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Studies on Natural vs. Artificial Control of the Pine Tortoise Scale

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STUDIES ON NATURAL VS. ARTIFICIAL CONTROL OF THE PINE TORTOISE SCALE

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INTRODUCTION

The control of sap-sucking insects on conifers presents one of the most difficult problems confronting economic entomologists. There are numerous records of experiments in which miscible oils or oil emulsions have been used with varying degrees of success. Oils that can safely be used on hardwoods and most fruit trees often severely burn the foliage of conifers. Consequently, the use of oil sprays on evergreens has been more or less discouraged, especially in the colder sections, such as Minnesota, where climatic factors appear to be important in determining the likelihood of foliage injury.

In most of the previous experiments in the use of oil sprays on conifers only a comparatively few trees have been treated in each case. Also, the effectiveness of the treatment has usually been measured only by more or less casual examination, and no attempt has been made to compare the relative values of the spraying and the natural control factors that may have been operating at the same time. Recent work in Nebraska, reported by Gates, apparently involved a large number of pine trees sprayed with oil emulsions with satisfactory results.[1] However, no mention is made of the presence of any natural enemies.

In the experiments on which the present paper is based, more than four thousand trees were sprayed. Actual counts were made on groups of sprayed and unsprayed trees to determine the degree of scale infestation following the treatment. These examinations also showed the remarkable effectiveness of certain natural enemies that were present and made possible this comparison of natural and artificial control.

The insect concerned was the pine tortoise scale, *Toumeyella numismaticum* Pt. and McD. This paper is a preliminary report on several phases of the study of the relation of this insect to the management of jack and Scotch pine plantations. The work was done at the St. Paul city water department plantations at Lake Vadnais, about seven miles north of St. Paul, through the co-operation of the Water Department and the Divisions of Entomology and Forestry of the University of Minnesota.

[1] Gates, L. M. "The Pine Tortoise Scale, *Lecanium numismaticum*, Pettit and McD., in Nebraska." Jour. of Econ. Ent., Vol. 23, pp. 544-547. 1930.

HISTORY OF THE OUTBREAK

The complete history of the insect in these plantations is not known. The effects of its presence were first noticed and reported by J. H. Allison, of the Division of Forestry, in August, 1926. The insects were well established but apparently confined to a small area at one side of a planting of jack pine. Unfortunately, no immediate action was taken. They were first called to the writer's attention in October, 1928, by Mr. Allison, and plans were immediately formulated for attacking the problem.

A paper describing what was known of the insect and its distribution and economic importance was prepared for publication in March, 1929, and was published in the Journal of Forestry for November, 1929.

Status in the Spring of 1929

A survey in the spring of 1929 showed that the pest had spread out from the original center over nearly all of a 50-acre tract. This included approximately 40 acres of mixed Norway and jack pine planted in 1918 in alternate rows and about ten acres of pure Scotch pine planted at the same time. The most serious injury was found in the jack pine on the 10 or 15 acres surrounding the original infestation. The rest of the area was already heavily infested but fewer trees had died. The Scotch pine was apparently as susceptible as jack pine to the scale injury, whereas the Norway pine was evidently entirely immune. The Scotch pine was planted in three separate blocks, one of which, located near the jack pine first infested, was already severely attacked altho few trees had then died. This area was selected for detailed study because of its very heavy and relatively recent attack by the scale. Figure 1 is a diagram of the section of the plantations involved in this study.

The scale was first noticed in this block of Scotch pine in the summer of 1927. Records made in connection with growth measurements by Allison on May 1, 1928, showed only 27 per cent of the trees infested on a half-acre plot established in about the center of the block. During 1928, the degree of infestation for the block as a whole had increased to about 86 per cent.

It was naturally expected that there was likely to be a similar increase and spread during the summer of 1929, with the consequent loss of a large part of the remaining stand. Another large planting on the opposite side of Lake Vadnais was also in danger of being infested. In fact, a few scattered infested trees were found in this planting in the spring of 1929 and were cut out.

The destructiveness of this scale is indicated in Table 1, showing results of counts made in representative parts of the infested plantations:

Table 1

Date	Species	Area	Condition of trees: Heavy infestation* No.	Heavy infestation* Per cent	Medium to light infestation No.	Medium to light infestation Per cent	Uninfested No.	Uninfested Per cent	Total No.
May 15	Scotch pine	Recently infested (sprayed)	32	1.58	1,712	84.59	280	13.83	2,024
May 15	Jack pine	Recently infested (sprayed)	546	41.14	622	46.87	159	11.98	1,327
May 26	Jack pine	Original infestation (unsprayed)	738	76.08	164	16.91	68	7.01	970

* Dead or dying.

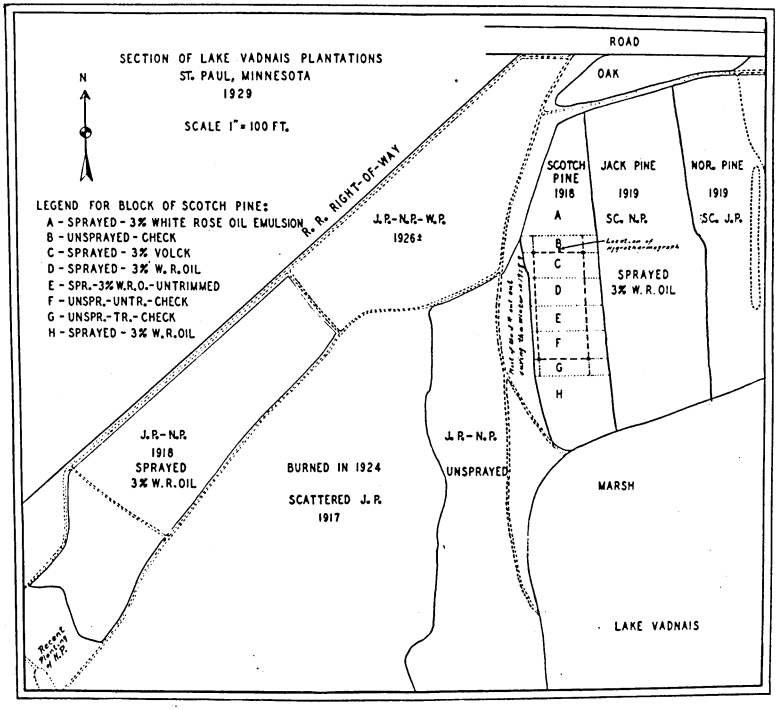

Fig. 1. Diagram of the Plantations Involved in the Studies Presented

The figures for the counts made on May 15 are very conservative because the lower branches, which are usually the first to be infested, had been trimmed off before the count was made in order to facilitate spraying. Undoubtedly many trees were counted as uninfested on which scales might have been found previous to trimming. In most cases only the lower two or three whorls of branches were removed, altho heavily infested trees were trimmed more severely. Dead or nearly dead trees were cut out. The area of original infestation had

not received such treatment and, therefore, the figures for May 26 are more exact.

Evidence of Immunity or Resistance of Certain Trees

One of the most significant observations made in this survey was the fact that certain individual trees are apparently immune to attack by the scale. Table 1 shows that 7 per cent of the jack pine in the area of oldest infestation were still uninfested in the early spring of 1929. In many instances these trees were standing next to or between infested living or dead trees, the branches interlacing. Some physiological characteristic must be involved that renders these trees resistant or immune. Evidently there are degrees of resistance, as

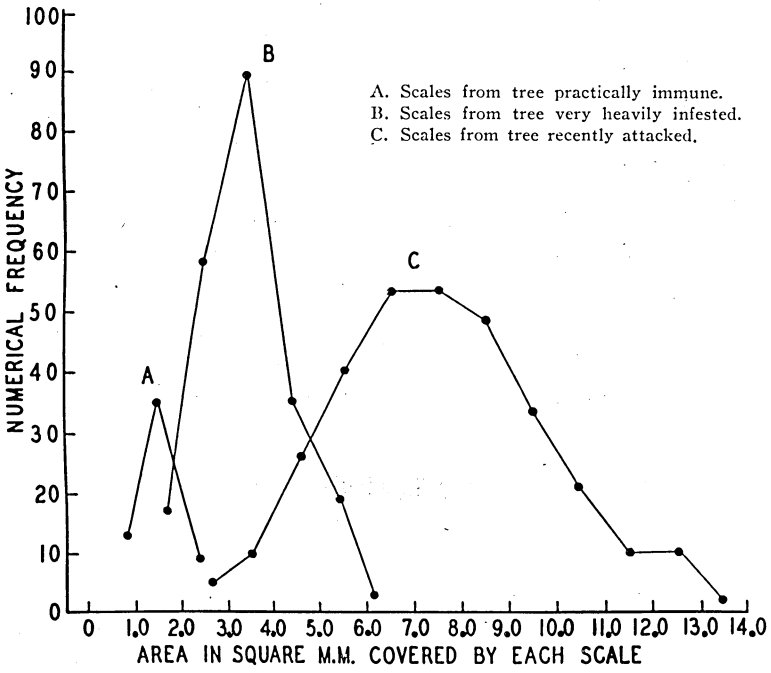

Fig. 2. Relation Between Tree Condition and Size of Scale

several trees were found with only a few very small scales on one or two branches that were interlaced with those of a heavily infested tree. Similar conditions were observed in the Scotch pine. Seeds collected from apparently immune jack pines were planted and many seedlings were obtained. These will be used later in an attempt to learn whether or not a resistant strain can be developed. Cross-fertilization with

susceptible trees will undoubtedly show its effects in the seeds already collected, but future collections, made now after most of the susceptible trees have been weeded out, should show a higher percentage of resistance. This line of attack is new in forest entomology but shows promise of very desirable results.

Tree Condition Affects Size of Individual Scales

The condition of a given tree appeared to be effective in determining the size of the scales found upon it. Scales on trees weakened by several seasons of attack were much smaller than those on trees more recently infested. In order to arrive at a more definite measure of this difference in size, typical branches were taken from such trees and all the scales found on them were measured. As the overwintering female scales are typically oblong, it was possible to get an approximate measure of the size of each by multiplying the length by the width. The products were expressed in square millimeters. Figure 2 shows the distribution of the size classes found on three jack pines.

No actual measurements were made of scales on Scotch pines but in general they averaged considerably smaller than those on jack pine of similar vigor. The maximum size of scales on Scotch pine was much less than that on jack pine.

Spraying Plan and Procedure

It was realized that the use of oil sprays on conifers, at least in the latitude of Minnesota, is a dangerous proposition, and that there was considerable risk of killing or injuring the trees with an oil that would ordinarily be safe enough in warmer regions. However, as there was every indication that there would be a large loss if artificial control was not attempted, it was decided to proceed in the hope of killing the insects without causing serious injury to the trees. It was thought that even if the trees were injured by the spraying the work would be justified if by so doing the insect could be prevented from spreading to other neighboring plantings that were still uninfested.

It was decided to leave the area in which the original infestation occurred unsprayed because there were not enough infested trees that had a chance to recover to warrant an attempt to save them. Most of the infested trees were dead or in a greatly weakened condition. The scales on most of these weakened trees were small, probably owing to lack of food. Therefore it was not likely that, even tho a considerable number of young might be produced, there would be enough new growth on these trees to allow many of the young scales to become established and reach maturity. Another possibility was that there might be a considerable degree of parasitism among the scales on these

trees and most of the parasites on emerging would be forced to go to other parts of the plantation to find hosts in which to oviposit. Thus this part of the plantation might actually prove an indirect aid in checking the scale in the more recently infested areas.

White Rose Oil No. 3 was selected as being safe to use and at the same time fairly reasonable in price. However, we were given Standard White Rose Oil instead of No. 3. This grade is somewhat more highly refined and this fact may explain why the spraying was not more effective than it was. This oil is a product of the Standard Oil Company of Indiana and is a white oil with a very high saturated hydrocarbon content. Kayso (calcium caseinate) was used as an emulsifier. The stock emulsion was made as follows: Add enough water to one pound of Kayso to make a thick paste and then dilute to 3 gallons. Stir this into 8 gallons of oil and pump the mixture from one container into another with a bucket pump.

One or two pumpings did not give a very good emulsion but the third gave very good results. Sufficient of this stock emulsion was then added to the spray tank of water, with the agitator working, to give the desired concentration.

Volck and Dendrol were used on a few trees for comparison with the home-made emulsion.

A Friend power sprayer with a 150-gallon tank was used. Two 140-foot lines of hose and two spray guns were used the greater part of the time, but it was necessary to use 240 feet of hose and only one nozzle to reach the trees farthest from the edges of the plantations or from the numerous plowed fire lines. The pressure gauge on the machine registered between 175 and 300 pounds, depending upon whether one or two spray guns were being used.

Best results were obtained by using a hard, driving spray rather than a fog or mist type, because it was necessary to drive the spray material between the needles so that it thoroly wet the scales on the bark of the branches.

Spraying with the power machine was begun on April 29. At this time the Scotch pine buds were swelling, but had not elongated much. Some of the scales were growing and a small amount of honeydew was present, enough to give the trees a glistening appearance on clear, warm days. The weather was cool and cloudy most of the time during and after the spraying period and several hard frosts occurred. A hygrothermograph in the plantations showed maximum and minimum temperatures for the period, as given in Table 2.

Table 2
Climatological Data, April 29 to May 20, 1929

Date	Temperature Maximum °F.	Maximum Time	Minimum °F.	Minimum Time	Nebulosity 0-10	Wind direction and velocity	Precipitation
Apr. 29	59	3:00 p.m.	28	4:00 a.m.	4- 7	S.—Mod.	
" 30	65	2:00 p.m.	43	12:30-3:00 a.m.	3- 5	SW.—Mod.	Light rain
May 1	62	2:00 p.m.	37	4:00 a.m.	9	N.—Mod.	" " 0.2 in.
" 2	52	1:00 p.m.	30	6:00 a.m.	9	NW.—Mod.	
" 3	49	12:30 p.m.	30	2:30-6:30 a.m.	3- 7	NW.—Light	
" 4	48	2:00 p.m.	30	6:00 a.m.	4-10	NW.—Mod.	
" 5	55	3:30 p.m.	30	5:00 a.m.	8-10	NW.—Mod.	
" 6	57	3:00 p.m.	24	3:30 a.m.	6-10	NW.—Mod.	
" 7	63	3:30 p.m.	26	5:30 a.m.	6-10	NW.—Mod.	
" 8	64	1:00 p.m.	32	4:30 a.m.	2-10	NW.—Light	
" 9	69	2:30 p.m.	26	3:00-5:00 a.m.	6-10	SE.—Light	
" 10	67	11:30 a.m.	44	2:00-4:00 a.m.	0- 2	SE.—Light	Drizzle
" 11	69	4:00 p.m.	51	6:00 a.m.	6- 8	NW.—Mod.	
" 12	73	3:00 p.m.	46	6:00 a.m.	9-10	SW.—Light	
" 13	80	4:00 p.m.	36	5:30 a.m.	9-10	S.—Mod.	
" 14	76	4:00 p.m.	46	5:00 a.m.	5	SE.—Mod.	
" 15	62	2:30 a.m.	33	8:00-10:00 p.m.	0- 2	NW.—Mod.	Mist
" 16	63	4:00 p.m.	25	5:00 a.m.	2- 8	SW.—Mod.	Snow
" 17	80	4:30 p.m.	47	3:00-5:00 a.m.	2-10	SE-SW.—Mod.	
" 18	57	3:00 p.m.	40	6:00 a.m.	2-10	NW.—Mod.	
" 19	63	1:30 p.m.	24	6:00 a.m.	5	NW.—Light	
" 20	69	2:00 p.m.	30	6:00 a.m.	9-10	N.—Light	

The cool weather made it necessary to stop the machine early in the afternoon on several days in order to allow time for the trees to dry partially before night. The machine was usually started at about 8:30 a.m. and stopped between 3:30 and 5:30 p.m. Facilities for getting water and for mixing the materials were none too good. As a result, the maximum amount applied in any one day was 750 gallons.

The Scotch pine planting was sprayed first, the spraying being completed on May 4. The work was continued until May 9 on jack pine. A total of 4,640 gallons of White Rose Oil emulsion, nearly all 3 per cent, and 290 gallons of 3 per cent Volck Heavy were applied.

When the spraying was completed the new shoots on the jack pine were from one to four inches long; those on Scotch pine, from one to two and one-half inches long. Many scales had nearly doubled in size but produced little honeydew. The reason for the comparatively small production of honeydew is not known. (Mr. Allison had found the trees to be wet with it in the spring of 1928.)

Results of the Spraying

Effects upon the Trees

The only apparent immediate effect upon the trees that was caused by the spraying with the 3 per cent emulsion was the removal of the natural bloom from the needles. No burning was observed during the early part of the summer except where there was a slight overlapping

in spraying on two successive days. Even these marginal trees showed no injury to the young shoots, but some of the older needles were burned and dropped off later, especially on the lower branches and in the denser crowns. There was some evidence that the oldest crop of needles on the sprayed trees ripened and fell off before they did on unsprayed trees.

About 130 gallons of 4 per cent homemade white oil emulsion was applied on some of the Scotch pines on May 4 and even this concentration caused relatively little burning. It was more effective in killing the scales than was the 3 per cent emulsion. A few trees were treated with a 5 per cent concentration on May 20 and these were severely burned, altho a 2½ per cent application on the same day did not cause injury.

The Volck that was used was applied at a concentration of 3 per cent and caused more burning than did the 4 per cent homemade emulsion, altho not severe enough to be serious.

Several applications of Dendrol at from 2 to 5 per cent concentrations were made on jack pine and Scotch pine between March 25 and May 11 with a wheelbarrow sprayer and a compressed-air hand sprayer. Severe burning resulted in all cases with concentrations of 3 per cent or higher. The lower concentrations caused some burning and did not kill many of the scales.

Effects upon the Scales

Most of the scales soon began to show effects of spraying, and within two weeks most of them were wrinkled and had become darker in color. They also loosened from the bark and could be brushed off easily. On unsprayed trees the scales were increasing rapidly in size and were considerably distended with developing eggs by the last of May.

It soon became evident that the spraying treatment had not been effective enough to kill all the scales. Practically every tree had a few living females, altho in most cases less than 5 per cent of the original population. The number of reproducing females was thus tremendously reduced, but the exceedingly high potential of the species made it possible for them to maintain a comparatively general infestation with even only a few females reproducing.

Effects upon the Parasites and Predators

Very little definite information was obtained as to the effect of the spraying upon the parasites and predators within the sprayed areas. That parasites are an important factor in natural control is indicated by the fact that several hundred specimens of a small Hymenopterous (Chalcid) parasite, *Microterys fuscicornis* How. (determined by A. B. Gahan, of the United States Bureau of Entomology), were reared from scales on a few jack pine branches that were taken into the laboratory in May. Natural emergence in the field occurred after about June 5, as the first were observed on that date. As many as eight emergence

holes were counted in one large scale. Many parasites were undoubtedly killed by the oil spray. It was found, however, that many parasites did emerge from scales on the branches that had been trimmed off and piled along the fire lines before the spraying was done.

Adults of the following species[2] of coccinellids were reared from larvae that were found feeding upon the scales: *Hyperaspis binotata* (Say), *Chilocorus bivulnerus* Mulsant, *Scymnus lacustris* Leconte, *Coccinella transversoguttata* Faldermann, *Coccinella novemnotata* Herbst, and *Brachyacantha ursina* (Fabricius). Of these *Hyperaspis* ~~*signata*~~ *binotata* (Say) was by far the most abundant.

The exact nature of the effect of the spraying upon the population of coccinellids is not known. Adults were not noticed when the spraying was done. If they were on the trees or under bark scales or in the ground litter, it is possible that some were killed. A more plausible and probable explanation is that the film of oil left on the needles may have acted as a repellant at the time of egg laying and caused the majority of the females to concentrate their egg laying on unsprayed trees.

Life History of *T. numismaticum*

Fertilized, partially developed females overwinter and continue their growth the following spring as soon as sap movement starts in their host trees. A copious production of honeydew by the scales is characteristic of this period.

When mature the females become greatly distended with eggs. An idea of the high fecundity of this species may be had from the fact that 1,524 eggs were dissected from one mature female. Egg laying started about June 10 in 1929 and continued until about the first of July. The eggs hatch almost immediately, usually in less than an hour after being laid, and as a result there are never many eggs beneath a given female at any one time, altho there may be numerous nymphs. The egg-laying period of each female must last from ten days to two weeks or longer, altho this point can not be stated definitely.

The young scales, or nymphs, wander about until they find a suitable place to settle down, insert their sucking beaks, and begin to feed on the sap of the tree. It is only during this very brief period immediately following hatching that the females of this species are capable of locomotion. Therefore natural spread or distribution from tree to tree or from one area to another must occur at this time.

Most of the young nymphs go to the new growth but some of them establish themselves on the older parts of the branches where the bark is still smooth and succulent. Others get on the needles but the writer has found only males maturing in such cases. It is suggested that perhaps the needles do not offer sufficient food for the development of the females.

[2] Determinations made by Dr. Wm. C. Stehr, Ohio University, Athens, Ohio.

In many cases the young scales cover nearly every bit of available space on the new shoots, especially the basal parts. They always arrange themselves with their heads toward the base of the branch and concentrate on the lower surface. As they increase in size there is often not room for them to lie flat on the bark surface, consequently they overlap like shingles on a roof.

The young male scales complete development by the middle or latter part of August, pass through a sort of transformation stage, and finally emerge from their protective coverings as two-winged adults. The so-called cocoons from which the males emerge remain on the trees and appear much like small grains of rice. The males fertilize the partly grown females and then die. The fertilized females pass the winter and continue their development the following spring.

Scale Distribution

Local spread of the insect may take place by the nymphs actually crawling from branch to branch on the same tree or from one tree to another where the branches are interlacing. Also, the coccinellids, as well as bees and other insects that are attracted to infested trees by the presence of honeydew, very likely carry the nymphs or "crawlers," from tree to tree. Birds and squirrels undoubtedly serve the same purpose. (The writer has observed red squirrels feeding voraciously upon the overwintering female scales during the winter and early spring.) Birds may also be responsible for carrying nymphs several miles, altho long-distance spread is not likely to occur in this way because most birds are nesting during this period and not making long flights. It appears that spread of this insect from one region to another is most likely to occur by means of shipments of infested nursery stock.

Feeding Habits of Coccinellids

The first collection of adult coccinellids was made on May 13 and they were abundant by May 27. The first larvae were observed on June 10 and they were numerous by June 12, the first day that the scales were found to be laying eggs. The adult coccinellids had disappeared by June 15, but the larvae were very abundant, especially on unsprayed trees. They seemed to do most of their feeding on the young scales and eggs beneath the mother scales. In many cases they were found to force their way under the mother scale and eat the contents of her body, leaving an empty shell. In such instances the shell of the scale often completely covered the young coccinellid. Before July 1 very little feeding was observed on young scales that had left their mothers and crawled out onto the new growth. In fact, it almost appeared as if young scales that had succeeded in getting out away from their mothers were comparatively safe. However, egg laying

ceased about the first of July and the coccinellid larvae were forced to move around more in search of food. They then began feeding on the young scales that had moved out and become established. It will be shown in Tables 3 to 6 that there was little, if any, destruction of the young scales on the new growth of the trees up to that time. From then on such feeding increased rapidly and was very effective, especially on unsprayed trees that had been left as checks. A few larvae were still on the trees as late as September 19, but it is the writer's belief that only one generation, or possibly a partial second, occurs each season. Young adults were quite numerous during the latter part of July and up to the first week in September.

Determining the Effectiveness of the Spraying

As already mentioned, the block of Scotch pine had been selected for detailed study and was subdivided into eight plots. Plots A, D, and H were trimmed and sprayed with 3 per cent White Rose Oil emulsion. Plot E was sprayed as above, but left untrimmed. Plot C was trimmed and sprayed with 3 per cent Volck Heavy. Plots B and G were trimmed and left unsprayed, and Plot F was untrimmed and unsprayed.

Table 3

	Relative vigor of trees									
	−−		−		x−		x		x+	
	No.	%	No.	%	No.	%	No.	%	No.	%
Unsprayed	1	1.30	3	3.90	14	18.18	36	46.75	23	29.87
Sprayed	2	1.57	10	7.87	35	27.56	64	50.39	16	12.60

	Proportion of trees infested									
	0		¼		½		¾		4/4	
	No.	%	No.	%	No.	%	No.	%	No.	%
Unsprayed	6	7.79	26	33.77	22	28.57	18	23.38	5	6.49
Sprayed	4	3.15	44	34.66	29	22.83	32	25.19	18	14.17

Unfortunately, no actual counts were made previous to spraying in order to determine the degree of infestation on each plot. The check plots were widely enough separated that it was thought the final results obtained would hardly be due to differences in the original infestation, especially as conditions appeared to be fairly uniform over the entire block. Table 3 shows that conditions were not as uniform as they were at first thought to be. These data were obtained in connection with the counts made during the summer to determine the infestation by individual shoots on trees within the plots. When these counts were made, the condition of the tree as a whole before the time of spraying was indicated by recording the proportion of the tree infested and its relative vigor. Five classes of vigor were recognized: nearly dead or dying (−−), weak (−), below average (x−), average or normal (x),

and above average (x+). The results show that the trees on the unsprayed, or check, plots average somewhat higher in vigor and lower in previous infestation.

In order to arrive at a satisfactory measure of the effectiveness of the oil spray, it was necessary to make actual counts on representative trees rather than to depend upon casual observation. It was impracticable to count the actual number of young scales on each tree or even on individual branches. The method adopted was that of examining 100 new shoots or twigs scattered at random over each tree in a row or parts of several rows across the block of Scotch pine. In order to get sufficient trees for a fair sample on the smaller plots it was necessary to examine trees in several adjacent rows. The relative abundance of young scales was recorded as light, medium, or heavy for each shoot examined. The results of the count made about the first of July are summarized in Table 4.

Table 4

Date	Plot	No. of trees	No. of twigs counted	Degree of infestation by young scales			Totals	
				Heavy— No. twigs	Medium— No. twigs	Light— No. twigs	Infested	Uninfested
				Sprayed Plots				
June 29 } July 1 }	A	21	2,100	47	91	477	615	1,485
July 1	C	9	900	67	61	375	503	397
Totals	..	30	3,000	114	152	852	1,118	1,882
Percentages	..	..	....	3.80	5.07	28.40	37.27	62.73
				Unsprayed Plots				
June 29	B	6	600	50	110	245	405	195
July 1	F	9	900	314	227	289	880	20
Totals	..	15	1,500	364	387	534	1,285	215
Percentages	..	..	....	24.27	25.80	35.60	85.66	14.33

The unsprayed plots, B and F, show a much higher degree of infestation than the sprayed plots. The difference is especially striking in the percentage of twigs heavily infested. This indicates that the oil had killed a high percentage of the developing females, but that a scattered few were left.

The effectiveness of the coccinellids was not very apparent up to the time that this first count was made. Their feeding thus far had been confined almost entirely to the eggs and young nymphs found near or under the mother scales. It was also observed that the great majority of the coccinellid larvae were to be found on unsprayed trees. It is reasonable to assume, therefore, that without coccinellids there would have been many more young scales on the unsprayed plots. The tremendous number of young scales destroyed during this early feeding period would have had an opportunity to distribute themselves over the new shoots of these trees.

A second count was made about the middle of July and a third the last of July. By that time the work of the coccinellid larvae was very apparent and, therefore, a further classification had to be made. Shoots on which all or nearly all of the young scales had been destroyed were recorded as previously heavily, medium, or lightly infested but cleaned off by coccinellids. In most cases the young scales were entirely removed from the bark, leaving small, light colored spots quite easily recognized, and an estimate could thus be made of the original infestation. Table 5 summarizes the data obtained; the columns headed "Scale" referring to the shoots on which scales were present at the time of the examination, and those headed "Cocc." referring to the shoots on which the scales had been cleaned off by coccinellids previous to the examination.

Table 5

Date	Plot	No. of trees	No. of twigs counted	Degree of infestation: Heavy Scale No.	Heavy Cocc. No.	Medium Scale No.	Medium Cocc. No.	Light Scale No.	Light Cocc. No.	Totals: Scale No.	Totals: Cocc. No.	Totals: Uninfested No.
				Sprayed Plots								
July 15	A	28	2,800	74	120	235	215	843	198	1,152	533	1,115
" 17	C	7	700	54	4	105	20	395	27	554	51	95
" 18	D	9	900	24	23	144	33	461	64	629	120	151
" 18	E	8	800	85	4	234	14	368	26	687	44	69
" 19	H	17	1,700	300	10	406	24	843	36	1,549	70	81
Totals	..	69	6,900	537	161	1,124	306	2,910	351	4,571	818	1,511
Percentages	..	..	....	7.78	2.33	16.29	4.43	42.17	5.09	66.25	11.85	21.90
July 31	A	*	*									
" 31	C	8	800	88	18	184	45	361	69	633	132	35
" 31	D	8	800	29	57	100	107	246	214	375	378	47
Aug. 1	E	8	800	59	60	154	90	221	124	434	274	92
" 1	H	*	*									
Totals	..	24	2,400	176	135	438	242	828	407	1,442	784	174
Percentages	..	..	....	7.33	5.63	18.25	10.08	34.50	16.96	60.08	32.67	7.25
				Unsprayed Plots								
July 17	B	5	500	2	72	35	89	134	111	171	272	57
" 18	F	7	700	47	89	33	150	185	118	265	357	78
" 19	G	4	400	53	55	78	102	77	26	208	183	9
Totals	..	16	1,600	102	216	146	341	396	255	644	812	144
Percentages	..	..	....	6.375	13.50	9.125	21.31	24.75	15.94	40.25	50.75	9.00
July 24	B	25	2,500	2	499	15	1,086	128	664	145	2,249	106
Aug. 1	F	9	900	....	247	....	388	4	216	4	851	45
" 1	G	11	1,100	....	261	....	414	12	351	12	1,026	62
Totals	..	45	4,500	2	1,007	15	1,888	144	1,231	161	4,126	213
Percentages	..	..	....	0.044	22.38	0.33	41.95	3.20	27.36	3.58	91.69	4.73

* No count made.

The most evident fact shown in Table 5 is that the coccinellids did not cause much reduction in scale infestation on the sprayed plots, but were effective on the unsprayed plots. It will be noted that the percentage of shoots recorded as uninfested decreased in both cases. This apparent discrepancy may be partly explained on the basis that as the young nymphs increased in size they became more conspicuous. Shoots that were at first considered as uninfested were later found to have a few scales. It is possible that a part of the shoots recorded as having had scales on them destroyed by coccinellids were never infested, but this error would be so small as not to affect materially the general conclusions.

A fourth count was made the last of August. The scales had grown enough that it was very difficult to record the relative abundance on each shoot so the record would be comparable with the previous data. It was also impossible to determine where scales had or had not been present and, therefore, no further record could be made of the progressive effect of the coccinellids. The system adopted was that of simply recording the number of shoots on which young scales were found in the course of examining 100 shoots on each tree. The summarized data are given in Table 6.

Table 6

Date	Plot	No. of trees examined	No. of shoots examined	Total No. of infested shoots	Per cent of total
1929			Sprayed Plots		
Aug. 29	A	28	2,800	419	14.96
" 29	C	15	1,500	153	10.20
" 30	D	17	1,700	312	18.35
" 30	E	16	1,600	105	6.56
" 30	H	15	1,500	289	19.26
Totals			9,100*	1,278*	
1929			Unsprayed Plots		
Aug. 29	B	36	3,600	7	0.194
" 30	F	16	1,600	5	0.312
" 30	G	15	1,500	2	0.133
Totals			6,700†	14†	

* An average infestation of 14.044 per cent.
† An average infestation of 0.209 per cent.

Figure 3 presents the changes in the scale population and coccinellid effectiveness during the season on sprayed and unsprayed plots. Figure 4 shows the percentage of tips infested with young scales on each tree on sprayed and unsprayed plots at the time of the last examination of the season.

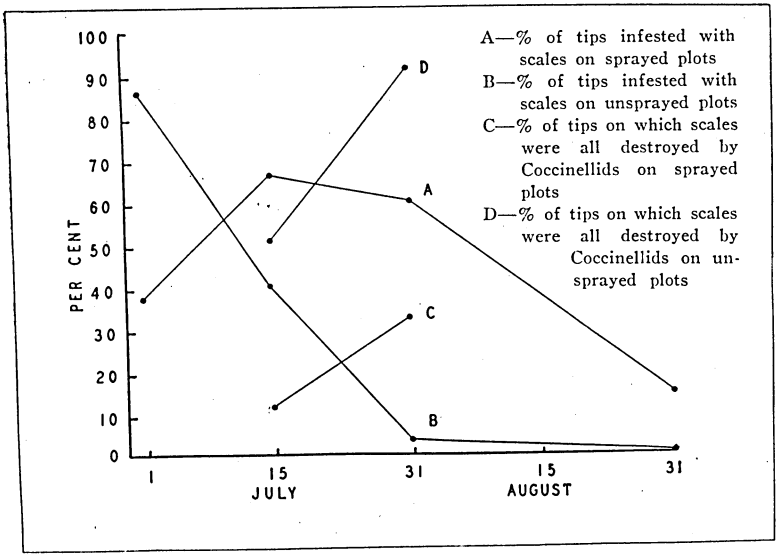

Fig. 3. Changes That Occurred During the Season on Sprayed and Unsprayed Plots in Degree of Scale Infestation and Coccinellid Effectiveness

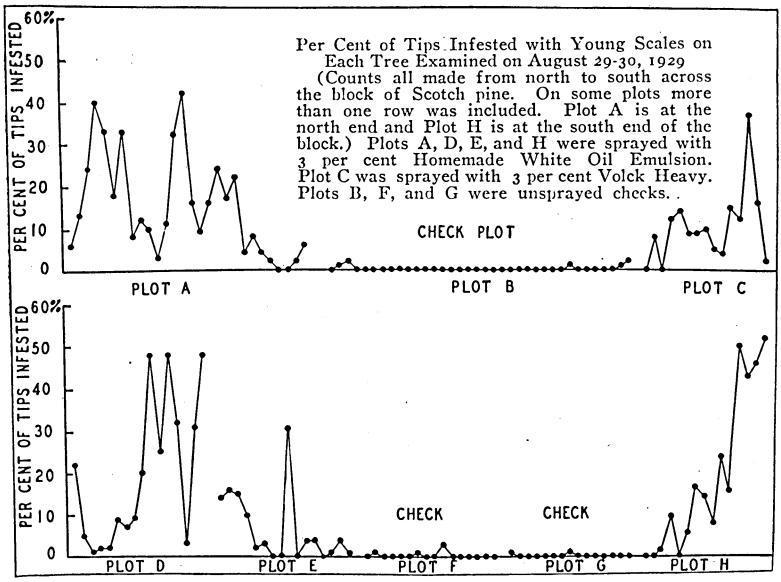

Fig. 4. Degree of Scale Infestation on Sprayed and Unsprayed Plots at the End of the Season

CONCLUSIONS

The final data show a comparatively low degree of infestation on the sprayed plots. If checks had not been left, and actual counts not made on both, this spraying experiment could be said to have been very effective and successful. However, the exceedingly low figure to which the infestation was reduced by natural enemies so greatly overshadows the results brought about by spraying that it appears the natural control was more effective without the aid of man. In fact, the spraying may have done more harm than good.

There are complicating factors, however, which may partly explain the unexpected results obtained. The growing season of 1929 was exceptionally dry in this region. It seems possible that this fact may have resulted in an unusually high biotic resistance nutritional factor. Trees growing near the edge of a marsh where soil moisture was not a limiting factor had many fairly large, healthy scales on them in September. In contrast, trees growing on the drier sites, on sprayed and unsprayed plots, had many very small scales on them but they all seemed to be dead and dry, with no apparent indication of external injury. This theory may at least partly account for the reduction of the scale population to a low point in the fall of 1929 for the plantation as a whole. The young scales were evidently prevented from developing as rapidly as usual. The small size of the young scales made it necessary for the coccinellid larvae to eat a greater number of them in order to get a full meal. At the same time, the dry, warm weather was probably favorable to the development of the coccinellids.

Evidently the spraying caused the coccinellids to concentrate on the unsprayed trees. We can not safely assume that they would have been as effective over the entire area if no spraying had been done. Our data may thus overemphasize the actual importance of this natural control factor.

It is unfortunate that work on this outbreak was not begun two or three years earlier. It would have been a comparatively simple matter to spray or destroy the few trees on which the pest first became established. Prompt and efficient control at that time would have prevented the large loss of trees and saved the considerable sum of money which was finally spent in the delayed effort at control.

Also, if a record of the numbers of coccinellids in 1928 had been available we could have assumed that it was not necessary to control the scales artificially in 1929.

This experiment is an excellent example of the importance of having the complete history of an insect in any given area before attempting artificial control measures. Artificial control applied early in the history of this outbreak would have saved a large number of trees and considerable financial loss, and would undoubtedly have been entirely

justified. There were not enough coccinellids at that time to be effective. Spraying would then have been a quick method of bringing the outbreak to an end.

What actually happened was that control was not attempted until it was almost too late to be worth while. Because of the meager amount of information available, the course followed was justified because we had no means of knowing that the outbreak was about to be brought to an end by natural control factors.

The spraying work, in itself, was satisfactory, as it resulted in a great reduction in the numbers of scales and might possibly have checked the outbreak even if there were no coccinellids. The homemade white oil emulsion would probably have been more effective if a less highly refined oil had been used, altho it might have caused more foliage injury.

This experiment is of unusual interest and importance because of the following points:

1. It concerns a species of a group of forest insect pests that as yet has received little attention from forest entomologists.

2. The present and probable future economic importance of jack and Scotch pines makes it important that we learn as much as possible about the control of their insect enemies.

3. The evident immunity of certain trees to this scale insect suggests the possibility of developing resistant strains of jack and Scotch pines.

4. The artificial control of scale insects on conifers is usually hazardous because of the difficulty of finding a spray material that will kill the insects without killing the trees.

5. The homemade white oil emulsion used did not cause much injury to the trees and did kill many of the scales. It is likely that a less highly refined oil would give better results.

6. It involved the treatment of a much larger number of coniferous trees with an oil spray than has usually been attempted in previous work of this nature.

7. Detailed observations were made on a comparatively large number of trees during the summer following the treatment in order to determine its effectiveness.

8. It is an excellent example of how parasites and predators may suddenly check an insect outbreak that has been in progress for several years.

9. It shows the importance of keeping complete records of the annual relative abundance of potential forest insect pests and their enemies in every forest area.

10. It indicates the necessity of careful study of such records before introducing artificial control measures.