2	1:2	0:370	1:78	1:13	1:34	577	1364	41	472
9	F.s.	89	88	73	68	1:118	1:11	1:4	1:25	0:355	1:2895	1:171	0:272	691	550	633	1036
10	Ferm.	75	86	17	27	0:301	1:8	1:1	1:2	0:301	1:54	1:9	1:6	394	584	256	210
11	L.s.	60	61	47	50	0:150	1:6	1:2	1:12	0:150	1:101	1:33	1:99	352	166	203	127
12	Copper		80	31	40		1:3	1:2	1:3		1:30	1:14	1:32	90	166	37	111
13	F.s.		78	77	87		1:9	1:5	1:116		1:1122	1:239	0:374	34	76	194	1329

Ferm.- Fermate; L.s.- Lime sulphur; Copper- Bordeaux and C.O.C.S.; F.s.- Flotation sulphur.

TABLE XVIII

Summary of oystershell scale results in the Palmer orchard from 1944-1946

Part A - Aphelinus mytilaspidis

		CONDITION OF 1944 SCALES		CONDITION OF 1945 SCALES								CONDITION OF 1946 SCALES		
Row	Treatment	No. mature scales per 100 twigs	% with Aphel.	No. 3rd.gen. adult Aphel. seen per 5 min.(1st.gen)	% 2nd. instar scales with Aphel.	No. 1st.gen. adult Aphel. seen per 5 min.(2nd.gen)	% 3rd. instar scales with Aphel	No. 2nd.gen. adult Aphel. seen per 5 min.(3rd.gen)	% 3rd. instar scales with Aphel	No. mature scales per 100 twigs	% of 1945 scales surviving with eggs	% of mature scales with Aphel.	No. mature scales per 100 twigs	% of 1946 scales surviving with eggs
1&2	Ferm.	58	24	1	13	?	22	12	7	1	.2		1	
3,4&5	"	562	33	10	23	8	20	23	7	3	.4		6	
6&7	L.s.	233	20	1	3	0	10	56	26	36	17	3	138	49
8	Copper	1364	26	14	17	31	35	186	25	41	12	24	472	34
9	F.s.	550	9	2	1	0	1	86	22	633	73	3	1036	68
10	Ferm.	584	11	2	9	16	37	216	29	256	17	24	210	27
11	L.s.	166	15	1	0	?	3	39	31	203	47	5	127	50
12	Copper	166	31	0	1	?	23	24	27	37	31	21	111	40
13	F.s.	76	10	?	0	?	10	12	19	194	72	1	1329	81

Part B - Hemisarcoptes malus

Row	% of mature healthy scales with H.malus	% 1st. instar scales with H.malus	% 2nd. instar healthy scales with H.malus	% 3rd. instar healthy scales (pre-oviposition) with H.malus	% 3rd. instar healthy scales after (oviposition) with H.malus	% of healthy mature scales with H.malus
1&2	19	7	4	17	0	
3,4&5	11	14	17	72	0	
6&7	0	0	0	1	1	1
8	1	2	3	13	8	3
9	0	0	0	0	1	0
10	2	2	2	17	11	15
11	1	0	0	0	3	1
12	3	1	1	8	7	3
13	0	0	0	0	0	0

LEGEND
Aphel.-Aphelinus mytilaspidis
Gen.-generation

Ferm.-Fermate; L.s.- Lime sulphur; Copper- Bordeaux and C.O.C.S.; F.s.-Flotation sulphur.

VII. SUPPLEMENTARY STUDIES ON SPRAY PRACTICES IN RELATION TO THE OYSTERSHELL SCALE PROBLEM MADE IN THE HILTZ -SOUTH YARMOUTH, THE SUTTON AND THE KELSALL ORCHARD.

A. Influence of Copper and Sulphur Sprays in the Hiltz-South Yarmouth Orchard on the Oystershell Scale Problem.

1. Description of the Orchard and Details of the Spray Program.

This experiment was carried out on an eight acre block consisting of parts of two adjoining orchards. Part of it was the property of Mr. A. Hiltz and the rest was a portion of the adjoining South Yarmouth block which is owned by the Minas Basin Pulp and Power Company. The project was begun in 1943 to measure the long term effect of the use of copper and sulphur sprays on the natural control of codling moth (Carpocapsa pomonella L). The larger plots in this experiment afforded an excellent opportunity to supplement the records obtained in the Palmer orchard.

In 1942 the Hiltz orchard received all six of the calendar sprays as well as three extra sprays for codling moth which included summer oils, whereas the South Yarmouth orchard was unsprayed that year. From 1943 to 1946 the two portions into which the orchard was divided received the following applications:-

North half of both orchards.

Application	Materials and amounts per 100 gallons
Delayed dormant	Bordeaux, 3-6-100.

Application	Materials and amounts per 100 gallons
Pre-pink	Bordeaux, 3-6-100.
Pink	C.O.C.S., 1 lb.; hydrated lime, 2 lbs.
Calyx	C.O.C.S, $\frac{3}{4}$ lb; hydrated lime, 2 lbs; lead arsenate, 3 lbs.
First cover	C.O.C.S., 1 lb.; hydrated lime 2 lbs.; lead arsenate, 3 lbs.
Second cover	Bordeaux, 3-10-100; lead arsenate 3 lbs.
Third cover	Lead arsenate, 3 lbs; hydrated lime, 3 lbs.
Fourth cover	Synthetic cryolite, 3 lbs.
Fifth cover	Synthetic cryolite, 3 lbs.

(C.O.C.S. - copper oxychloride sulphate)

South half of both orchards.

Application	Materials and amounts per 100 gallons.
Delayed dormant	Flotation sulphur, 15 lbs.
Pre-pink	Flotation sulphur, 15 lbs.
Pink	Flotation sulphur, 15 lbs.
Calyx	Flotation sulphur, 15 lbs.; lead arsenate, 3 lbs.
First cover	Flotation sulphur, 15 lbs.; lead arsenate, 3 lbs.
Second cover	Same as north half.
Third cover	Same as north half.
Fourth cover	Same as north half.
Fifth cover	Same as north half.

(In 1944 lime-sulphur was used in the pre-blossom sprays).

2. Interpretation of the Tables on the Hiltz-South Yarmouth Experiment.

Table XIX gives a summary of the results of examinations of scales made during the winter and Table XX summarizes the counts made on terminal wood each fall to compare the mature oystershell scale populations on the two types of treatment. The numbers of *H.malus* found in the winter on the copper plots was rather small for the most part. Scale was, however, rather widely dispersed over the copper plots, and where scale is thus widely dispersed, the predator mite is usually scarce. As was stated in another section, the numbers of mites found in the winter is not necessarily a measure of the effect they may have had earlier. In view of the records obtained in the Palmer experiment the changes in the *A. mytilaspidis* populations each year are, if the following interpretation is correct, quite illuminating. Although no record was made of the scale population in 1944 they are believed to have been higher than in the following years. In interpretating the numbers of overwintering *A. mytilaspidis* larvae on the plots it is assumed that there was little sulphur spray residue on the trees when the second generation adult parasites was present each fall. In the fall of 1944 there must have been a larger total number of second generation adult parasites on the copper plots. When some of these migrated to the sulphur plots there was at that time a fairly small population of healthy scales with the result that the available adults could parasitize a larger percentage of them than in succeeding years. In the autumn of 1945 the situation had changed somewhat in that there was a small number of scales left on the copper plots. When the parasites from these emerged in September the total numbers were smaller than in 1944 and scale had increased on the sulphur plots some. The result was that parasitism by overwintering larvae was lower than the previous year but was still more or less comparable on both plots. By the fall of 1946 the scale population on the sulphur plots was quite heavy so that the available parasites which migrated from the copper plot were only able to parasitize a much smaller percentage of them. There was a considerable portion of the scales surviving each year on the sulphur plots, whereas it was lower and more variable on the copper plots where scales were also scarcer. The influence of the sprays on natural control is well illustrated by the scale population counts given in Table XX. There can be little doubt that sulphur sprays interfere seriously with the natural control of oystershell scale and that copper sprays do not.

Results of winter examinations of oystershell scale from the Hiltz and South Yarmouth orchards to measure the influence of copper and sulphur sprays on the natural control of oystershell scale from 1944 to 1946.

Block	Treatment	% of scales surviving i.e. with eggs	% of total current years scales killed by *A. mytilaspidis* 1st. gen.	2nd. gen.	3rd. gen.	% of mature scales killed by *A. mytilaspidis*	% of mature scales with *H. malus*
RESULTS OF THE 1944 EXAMINATION							
Hiltz	Copper	48.4	?	12.5	29.4	34.9	0.2
S. Yarm.	"	25.7	?	11.0	22.7	24.9	6.7
Hiltz	Sulphur	58.1	?	2.3	29.5	33.8	0.0
S. Yarm.	"	64.2	?	2.4	25.1	27.1	0.1
RESULTS OF THE 1945 EXAMINATION							
Hiltz	Copper	9.4	?	13.1	?	19.0	0.0
S. Yarm.	"	4.7	?	12.1	?	13.5	1.2
Hiltz	Sulphur	75.4	?	4.3	?	17.4	0.0
S. Yarm.	"	70.4	?	3.5	?	15.0	0.0
RESULTS OF THE 1946 EXAMINATION							
Hiltz	Copper	18.7	4.2	8.3	16.0	22.5	0.0
S. Yarm.	"	19.3	2.3	6.0	11.0	22.5	0.5
Hiltz	Sulphur	89.3	.3	.3	1.5	1.6	0.0
S. Yarm.	"	69.0	.5	.7	3.0	3.6	0.0

LEGEND.

gen. - generation
H. malus - *Hemisarcoptes malus*
A. mytilaspidis - *Aphelinus mytilaspidis*
Copper - Bordeaux & C.O.C.S.
S. Yarm. - South Yarmouth orchard
Sulphur - Flotation sulphur

Results of counts of mature Oystershell Scale on the basal two inches of terminal wood of the current years growth in the Hiltz & South Yarmouth orchards in 1945-1946.

			1945			1946		
Plot	Treat-ment	Variety	No. twigs exam'd	No. mature scales found	Average mature scales per 100 twigs	No. twigs exam'd	No. mature scales found	Average mature scales per 100 twigs
Hiltz-	Copper	Baldwin	762	27	4	690	53	8
Hiltz-	"	Grav.	365	6	2	350	2	1
S. Yar.-	"	Baldwin	955	13	1	897	13	1
S. Yar.-	"	Grav.	880	6	1	635	17	3
TOTAL-			2962	52	2	2522	85	3
Hiltz-	Sulphur	Baldwin	972	720	74	961	2397	249
Hiltz-	"	Grav.	151	27	18	133	119	90
S. Yar.-	"	Baldwin	815	1124	138	850	5963	702
S. Yar.-	"	Grav.	1295	452	35	1102	1828	166
TOTAL -			3233	2322	72	3046	10307	338

Copper - Bordeaux & C.O.C.S.; Sulphur - Flotation sulphur; S. Yar. - South Yarmouth; Grav.-Gravenstein .

B. Influence of Bordeaux-Fermate Sprays in the Sutton (Parade) Orchard on the Oystershell Scale Problem.

Definite enough trends began to show up in the Palmer orchard during the summer of 1944 and the following winter to merit further tests. An excellent opportunity presented itself when Mr. R.D. Sutton of Starr's Point offered to try some of these materials in his "Parade" orchard. The orchard had been sprayed with a dormant oil in 1942 to control oystershell scale and scale was again becoming a serious pest by the fall of 1944. Mr. Sutton agreed to apply a bordeaux-Fermate spray calendar during 1945 and 1946 in an attempt to remove the menace of oystershell scale. In 1945 the sprays applied were, two bordeaux sprays followed by two of Fermate and ending with a bordeaux. In 1946 the sprays were two bordeaux, followed by three Fermate and ending with a bordeaux application. Nicotine sulphate was added to the first spray in the spring of 1946.

As may be seen from Table XXI and XXII excellent control of scale was obtained through an increase in it's natural control agents during 1945. During 1946 natural control kept the scale at a low level thus showing that the program used is satisfactory for this purpose. After the first year of treatment, winter records showed that only five percent of the years scales had survived. The scale population was smaller in 1946 but again there was only a small percentage of the scales which survived. H. malus were probably less important in 1945 than the parasite A. mytilaspidis but it must be borne in mind that records on the mite are not as reliable a measure as the records for the parasite. When the mites kill a scale they wander away and for this reason the control they may exert cannot readily be measured, as the same mites may kill more than one scale. Each parasite kills only one host and if not present it leaves an exit hole where it has been present (except the first generation which often emerge from beneath the edge of second instar scales)and a measure of it's effectiveness is therefore more readily obtained. About the time the observations were made in September 1945, the mature mites were found in association with fairly large groups of mite eggs. This being the case, the mites which hatched from them could have caused a considerable amount of destruction of scales and this would appear to have been the case, judging from the number of mature scales in which there were no viable scale eggs in January 1946.

A single examination was made late in 1946 to determine the gross effect of the 1946 program and also to compare the two years (see Table XXII). As was mentioned above adults from parasite larvae which developed under second instar scales very often emerge from under the edge of the scales instead of boring through them. It is therefore quite probable that destruction of scales by the second generation of parasite larvae was higher than the Table indicates. When the examination of 1946 scales was made it was found that 24.6 percent of them had been destroyed in the first and second instar and 66.4 percent had been destroyed in the third instar before they were able to lay eggs. Of this latter percentage only 29.2 percent were killed by parasites so it is reasonable to assume that most of the remaining 37.2 percent were destroyed by *H. malus*. The percentage of the scales killed in the first and second instar by *H. malus* cannot be estimated since the real amount killed by *A. mytilaspidis* is unknown.

It is very evident that a bordeaux-Fermate program will allow natural control to function efficiently in the destruction of oystershell scale.

TABLE XXII.

Comparison of winter examinations of oystershell scale from the Sutton (Parade) orchard to measure the influence of a bordeaux-Fermate spray program on the natural control of oystershell scale in 1945 and 1946.

Year	No. scales exam.	% of scales surviving i.e. with eggs	% of total scales killed by A. mytilaspidis			% of mature scales with A. mytilaspidis	% of mature scales with H. malus	Average no. mature scales per 100 twigs
			1st. gen.	2nd. gen.	3rd. gen.			
1945	1000	5.0	?	19.0	4.0	15.0	2.0	99
1946	500	8.8	2.6	21.0	8.2	10.8	0.0	3

gen.- generation.

C. Influence of a Year Without Spray Followed by a Season with Bordeaux-Fermate Spray in the Marshall (Kelsall) Orchard.

This orchard had been sprayed regularly each year until 1945 and by that year a very large population of oystershell scale was threatening to kill many of the trees. During 1945 no sprays were applied in the orchard, thus providing an excellent opportunity to study natural control of scale under these conditions. Seven trees were selected and tagged and all samples were taken from these trees in 1945. A general sample from the seven trees was examined also in the late fall of 1946 after one season of treatment with bordeaux-Fermate sprays.

In the early spring of 1945 a sample of scales examined showed about 13 percent of the mature scales to have over-wintering _A. mytilaspidis_ and a trace of _H. malus_ was also found. When it is recalled that the percentage shown to be infested at any one time by _H. malus_ is smaller than the actual destruction of scales wrought by them it will be seen that _H. malus_ was about as important as the parasite in this orchard. A winter examination made in December 1945 showed that 95% of the years scales had been destroyed.

In 1946 bordeaux-Fermate sprays were used in this orchard and, as a check an examination of scales was made late in the fall. This examination showed that 87.3 percent of the years scales had been destroyed. This is a considerable amount of control where scale had already been reduced to a low level the previous year.

The reduction of a heavy scale population to a low level in one year presents a good picture of what H. malus and A. mytilaspidis are capable of in controlling oystershell scale at a high level of population.

TABLE XXIII.

Summary of summer and winter examinations of oystershell scale from the Marshall orchard in 1945 & 1946 (unsprayed in 1945 but sprayed in previous years) and treated in 1946 with bordeaux-Fermate spray.

Date exam.	No. scales exam.	Stage exam.	% of scales with *H. malus*	% of scales with *A. mytilaspidis*	% of scales surviving i.e. with eggs
			Results in 1945.		
June 25	2900	1st. instar	0.7	-	
July 13	2800	2nd. instar	9.4	11.0	
Aug. 28	2800	3rd. instar (before oviposition.)	38.0	20.3	
Dec.	1200	all 3rd. instar	5.0*	13.4*	5.4
			Results in 1946.		
Nov.	300	all stages	6.5	6.4	12.7

* There is no way to eliminate from the third instar scales counted in Dec., those dead due to the earlier attacks of second generation parasites and summer mite broods. This results in unduly low % of infestation records in Dec.

VIII. OBSERVATION ON THE USE OF BORDEAUX AND FERMATE SPRAYS IN COMMERCIAL USE IN THE CHASE ORCHARDS.

A. Notes on the Oystershell Scale Problem and Details of Spray Treatment.

Commercial orchards in the Annapolis Valley have for some years now employed a spray calendar in which sulphur sprays were used in the pink, calyx and first cover spray. Usually the first two sprays and the last were bordeaux applications. A lime sulphur-iron sulphate mixture was widely used during the 1930's, in some cases being used throughout the spraying season. Since about 1940 flotation sulphur has been very widely used, in some cases being used all through the season and in others in all except the first two sprays. In general, however, the spray program consisted of two bordeaux sprays, followed by three flotation sulphur sprays and ending with a bordeaux spray.

The work in 1944 and 1945 on the oystershell scale problem had shown that sulphur sprays were very detrimental to H. malus and A. mytilaspidis. The greatest damage to natural control was caused by using sulphur in the calyx, the first cover and the second cover sprays. Fermate and copper sprays (bordeaux C.O.C.S.) were found to favour the increase of both the predacious mite and the parasite.

In the fall of 1945 Mr. George Chase of Port Williams approached Mr. A.D. Pickett the officer-in-charge of the Dominion Entomological Laboratory at Annapolis Royal concerning the oystershell scale problem in his extensive blocks of orchard. In consequence of this a survey of his orchards was made and samples collected by the staff of the Entomological Laboratory and examined in the winter. The writer was responsible for these examinations but all members of the staff assisted in the work and the officer-in-charge of the laboratory assumed the chief responsibility for recommendations based on the result of the examinations.

In the cases where a dormant application of oil was advised, Mr. Chase followed the recommendation. In all other cases he used a bordeaux-Fermate program except for the orchards in one unit at Aylesford.

Winter examination of oystershell scale does not present a complete picture, but it does give a good idea of what may be expected the following season with regard to the amount of the natural control agents present at the beginning of the next spray season. As was stated in Section VI 3, tests made on samples of scale showed that the method of taking the sample was more important than the number of scales examined. Five hundred scales per sample were shown to give about as good a measure as a larger sample when this condition was observed. The winter examination of 1945 scales was made only on mature scales but subsequent reorganization of the method of examination made it possible to measure the total destruction of the scales as well. When the winter examination of 1946 scales was made this method was used.

B. Interpretation of the Tables on the Chase Orchards.

The results of the examinations of 1945 and 1946 scales have been summarized in Tables XXIV - XXVI. Parasites are found overwintering under third instar scales in which there are usually no eggs and also many of the third instar scales without eggs may have been killed by H. malus or by second generation parasites. The percentage of mature scales parasitized does not therefore present a good picture of the number of parasites present to attack healthy scale the following year. By presenting the number of living parasites in comparison with the number of scales with eggs in the form of a ratio this relationship may be seen at a glance.

1. Discussion of Results from the Orchards in the Canard Unit.

These orchards were all treated with dormant oil in 1943 for the control of oystershell scale. Except for 1945, the fungicide program has consisted of two bordeaux applications followed by four sprays of flotation sulphur. A heavy frost after the buds had burst in 1945 destroyed most of the fruit buds, so a light program of one preblossom bordeaux spray and two post blossom flotation sulphur sprays was used. It is not known of course, how thorough the last flotation sulphur spray may have been but at least it was probably applied considerably earlier than the last cover spray in the Chase orchards is usually applied. Without attempting to analyze too carefully the causes, it is apparent that in 1945 A. mytilaspidis had been able to build up considerably. During 1946 bordeaux and Fermate sprays have apparently favoured the increase of both the parasite and the predator mite. Some flotation sulphur was used in these orchards as Fermate was not available in sufficient quantities early enough in the season. There appears to have been little difference where one, two or three flotation sulphur applications were used. These latter results were unexpected and cannot be explained without much more detailed information than is available. It is important, however, that on large blocks of commercial orchards such as this unit that a marked reduction of scale has taken place where the sulphur program has been reduced. One orchard in this unit was sprayed with bordeaux-Fermate and, in this, synthetic cryolite was substituted for an arsenical. The cryolite had little, if any, effect on either of the natural control agents.

2. Discussion of Results from the Orchards in the Blomidon Unit.

These are, for the most part large blocks of orchard in which a good deal of flotation sulphur has been used. Until 1946 two bordeaux were applied and this was followed by four flotation sulphur sprays. Unlike the Canard unit, the Blomidon unit received the full schedule of six fungicide sprays in 1945. In 1946 a bordeaux-Fermate calendar was applied to all these orchards except to one known as the Long Hill orchard. By way of comparison this orchard received a dormant oil application followed by the usual bordeaux flotation calendar sprays. An adjacent block known as the DeWitt orchard also received the dormant oil but during the 1946 season it received bordeaux and Fermate sprays.

Though only a partial reduction of scale was obtained in most cases in 1946 there was a decided build up of A. mytilaspidis and in one orchard H. malus was very plentiful. In contrast to this the Long Hill orchard is little better than it was a year ago with respect to natural control agents. Orchards which have been sprayed with a dormant oil in recent years and treated with bordeaux and Fermate sprays were found to have a higher ratio of parasites to the number of healthy scale. Presumably the cause of this is the smaller population of scales for the parasites to work on combined with the parasites apparent ability to find scale even in a light infestation.

3. Discussion of Results from the Orchards in the Hillcrest Unit.

The results of examinations of scales from the orchards in the Hillcrest Unit are given in Table XXVI. The program for these orchards in 1945 was two bordeaux sprays followed by three flotation sulphur sprays. By omitting the sixth application (flotation sulphur) apparently A. mytilaspidis were appreciably hindered less by spray residue. The ratio of overwintering parasites per sample to the number of scales with healthy eggs in 1945 was quite high probably due partly at least to the reason given above. By the end of 1946 the major portion of the scales had been destroyed in these orchards through natural control. The program of bordeaux and Fermate sprays allowed A. mytilaspidis to thrive during 1946. There was a very appreciably control by *H. malus* as well in this unit.

Two small blocks in this unit were sprayed in 1946 with bordeaux-Fermate sprays, but instead of the usual arsenical insecticide, nicotine sulphate was substituted. From the winter results it is quite apparent that nicotine sulphate did not greatly hamper control by natural means.

TABLE XXIV.

Results of winter examinations of 1945 and 1946 oystershell scale in the Chase Canard Unit. Sprayed in 1945 with 1 preblossom bordeaux and two postblossom flotation sulphur sprays.

Orch. no.	Amount of scale 1945	Amount of scale 1946	Dormant oil history	No. exam. 1945	No. exam. 1946	Ratio of live parasites to mature scales with eggs 1945	Ratio of live parasites to mature scales with eggs 1946	Ratio mature scales with *H. malus* to mature scales with eggs 1945	Ratio mature scales with *H. malus* to mature scales with eggs 1946	% of 1946 scales surviving i.e. with eggs
The following had - spray #1&2 bord.; #3 flot. sul.; #4-6 Fermate.										
1	L	L	in 1943	93	200	1:3	1:9	0:6	0:6	3
2	M-H	L-fM	in 1943	1000	500	1:5	1:4	1:30	1:24	24
3	L-M	L-M	in 1943	500	500	1:8	1:6	0:244	0:205	41
4	L	L-M	in 1943	400	500	1:17	1:12	0:343	1:10	54
The following had - spray #1,2&7 bord.; #3&4 flotation sulphur; #5 &6 Fermate.										
5	S	L-fM	in 1943	500	500	1:2	1:3	1:116	1:31	49
6	L	L-M	in 1943	200	500	1:6	1:20	0:150	0:320	64
7	M	S-L	in 1943	612	500	1:2	1:0.5	1:296	1:27	5
8	S	S	in 1943	300	500	1:2	1:1	1:21	1:14	3
The following had - spray #1&2 bord.; #3-5 flotation sulphur; #6 Fermate.										
9	S-fM	S-L	in 1943	1024	500	1:3	1:2	1:118	1:26	32
The following had-spray #1&2 bord.; #3-6 Fermate plus cryolite instead of arsenic.										
10		L-fM	in 1943		500		1:1		1:24	24

L- light; M- medium; H-heavy; S- scarce; f- few; bord.- bordeaux; flot.sul.-flotation sulphur.

TABLE XXV.

Results of examinations of 1945 and 1946 oystershell scale in the Chase Blomidon Unit. Treated in 1945 with 2 bordeaux sprays and four flotation sulphur sprays and in 1946 with bordeaux and Fermate sprays.

Orch. no.	Amount of scale 1945	Amount of scale 1946	Dormant oil history	No. exam. 1945	No. exam. 1946	Ratio of live parasites to mature scales with eggs 1945	Ratio of live parasites to mature scales with eggs 1946	Ratio mature scales with *H. malus* to mature scales with eggs 1945	Ratio mature scales with *H. malus* to mature scales with eggs 1946	% of 1946 scales surviving i.e. with eggs
1	S	L-M	never	1000	500	1:35	1:17	0:830	0:409	82
2	L-H	L-H	never	1000	500	1:990	1:58	0:990	0:462	92
3	S	L-M	never	200	510	1:166	1:34	1:166	0:382	75
4	L-fH	L-H	never	1000	500	1:469	1:20	0:938	0:346	69
5	H	S	never	1000	512	1:46	1:9	0:926	1:4	18
6	H	H	never	1000	500	1:132	1:19	0:925	0:414	83
7	S	S-L	in 1943	200	400	0:182	1:7	0:182	0:275	69
8	S-L	S	in 1945	535	300	0:513	1:3	0:513	0:204	68
9	S	L	in 1945	150	500	0:133	1:2	0:133	1:148	51
10	S-L	S-H	in 1945	400	500	0:153	1:4	0:370	0:368	74
11	S	S-L	in 1945	200	500	0:19	1:5	0:175	1:338	78
DEWITT (never oiled before 1946; bord.- Fermate in 1946.)										
	M-H	S	in 1946	1000	500	0:960	1:8	0:960	0:410	82
LONGHILL (never oiled before 1946; bord.-flot.sul. in 1946.)										
	M-H	S-L	in 1946	1000	500	1:227	0:375	0:909	0:375	74

L- light; M- medium; H- heavy; S- scarce; f- few; bord.- bordeaux; flot.sul.-flotation sulphur.

TABLE XXVI.

Results of winter examinations of 1945 and 1946 oystershell scale in the Chase Hillcrest Unit. Sprayed in 1945 with one bordeaux and two flotation sulphur sprays and in 1946 with bordeaux and Fermate sprays.

Orch. no.	Amount of scale 1945	Amount of scale 1946	Dormant oil history	No. exam. 1945	No. exam. 1946	Ratio of live parasites to mature scales with eggs 1945	Ratio of live parasites to mature scales with eggs 1946	Ratio mature scales with *H. malus* to mature scales with eggs 1945	Ratio mature scales with *H. malus* to mature scales with eggs 1946	% of 1946 scales surviving i.e. with eggs
	HILLCREST UNIT -		(in 1945, spray #1&2 bord.- spray #3-5 flotation sulphur). in 1946, bord. - Fermate.)							
3	L-H	L-fM	never	1000	500	1:3	1:1	1:626	0:87	15
4	H	M	never	1000	500	1:5	1:2	1:749	1:15	12
5	L	L	in 1941	1000	500	1:3	1:0.4	0:778	1:32	6
	HILLCREST UNIT -		(Spray program as above but nicotine sulphate used in place of arsenic.)							
1	L-M	S	never	500	500	1:1.3	1:1	1:37	1:3	11
2		S	never		200		1:5		1:12	29

L - light; H - heavy; M - medium; S - scarce; f - few; bord. - bordeaux.

IX. INFLUENCE OF SPRAYS ON THE MITE FAUNA OF APPLE TREES.

In the preceding sections detailed studies of the part played by fungicide sprays on the oystershell scale problem have been given. It has been shown that sulphur sprays are very detrimental to the chalcid parasite *A. mytilaspidis* and to the predator mite *H. malus*. Copper sprays and Fermate, on the other hand, have allowed both species to flourish to a degree where biological control rendered dormant oil applications unnecessary.

It was stated at the beginning of this paper that a vigorous attempt is being made in the Annapolis Valley to apply ecological methods to the problem of insect control. The basis of this approach has been discussed in some detail by Pickett et. al. (1946). The studies on oystershell scale have been part of a many sided study of as much as possible of the whole orchard fauna. The writer has been responsible for detailed records on the mite fauna of apple trees as well as for the investigations on oystershell scale. The short time that these investigations have been underway has been sufficient, when dealing with dense populations such as oystershell scale, red mite and the clover mite (*Bryobia praetiosa* Koch), to show definite trends. In the case of such insects as codling moth and bud moth, currently being studied by other members of the Entomological Laboratory, this interval has not been long enough to yield results that may be quoted.

It has been found that the mite fauna of apple trees treated with copper sprays is not greatly different from that of unsprayed trees while Fermate is distinctly deterrent to several beneficial species of mites. Sulphur sprays show a marked contrast to either copper or Fermate in the small number of species of mite surviving treatment with this material. The copper sprays used so far viz. bordeaux and C.O.C.S. give excellent control of apple scab but many varieties of fruit are seriously russeted by these materials. In the Hiltz South Yarmouth orchard there has been a rapid decrease of red mite where copper sprays were used, due mostly to the predator mite <u>Seiulus</u> sp. Clover mite has been kept somewhat in check by the predacious mite <u>Mediolata</u> <u>novae-scotiae</u> Nesbitt. It has however continued to increase some each year since 1943 though not as yet a serious pest. Fermate also gave very good control of apple scab particularly when used in a bordeaux-Fermate calendar. It also has the advantage of not russeting the fruit, being possibly better than flotation sulphur in this respect. Close study however has shown that it is detrimental to <u>Seiulus</u> sp. a mite which is one of the most important predator of red mite. Fermate is even more disastrous to <u>Mediolata</u> <u>novae-scotiae</u> an important mite predator on the clover mite. Where this material has been used as the only fungicide, but with an arsenical insecticide, for several years successively on the same trees in orchards which had a history of sulphur sprays, trouble has been encountered from both the clover mite and the red mite. It is possible that in a few years other predators may reduce this problem but so far this has not happened. In one orchard, neglected prior to 1944, but sprayed with Fermate (without arsenic) since then, there has as yet been no red mite or clover mite problem but red mite has increased appreciably in the three years. Clover mite, in the same orchard, has not increased greatly, apparently due to the predacious mite <u>Anystis</u> which is rarely found where an arsenical is used.

The continued use of flotation sulphur sprays has created a red mite as well as an oystershell scale problem. The increase has been more rapid where sulphurs have been used in the past than where sulphurs were used following a period of neglect. Sulphur sprays are very detrimental to <u>Seiulus</u> sp. as well as to <u>M. novae-scotiae</u>. The clover mite however is never a problem where sulphur sprays are used and the absence of <u>M. novae-scotiae</u> may be due to lack of a favourite host the clover mite.

The investigations so far have by no means solved even these problems but they show very clearly that the influence of the sprays on natural control must be given an important place in future studies on practical spraying problems.

[. SUMMARY AND CONCLUSIONS.

The oystershell scale has been rated as a pest of apple rees for many years, dating back before fungicides were used o any extent in orchards. A reliable comparison of the trouble rom this insect sixty years ago and today is not possible.

Basing judgement on the memory of a few individuals, and on the status of oystershell scale in neglected orchards today it would seem that most of the damage sixty years ago was to young trees and to occasional trees or groups of trees in some orchards. Since the 1930's many whole orchards have been heavily infested, so that dormant oil applications have been utilized in it's control every three or four years. The older records show a number of interesting remedies, and one cannot help but wonder if the success attributed to them may have been due to their innocuous nature, the control having been in reality due to biological agencies.

It is probable that the natural levels about which species fluctuate when unhindered by sprays may lie in a degree of infestation which still allows the apple tree as a species to survive in nature. These levels, with some species, may be too high for the economical production of clean fruit. It would appear from the records that the normal level of oystershell scale is below a dangerous economic level of infestation and that it's upward fluctuations in unsprayed orchards in the past had given rise to economic problems. After the introduction of sulphur sprays natural competition by H. malus and A. mytilaspidis must have been greatly reduced. Judging from the literature and from the results in the Palmer orchard it is evident that lime sulphur makes up somewhat for the loss of natural control by it's toxic effect on the scale itself. This may also have been true of the lime sulphur and iron sulphate mixture to a degree, but there are no records with which to analyze it's possibilities. It is significant that the inclusion in the spray calendar of oil sprays for the control of oystershell scale took place at a time when the mild sulphurs were beginning to be widely used in the Annapolis Valley.

After the beginning of the oystershell survey by the Annapolis Royal Laboratory in 1942 it gradually became apparent that, in general, the degree of biological control of scale was roughly proportional to the degree of neglect or care in the spray program. When it was found that this seemed to be true definite experiments were begun to find out in what manner sprays were interfering with the biological control of oystershell scale. A brief study was made of the biology of oystershell scale, H. malus, A. mytilaspidis and on the inter-relations of this complex. It was found that the mite H. malus increased very rapidly and spread to other trees attacking all stages of the scale and leaving no trace except the dead scales. When scale eggs have been attacked it is usually possible to tell mite work even when the mites are no longer present. The chalcid parasite A. mytilaspidis has three generations a year, one during July on second instar scales,one during August on third instar scales before oviposition begins and a third generation developing during scale oviposition. The larvae of the last generation overwinter in scales which usually have been unable to lay eggs due to the parasites'feeding.

Neither of these control agents are found in any numbers until some time after the spraying season, on trees which have been treated with sulphur sprays. Where small plots were employed many of the second generation adult parasites and a few of the predacious mites were able to migrate from the non sulphur plots to the sulphur plots after the spray residue had weathered off the trees. This gave the sulphur plots a higher percentage of parasitism during the winter than would be the case on larger areas. Even on larger plots there can be considerable migration from non sulphur to sulphur plots in September, some of these possibly coming from other scale infested plants in the vicinity.

In the Palmer orchard, six sprays of Fermate allowed natural control to practically eliminate oystershell scale in two years. The results with copper sprays were somewhat indecisive due to the use of single row plots, but an evident trend toward elimination of scales was apparent. Both lime sulphur and flotation sulphur very seriously reduced _H. malus_ and _A. mytilaspidis_ but the former also had some toxic action on the scales which served to keep scale in check. There was a very decided build up of oystershell scale on the flotation sulphur plots since there was very little natural control or chemical control from this material. In the Marshall (Kelsall) orchard one year without sprays was sufficient to decimate the scale population while in the Sutton (Parade) orchard scale was practically eliminated by natural means in two years. In the larger experimental blocks of the Hiltz-South Yarmouth orchards, scale had been practically eliminated by natural causes on the copper plot (bordeaux and

C.O.C.S.) while flotation sulphur sprays have brought about a dangerously high scale population on that plot.

Sprays of bordeaux and Fermate in the large Chase blocks during 1946 did not, in many cases, control the scale due to the low level of natural control at the end of 1945. There was a marked increase in the parasite and some increase of the predator mite during 1946. If a non-sulphur program is used in these orchards in 1947 scale should be greatly reduced.

There can be no doubt that the two agencies H. malus and A. mytilaspidis can, under favourable conditions, control oystershell scale and that the oystershell scale problem in the Annapolis Valley is due to the deterrent effect of sulphur sprays on these two species.

Records on the Acarid fauna of orchards, not presented in this paper, do not paint such a happy picture. Fermate has created an European red mite problem due to interference with biological control. Copper sprays seem to be increasing the amount of the clover mite while causing the disappearance of red mite through natural means. Both Fermate and copper sprays have a much less drastic effect on the mite fauna in general than sulphur sprays. Sulphur sprays seem to kill most all mites except the red mite which often becomes a major pest where sulphur sprays are used.

The use of non-sulphur sprays has, in these experiments, made unnecessary a dormant oil application for the control of oystershell scale.

The increase in oystershell scale from a minor to a major problem during the period in which mild sulphur sprays were used for the control of apple scab, illustrates very well the possibility of latent effects from the continued use of a spray material. The special application of dormant oils to alleviate the trouble is also an example of the trend toward more and heavier applications of sprays. Not only has the use of the mild sulphurs for apple scab control resulted in trouble from oystershell scale but the European red mite has also been a persistent pest. These cases offer evidence that by concentrating upon the control of specific pests while largely ignoring the ecological factors of time, space and interaction we may be leading to the creation of new problems. In the cases cited above we are dealing with species capable of building up dense populations in a short time so that the adverse effect of a spray may make itself felt in a few years. Where species with greater powers of motion and which, with much smaller numbers, can create havoc with an apple crop, the problem is much more complex. In the latter case time and space become of very great importance so that studies must be made over a much longer time taking regard also to much greater areas.

The oystershell scale problem was one that needed immediate attention and because of this work it is now possible to use the information for the economic benefit of the growers. It will in no way minimize the need for attacking problems needing a quick solution to say that great caution must be exercised in recommending treatments. A great deal of detailed knowledge is necessary before the latent effects of the use of a spray material can be added to the immediate effects. The only way to avoid costly errors and delays is to study the total effect of the spray material and the complete ecology of orchards by long term studies.

XI. BIBLIOGRAPHY.

Brittain, W.H.

1915 Some Hemiptera attacking the apple. Proc. Ent. Soc. Nova Scotia, 1: 7-47.

____

1916 Sucking insects of the apple. 52nd. Ann. Rept. N.S. Fruit Growers Assn., p. 85-111.

Buckell, E.R.

1931 <u>Hemisarcoptes coccisugus</u> Lignières, an enemy of oyster shell scale. Proc. Ent. Soc. B.C.,28:14.

Caesar, L.

1914 The San José and oystershell scales. Ont. Dept. Agric. Bul. 219.

Cameron, J. MacBain and A.D. Pickett.

1940 The insect outlook for 1940. 76th. Ann. Rept. N.S. Fruit Growers Assn., p. 19-22.

____

1940 The insect outlook for 1941. 77th. Ann. Rept. N.S. Fruit Growers Assn., p. 23-29.

Comstock, J. Henry

1881 Report on scale insects. Report of the Entomologist, Part 2. U.S. Agric. Comm. Ann. Rept. 1880, p. 276-349, 372-373. <u>Cited in</u> Griswold, Grace H., A study of the oyster-shell scale <u>Lepidosaphes ulmi</u> (L.), and one of its parasites, <u>Aphelinus mytilaspidis</u> LeB., Memoir 93, Cornell Univ. Agric. Expt. Sta., 1925.

Ewing, H.E. and R.L. Webster

1912 Mites associated with the oyster-shell scale *Lepidosaphes ulmi* (Linné). Psyche 19: 121-134.

Fitch, Asa.

1856 The apple bark louse, *Aspidiotus conchiformis* Gmelin. First and second report on noxious, beneficial and other insects of the State of New York. *Cited in* Griswold, Grace H., A study of the oyster-shell scale *Lepidosaphes ulmi* (L.), and one of its parasites, *Aphelinus mytilaspidis* LeB., Memoir 93, Cornell Univ. Agric. Expt. Sta., 1925.

Fletcher, James

1885 Report of the Entomologist. Central Expt. Farms Ann. Rept. Dept. Agric., Ottawa, p. 21-22.

____

1893 Report of the Entomologist and Botanist. Central Expt. Farms Ann. Rept. Dept. Agric., Ottawa, p. 177-178.

____

1896 Report of the Entomologist and Botanist. Central Expt. Farms Ann. Rept., Dept. Agric., Ottawa, p. 252.

____

1897 Report of the Entomologist and Botanist. Central Expt. Farms Ann. Rept., Dept. Agric., Ottawa, p. 199-221.

Fletcher, James

1900 Report of the Entomologist and Botanist. Central Expt. Farms Ann. Rept., Dept. Agric., Ottawa, p. 239.

———

1903 Report of the Entomologist and Botanist. Central Expt. Farms Ann. Rept., Dept. of Agric., Ottawa, p. 188-189.

———

1906 Report of the Entomologist and Botanist. Central Expt. Farms Ann. Rept., Dept. of Agric., Ottawa, p. 219.

———

1908 Report of the Entomologist and Botanist. Central Expt. Farms Ann. Rept., Dept. of Agric., Ottawa, p. 199-200.

Gilliat, F.C.

1934-1935 Insects of the year. Ann. Reports, Dom. Ent. Lab. Annapolis Royal, N.S. (Unpublished).

Glendenning, R.

1931 The progress of parasite introduction in British Columbia. Proc. Ent. Soc. B.C., 28: 29-32.

Griswold, Grace H.

1925 A study of the oyster-shell scale _Lepidosaphes ulmi_ (L.), and one of its parasites, _Aphelinus mytilaspidis_ LeB., Memoir 93, Cornell Univ.Agric. Expt. Sta.

Hewitt, C. Gordon

1912 Report of the Dominion Entomologist. Central Expt. Farms Ann. Rept., Dept. of Agric., Ottawa, p. 179.

____

1915 Report of the Dominion Entomologist. Central Expt. Farms Ann. Rept.,Dept. of Agric., Ottawa, p. 23-27.

____

1917 Report of the Dominion Entomologist. Central Expt. Farms Ann. Rept., Dept. of Agric., Ottawa, p. 13-14.

Hubbard, H.G.

1885 Insects affecting the orange. U.S. Dept. Agric. Div. Ent., Washington, D.C. Cited in Tothill, John D., Some notes on natural control of oyster-shell scale, *Lepidosaphes ulmi* (L.), Bul. Ent. Res. 9: 183-196, 1919.

Jarvis, F.D.

1910 The Coccidae of Canada. 41st. Ann. Rept. Ent. Soc. Ont., p. 64-77.

Kelsall, A.

1939 Thirty years experience with orchard sprays in Nova Scotia. Sci. Agric. 19:405-410.

LeBaron, Wm.

1870 The chalcideous parasite of the apple-tree bark-louse (Chalcis (Aphelinus) mytilaspidis n.sp.) Amer. Ent. and Bot. 2: 360-362. Cited in Griswold, Grace H., A study of the oyster-shell scale Lepidosaphes ulmi (L.), and one of its parasites, Aphelinus mytilaspidis LeB., Memoir 93, Cornell Univ. Agric. Expt. Sta., 1925.

____

1871 The oyster-shell bark-louse (Mytilaspidis conchiformis, Gmelin). First annual report on the noxious insects of the State of Illinois p. 24-46. Cited in Griswold, Grace H., A study of the oyster-shell scale Lepidosaphes ulmi (L.), and one of its parasites, Aphelinus mytilaspidis LeB., Memoir 93, Cornell Univ. Agric. Expt. Sta., 1925.

Lignières, Joseph

1893 Etude zoologique et anatomique de l'Hemisarcoptes coccisugus. Mém. Soc. Zool. France 16-25. Cited in Tothill, John D., Some notes on natural control of oyster-shell scale Lepidosaphes ulmi (L.), Bul. Ent. Res. 9: 183-196, 1919.

Neary, M.E.

1941 The insect outlook for 1942. 78th. Ann. Rept. N.S. Fruit Growers Assn., p. 37-41.

Neary, M. E.

1944 The insect outlook for 1945. 81st. Ann. Rept. N.S. Fruit Growers Assn.,p. 24-29.

———

1945 The insect outlook for 1946. 82nd. Ann. Rept. N.S. Fruit Growers Assn., p. 33-38.

Nicholson, A.J.

1938 Indirect effects of spray practice on pest populations. Verh. 7 int. Kongr. Ent. Berlin 1938, p. 3022-3028.

Pickett, A.D.

1935 Insect outlook for 1936. 72nd. Ann. Rept. N.S. Fruit Growers Assn., p. 71-74.

———

1936 Insect outlook for 1937. 73rd. Ann. Rept. N.S. Fruit Growers Assn., p. 109-112.

———

1937 Insect outlook for 1938. 74th. Ann. Rept. N.S. Fruit Growers Assn., p. 78-82.

———

1938 The insect outlook for 1939. 75th. Ann. Rept. N.S. Fruit Growers Assn., p. 62-68.

——— & N.A. Patterson

1940 Experiments with insecticides in 1940. 76th. Ann. Rept. N.S. Fruit Growers Assn., p. 29-35.

Pickett, A.D. & N.A. Patterson

1941 Experiments with insecticides in 1941. 78th. Ann. Rept. N.S. Fruit Growers Assn., p. 21-25.

____

1942 Recent experiments in insect control in Nova Scotia. 79th. Ann. Rept. N.S. Fruit Growers Assn., p. 19-23.

__________, N.A. Patterson, H.T. Stultz and F.T. Lord.

1946 The influence of spray programs on the fauna of apple orchards in Nova Scotia: I. An appraisal of the problem and a method of approach. Sci. Agric. 26: 590-600.

Quaintance, A.L.

1916 The oyster-shell scale and the scurfy scale. U.S. Dept. Agric. Farm. bul., p. 723.

Reaumur (Rene Antoine Ferchault) De

1738 Memoires pour servir a L'histoire des insectes. 4: 1-636, Paris. Cited in Griswold, Grace H., A study of the oyster-shell scale, *Lepidosaphes ulmi* (L.), and one of its parasites, *Aphelinus mytilaspidis* LeB., Memoir 93, Cornell Univ. Agric. Expt. Sta., 1925.

Riley, Charles V.

1869 The bark-lice of the apple (Homoptera- Coccidae). First annual report on the noxious, beneficial and other insects of the State of Missouri. Cited in Griswold, Grace H., A study of the oyster-shell scale, *Lepidosaphes ulmi* (L.),and one of its parasites, *Aphelinus mytilaspidis* LeB., Memoir 93, Cornell Univ. Agric. Expt. Sta., 1925.

Riley, Charles V.

1873 The oyster-shell bark-louse of the apple (*Mytilaspis pomicorticis* n. sp.). Fifth annual report on the noxious, beneficial and other insects of the State of Missouri. Cited in Tothill, John D. Some notes on natural control of oyster-shell scale *Lepidosaphes ulmi* (L.), Bul. Ent. Res. 9: 183-196.

Sanders, G.E. & W.H. Brittain

1918 A modified Bordeaux Mixture. Proc. Ent. Soc. N.S., 4: 51-61.

Shimer, Henry

1868 Notes on the apple bark-louse (*Lepidosaphes conchiformis* Gmelin) with a description of a supposed new Acarus. Amer. Ent. Soc. Trans. 1: 361-373.

Spittall, J.P.

1924-1932 Insects of the year. Ann. Reports, Dom. Ent. Lab. Annapolis Royal, N.S. (Unpublished).

Tothill, John D.

1919 Some notes on natural control of oyster-shell scale

Walsh, Benj. D.

1868 The oyster-shell bark-louse. (*Aspidiotus conchiformis* Gmelin). First annual report on noxious and beneficial insects of the State of Illinois. p. 34-53. *Cited in* Griswold, Grace H., A study of the oyster-shell scale *Lepidosaphes ulmi* (L.), and one of its parasites, *Aphelinus mytilaspidis* LeB., Memoir 93, Cornell Univ. Agric. Expt. Sta., 1925.

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