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Yasumatsu, Keizo
Entomological Laboratory, Department of Agriculture, Kyushu University

Umeda, Kanehiro

Kaku, Toshinori

https://doi.org/10.5109/22650

出版情報：九州大学大学院農学研究院紀要. 10 (2), pp.151-162, 1953-09. Kyushu University
バージョン：
権利関係：

Journal of the Faculty of Agriculture, Kyūshū University, Vol. 10, No. 2
September 30, 1953

CONTROL OF PINE BEETLES BY THE USE OF ORGANIC CHEMICALS

KEIZÔ YASUMATSU, KANEHIRO UMEDA
and TOSHINORI KAKU

INTRODUCTION

During the past decade we have experienced increasing damage of pine trees by some Coleopterous insects in Japan. Once infested by these beetles, it has been impossible to kill the beetles alone without destroying the host trees at the same time. Although felling, peeling and burning or trapping have been the standard recommended control methods for years, the control has not always been satisfactory, and the damage has been increasing year after year.

The studies reported in this paper were conducted in an area infested by some of those Coleopterous insects in the Kasuya Experiment Forest, of the Kyushu University, in Sasaguri, Province of Chikuzen, during the spring and autumn seasons of 1949, 1950 and 1951. In the Experiment Forest, the important destructive insects of pine trees were *Myleophilus piniperda* Linné, *Cryphalus fulvus* Niijima, *Xyleborus validus* Eichhoff (Ipidae), *Cryptorrhynchidius insidiosus* Roelofs, *Pissodes nitidus* Roelofs, *Pissodes obscurus* Roelofs, *Sipalus hypocrita* Boheman (Curculionidae) and *Monochamus tesserula* White (Cerambycidae), of which the Ipid beetles were of primary importance, while Curculionid and Cerambycid beetles were of secondary importance. Studies conducted in 1949 showed that *Cryphalus fulvus* was outstanding as the dominant pest in this complex, its damage was almost always antecedent to that of other pests, and consequently the possible complete elimination of this Ipid may have had the advantage of preventing pine trees from the infestation of other beetles.

As is well known, most experimental works on pine beetles control made in Japan have been confined to the direct destruction of insects either by the methods mentioned above or by chemicals. In our studies attempts have been made to make a preliminary test in the evaluation of some chemical repellents for *Cryphalus fulvus*, and the results with some organic chemicals have been encouraging.

Acknowledgments

The present experimentation was undertaken as a cooperative project of the research programme of the Ministry of Education, to which we express our gratitude for financial help. Our deepest thanks are due to Professor T. Esaki, under whose direction the present investigation was carried out and to Professors H. Watanabe, Y. Inoue, S. Ôno and M. Harada for providing facilities for field work at the Kasuya Experiment Forest. Our hearty thanks are also due to Dr. F. P. Keen, Dr. C. H. Hoffmann and Mr. R. Roberts for the gift of many valuable reprints. Acknowledgment is made to Mr. M. Kakei of the Mikasa Chemical Industrial Company, for preparing desired chemicals. Further we are particularly indebted to Messrs. T. Shirôzu, Y. Hirashima, R. Matsuda, A. Nagatomi and Miss C. Ôkuma for assistance in all phases of the experimentation.

Chemicals Used and Experimental Procedure

The chemicals used in this experimentation were supplied from the Mikasa Chemical Industrial Company and included in the following list.

Formula 1. BHC water suspension (BHC 34 % (γ 10 %), bentonite 61 %, adhesive agent 5 %)—γ: 0.05, 0.02, 0.01, 0.008, 0.005, 0.003, 0.001 %.

Formula 2. DDT water suspension (DDT 20 %, bentonite 75 %, adhesive agent 5 %)—DDT: 0.04, 0.02, 0.016, 0.010, 0.0006, 0.002 %.

Formula 3. DDT water emulsion (DDT 20 %, turkey red oil 22 %, cresol 2 %, methyl acetate 1 %, naphtha 55 %)—DDT: 0.1, 0.04, 0.02, 0.016, 0.010, 0.006, 0.002 %.)

Formula 4. BHC water emulsion (BHC 34%, (γ 10%), tween 2%, naphtha 64%)—γ: 0.01, 0.005%.
Formula 5. DDT water emulsion (DDT 20%, turkey red oil 20%, methyl acetate 2%, cresol 2%, naphtha 56%)—DDT: 0.02, 0.01%.
Formula 6. DDT water emulsion (DDT 20%, turkey red oil 20%, methyl acetate 2%, cresol 2%, naphtha 54%, orthodichlorobenzene 2%)—DDT: 0.02, 0.01%.
Formula 7. BHC powder. γ: 0.5%.

In connection with the chemical repellency experiments, small scale tests have been made during 1950 on the phytotoxic effects of these chemicals on the young shoots of pine trees. However, it must be noted that during these experiments no incidents of injury have ever been detected on the foliage from the use of these chemicals.

A row of pine logs used in the field experiments on chemical treatments repellent to the Coleopterous insects.

Uninfested pine tree logs, about three meters in length, suitable for bark beetle attack were used for both checks and treatments, and the bark area was recorded for each log. Sufficient spray or dusting was applied to wet or cover thoroughly the entire bark surface of the material under treatment. Immediately after the treatment both the check and treated logs

were lined out, arranged singly in part shade, and exposed for varying periods of time in the area where bark beetles were known to occur in sufficient numbers. Periodic examinations of these logs were made throughout spring, summer and autumn, and only actual entrance holes of Ipid galleries and oviposition holes of Curculionidae and Cerambycidae were recorded. Thus the difference between the number of entrance holes or oviposition holes in the check logs and in the treated logs gave the measure of repellent effect of the chemicals, and observations on this area were continued to determine how long the difference would continue between these two kinds of logs.

Results

There are four conclusions which are evident from the experimental results secured in 1950. 1. For preventive treatment such chemicals are convenient insecticides, as used in the present experimentation in that they possess the marked advantages of very high repellency effect on *Cryphalus fulvus*. 2. BHC water suspension has a slight repellency effect upon *Myelophilus piniperda* and *Pissodes nitidus*. 3. DDT water suspension possesses a slight repellency effect on *Cryptorrhynchidius insidiosus*. 4. Such chemical treatments are entirely ineffective against *Sipalus hypocrita* and *Monochamus tesserula*. As is mentioned in the introduction, *Cryphalus fulvus* is exclusively abundant in number, and its damage is almost always antecedent to those of other beetles. For such reasons together with the first conclusion mentioned above, our repellency experiments have been concentrated against this bark beetle. The results of the experiments and accumulated rainfall in the experimental periods are given in Tables 1 to 7.

Table 1. Experiment 1—Repellent effect of chemicals applied to pine logs on April 21st, 23rd*, 29th† and May 13th** respectively. (Period of experiment: 21. iv.—1. vii. 1950).

Test No.	Chemical formula	Entrance holes per square foot of bark area										
		After 3 days	5	9	15	19	23	34	40	47	56	72
3	Check	—	—	—	—	—	—	—	2.0	3.0	5.5	6.4
5	„	0.2	0.3	0.7	0.7	0.7	0.7	0.7	1.3	3.9	6.1	7.3
6	„	—	—	—	—	—	—	0.1	1.3	6.6	8.6	10.2

7	„	—	—	—	—	—	—	0.1	0.3	2.4	4.6	6.5
8	„	—	0.1	0.2	0.2	0.9	1.3	1.8	4.0	5.7	10.1	10.1
9	„	—	—	0.4	0.4	0.7	0.7	3.9	6.0	7.6	8.8	9.1
10	„	—	—	0.1	0.1	0.1	0.1	7.1	10.6	13.0	14.7	16.0
11	„	—	—	—	—	—	—	7.1	9.4	17.1	19.2	21.4
12	„	—	—	0.1	0.1	0.3	0.7	1.7	4.5	16.3	20.3	20.7
13	„	0.1	0.1	0.1	0.1	0.4	0.4	5.8	8.1	11.6	13.5	13.5
14	„	—	—	0.2	0.2	3.9	3.9	10.0	15.8	20.0	24.3	24.3
16	B1	—*	—	—	—	—	—**	—	—	—	—	0.9
17	B2	—*	—	—†	—	—	—	0.1	0.1	0.1	0.2	1.1
18	B3	—*	—	—†	—	—	—**	—	—	—	—	—

B1 : BHC water suspension (γ 0.02 %). B2 : DDT water suspension (DDT 0.04%). B3 : DDT water emulsion (DDT 0.04 %). Accumulated rainfall : more than 470 mm. Heavy rainfall : 26. iv., 12. v., 20. v., 16. vi., 18. vi., 19. vi., 20. vi., 21. vi., 29. vi.

Table 2. Experiment 2—Repellent effect of chemicals applied to pine logs on April 25th and May 5th* respectively. (Period of experiment: 25. iv.—15. vi. 1950).

Test No.	Chemical formula	Entrance holes per square foot of bark area						
		11	15	19	31	36	43	52
19	Check	—	—	—	—	0.1	0.5	2.5
20	„	—	—	—	11.6	11.6	11.6	11.6
21	„	—	0.1	0.1	0.1	4.1	5.1	5.4
22	„	—	—	—	4.9	8.8	11.8	15.0
23	„	—	0.9	0.9	5.0	12.3	17.1	19.8
24	„	—	0.3	0.3	0.3	4.6	10.0	11.6
25	„	—	—	—	2.4	9.1	13.0	13.7
26	B5	—*	—	—	—	—	—	—
27	B6	—*	—	—	—	—	—	—
28	B7	—*	—	—	—	—	—	—

B5 : BHC water suspension (γ 0.02 %). B6 : DDT water suspension (DDT 0.04 %). B7 : DDT water emulsion (DDT 0.04 %). Accumulated rainfall: more than 200 mm. Heavy rainfall : 26. iv., 12. v., 20. v.

Table 3. Experiment 3—Repellent effect of chemicals applied to pine logs on May 9th. (Period of experiment: 9. v.—25. vii. 1950).

Test No.	Chemical formula	Entrance holes per square foot of bark area					
		16	22	29	38	54	79
29	Check	0.2	0.2	0.3	0.5	0.5	1.8
30	„	0.3	1.1	1.3	1.3	2.8	6.6
31	„	0.8	4.8	14.2	16.2	19.9	20.2
32	„	0.4	2.3	3.9	5.0	10.0	11.3
33	„	1.4	20.9	31.0	34.0	39.4	47.0
34	„	1.9	13.1	19.3	19.6	21.6	26.2
35	„	12.6	49.7	62.7	66.8	72.7	75.9
36	B9	—	—	—	—	—	—
37	B10	—	—	—	—	—	0.1
38	B11	—	—	—	—	—	—
39	B12	0.1	0.1	0.3	0.3	0.3	7.2
40	B13	—	0.5	0.7	0.7	0.9	3.3
41	B14	—	0.1	0.1	0.5	1.8	7.3

B9 : BHC water suspension (γ 0.05%). B10 : BHC water suspension (γ 0.02 %). B11: BHC water suspension (γ 0.01 %). B12 : DDT water emulsion (DDT 0.1 %). B13 : DDT water emulsion (DDT 0.04 %). B14 : DDT water emulsion (DDT 0.02 %). Accumulated rainfall: more than 600 mm. Heavy rainfall : 12. v., 20 v., 16. vi., 18—21. vi., 29. vi., 2. vii., 5. vii.

Table 4. Experiment 4—Repellent effect of chemicals applied to pine logs on June 25th.
(Period of experiment : 25. vi.—23. viii. 1950).

Test No.	Chemical formula	Entrance holes per square foot of bark area			
		7	34	49	60
42	Check	—	3.4	5.4	5.4
43	„	—	30.6	37.5	38.5
44	„	—	57.6	70.0	71.9
45	„	—	75.1	88.3	90.6
46	„	—	130.9	158.1	160.5
47	B25	—	1.2	7.1	8.0
48	B26	0.1	0.8	3.8	5.2
49	B27	—	0.5	8.1	8.8

50	B28	—	7.2	16.1	17.3
51	B29	0.1	7.0	16.2	19.3
52	B30	1.1	13.8	26.4	32.1
53	B31	—	0.5	7.3	9.4
54	B32	—	1.3	7.0	8.1
55	B33	—	0.8	4.7	6.0

B25 : BHC water suspension (γ 0.008 %). B26 : BHC water suspension (γ 0.005 %). B27 : BHC water suspension (γ 0.003 %). B28 : DDT water suspension (DDT 0.016 %). B29 : DDT water suspension (DDT 0.010 %). B30 : DDT water suspension (DDT 0.006 %). B31 : DDT water emulsion (DDT 0.016 %). B32 : DDT water emulsion (DDT 0.010 %). B33 : DDT water emulsion (DDT 0.006 %). Accumulated rainfall : more than 500 mm. Heavy rainfall : 29. vi., 2. vii., 5. vii., 16. viii., 17. viii.

Table 5. Experiment 5—Repellent effect of chemicals applied to pine logs on August 7th.
(Period of experiment : 22. vii.—5. ix. 1950).

Test No.	Chemical formula	Entrance holes per square foot of bark area				
		4	8	21	31	46
56	Check	—	15.1	15.6	19.4	23.5
57	„	—	6.7	17.5	22.1	25.3
58	„	0.8	29.0	45.7	55.2	60.0
59	B34	—	—	0.1	0.3	1.0
60	B35	—	0.2	0.2	0.4	1.0
61	B36	—	6.1	8.3	10.6	12.1
62	B37	—	2.4	4.8	11.9	16.1
63	B38	—	1.5	2.3	3.8	5.8
64	B39	—	2.7	4.0	6.7	9.1
65	B40	—	—	—	—	—
66	B41	—	0.1	0.4	0.7	1.1
67	B42	—	0.3	0.5	2.9	6.1

B34 : BHC water suspension (γ 0.008 %). B35 : BHC water suspension (γ 0.005 %). B36 : BHC water suspension (γ 0.003 %). B37 : DDT water suspension (DDT 0.016 %). B38 : DDT water suspension (DDT 0.010 %). B39 : DDT water suspension (DDT 0.006 %). B40 : DDT water emulsion (DDT 0.016 %). B41 : DDT water emulsion (DDT 0.010 %). B42 : DDT water emulsion (DDT 0.006 %). Accumulated rainfall : more than 350 mm. Heavy rainfall : 16. vii., 28. viii., 30. vii., 31. viii.

Table 6. Experiment 6—Repellent effect of chemicals applied to pine logs on August 7th.
(Period of experiment: 7. viii.—28. ix. 1950).

Test No.	Chemical formula	Entrance holes per square foot of bark area		
		15	30	53
68	Check	1.1	1.6	1.8
69	„	—	0.1	0.1
70	„	2.2	2.5	3.2
71	B43	—	0.1	3.0
72	B44	0.1	0.2	0.8
73	B45	0.4	1.0	2.6
74	B46	3.4	3.9	9.7
75	B47	1.6	2.6	8.2
76	B48	4.3	4.8	18.8
77	B49	—	—	—
78	B50	0.1	0.1	0.2
79	B51	0.5	1.0	6.9

B43 : BHC water suspension (γ 0.008%). B44 : BHC water suspension (γ 0.005%). B45 : BHC water suspension (γ 0.003%). B46 : DDT water suspension (DDT 0.016%). B47 : DDT water suspension (DDT 0.010%). B48 : DDT water suspension (DDT 0.006%). B49 : DDT water emulsion (DDT 0.016%). B50 : DDT water emulsion (DDT 0.010%). B51 : DDT water emulsion (DDT 0.006%). Accumulated rainfall : more than 150 mm. Heavy rainfall : 16. viii., 17. viii., 28. viii., 30. viii., 31. viii., 19. ix., 22. ix.

Table 7. Experiment 7—Repellent effect of chemicals applied to pine logs on September 5th.
(Period of experiment: 5. ix.—19. ix. 1951).

Test No.	Chemical formula	Entrance holes per square foot of bark area		Test No.	Chemical formula	Entrance holes per square foot of bark area	
		7	14			7	14
80	Check	18.8	36.4	87	B70	0.1	0.7
81	„	15.0	39.4	88	B71	0.4	1.3
82	„	10.9	21.9	89	B72	0.1	0.7
83	B66	0.7	1.7	90	B73	0.4	1.7
84	B67	0.8	2.1	91	B74	0.4	2.9
85	B68	0.1	4.3	92	B75	1.3	5.0
86	B69	0.3	1.4	93	B76	0.1	3.3

B66 : DDT water suspension (DDT 0.02%). B67 : DDT water suspension (DDT 0.01%). B68 : DDT water emulsion (DDT 0.02%). B69 : DDT water

emulsion (DDT 0.01 %). B70 : DDT water emulsion No. 6 (DDT 0.02 %). B71 : DDT water emulsion No. 6 (DDT 0.01 %). B72 : DDT water emulsion No. 5 (DDT 0.02 %). B73 : DDT water emulsion No. 5 (DDT 0.01 %). B74 : BHC water emulsion (γ 0.01 %). B75 : BHC water emulsion (γ 0.01 %). B75 : BHC water emulsion (γ 0.005 %). B76 : BHC dust (γ 0.5 %). Accumulated rainfall : more than 250 mm. Heavy rainfall : 13. ix., 14. ix., 16. ix.

The following conclusions may be derived from an examination of the data presented in tables given above. In general all the chemicals used in the experiments have repellency effect against *Cryphalus fulvus* to a more or less extent. DDT is the most effective against this bark beetle when it is used in the form of a water emulsion. BHC and DDT are also effective repellents, when they are used in the form of a water suspension. BHC dust (γ 0.5 %) is promising under condition of a small amount of rainfall. BHC water suspension (formula 1) (γ : 0.003, 0.001 %), DDT water suspension (formula 2) (DDT : 0.006, 0.002 %), and DDT water emulsion (formula 3) (DDT : 0.006, 0.002 %) are ineffective as repellents. BHC water suspension (formula 1) (γ : 0.05, 0.02, 0.01, 0.008, 0.005 %), DDT water suspension (formula 2) (DDT : 0.04, 0.02, 0.016, 0.010 %), DDT water emulsion (formuia 3) (DDT : 0.1, 0.04, 0.02, 0.016, 0.010 %), BHC water emulsion (formula 4) (γ : 0.01, 0.005 %), DDT water emulsion (formula 5) (DDT : 0.02, 0.01 %), and DDT water emulsion (formula 6) (DDT : 0.02, 0.01 %) are suitable for the preventive treatment against infestation by this bark beetle. There are found no definite difference in the repellency effect of BHC water suspension of γ-contents between 0.05 and 0.01 %. There are also found no marked difference in repellency of DDT water suspension and emulsion of DDT contents between 0.1 and 0.02 %. The residual effect of these chemicals lasts at least two weeks. Under favourable conditions the repellency effect lasts more than two months. It would seem that there is wide variation in repellency of a given formula under similar conditions and there are considerable logs which are virtually almost immune to infestation by *Cryphalus fulvus*. But it is at present impossible to determine whether these phenomena are ascribed to some physiological or racial properties of the tree itself. Under conditions of heavy rainfall, a higher dosage of DDT and BHC or two or three successive

applications at an interval of a week may be necessary as the movement of these chemicals would be more rapid.

CONSIDERATIONS

Very little scientific information has been published on the satisfactory protection of living trees from infestation of bark beetles by the use of organic chemicals. The paper giving the most interesting information was one by G. H. Plumb (1950). The primary objective of his study was to determine whether or not large elm trees in an area of high infestation rate could be protected by spray directed against the bark beetle vectors of Dutch elm disease. He used a DDT emulsion throughout his experiment in Connecticut, and DDT has shown to be highly effective against *Scolytus multistriatus*. Industrial grade of Xylene was the solvent and an emulsifying agent was used. An emulsion of 12.5 per cent was used as a dormant spray, and one of 6.25 per cent as a summer spray when the trees were in leaf. Periodic examinations of the trees were made throughout each summer for evidence of disease. The final inspection in 1948, made in early September, indicates that 3 trees, or 2.9 per cent of the sprayed trees; and 21, or 21.0 per cent of the check trees, were infested. At the end of August, 1949, 9 trees, or 8.9 per cent of the trees sprayed; and 39, or 38.6 per cent of the check trees, were diseased.

When we planned to conduct our experimentation in 1949, we were unaware of the study of Plumb. In 1951 we have had the good fortune to find Plumb's paper and thereby recognized that the objective of our study was quite similar to that of Plumb. It is now clear from our experimentation that DDT and BHC are highly suitable repellents for the prevention treatment of pine trees against infestation by *Cryphalus fulvus*. Namely, an application of the lowest dosage, 0.005 per cent of γ BHC or 0.01 per cent DDT was satisfactory in preventing the bark beetle attack.

According to the unpublished data secured by Kaku, one of the authors, the adult *Cryphalus fulvus* occurs three times a year in our province, viz., April to June (maximum in May), June to August (maximum in July) and September to November (maximum at the end of October). The adults are most abundant in July

and quite few in October in comparison with those in May. Therefore, more attention would need to be given to applying DDT or BHC at a time coinciding with the emergence of the adult bark beetles. Ideally these chemicals should be applied immediately before the emergence of the adult bark beetles. If we can eliminate this bark beetle in its first and second generations, the emergence of the third brood would become negligible.

Having determined that prevention of pine trees from *Cryphalus fulvus* by the use of repellents is possible under experimental conditions, it becomes desirable to test our results in the forest and a means of applying such chemicals which involve the use of conventional equipment and which could be employed by some sprayers or dusters at a minimum cost. In conjunction with the practical application of these repellents in the forest, it must be borne in mind that these chemicals have certain characteristics that may limit their use as a control for the bark beetles. One of those characteristics may be seen in their extensive survey made by Hoffmann and al. (1948, 1949), and their general conclusions are cited in the following lines. "A single airplane application of DDT to a forest at the rate of 1 pound per acre—enough to control many forest pests—does not seriously damage the general arthropod fauna, although a few species would probably be exterminated by a thorough application at this rate. DDT used at moderately light dosage will tend to restrict the range and abundance of many harmless and beneficial species, and its widespread use on forest threatens extermination to some of the more susceptible and sedentary species. However, even with a dosage of 5 pounds of DDT per acre, the effect on the arthropod fauna as a whole is far from being calamitous." Thus it seems possible that the application of these repellents within the limit derived from the survey of Hoffmann and al. should prevent the pine trees from attack by bark beetles in question without damaging the general Arthropod fauna and result the shortage of food for the bark beetle populations in a given area.

In their studies on the protection of elm wood from attack by bark beetles, R. R. Whitten (1942) and D. P. Connola et al. (1947) experienced the wide variation in repellency of a given formula under similar experimental conditions. This phenomenon was also observed in our experiments. Further careful experi-

ments by applying the statistical method may throw some light upon the analysis of this phenomenon, and it would be expected that at least the specific behaviour of the bark beetles and the nature of the pine tree itself would be responsible for the analysis.

Summary

Field studies on the control of pine beetles were conducted with some organic chemicals in the Kasuya Experiment Forest, Province of Chikuzen.

Cryphalus fulvus is by far the most important and harmful bark beetle among others. The control of this bark beetle results the prevention of attack of all other beetles on the living pine trees.

Both DDT and BHC have an excellent repellency effect on *Cryphalus fulvus* at the lowest dosage of 0.01 per cent DDT or 0.005 per cent BHC spray without giving any phytotoxic effects even on the young shoots of pine trees.

Under favourable conditions the repellency effect lasts more than two months.

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