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OBSERVATIONS ON THE MODE OF ACTION OF CONTACT INSECTICIDES¹

By WILLIAM MOORE, *Division of Entomology and Economic Zoölogy,
University of Minnesota*

During the present year, certain experiments have been conducted, which throw further light on the action of contact insecticides, and since it does not appear possible to make a more complete study in the near future, the following brief account is given in the hope that it will prove of some value to entomologists.

In a recent paper on essential physical properties of contact insecticides,² it was shown that fat solvents, oils and soaps were able to penetrate the tracheæ of insects by capillarity. It was further noted that heavy, practically nonvolatile and nontoxic oils, which had thus penetrated the tracheæ caused the death of the insects, but that the tissues of such insects were not stained by trypan blue (which stains dead tissue and not living tissues) until, ten, twenty or more hours had elapsed. From these observations, the question arose as to whether the insects did not die from the lack of oxygen resulting from the closing of the tracheæ. Shafer³ has shown that methylene blue or indigo carmine injected into the body of an insect, which is then placed in an atmosphere free of oxygen, is reduced to its leuco compound and the body of the insect again becomes white or yellowish white. Upon

¹ Published with the approval of the Director as Paper No. 141, of the Journal Series of the Minnesota Agricultural Experiment Station.

² Moore, Wm., and Graham, S. A. Physical Properties governing the efficacy of Contact Insecticides. *Journ. of Agr. Res.* Vol. xiii, No. 11, 1918, pp. 523-538.

³ Shafer, Geo. D. How Contact Insecticides Kill. *Mich. Agri. Exp. Sta. Tech. Bull.*, 11-65 p., 1911.

being removed to the air, the stain is again oxidized and the body of the insect becomes blue. The following experiments were conducted to determine if treatment with an insecticide capable of plugging the tracheæ would thus reduce methylene blue.

Exp. 1. Larvæ of waxmoth (*Galleria mellonella*) were injected, with a saturated solution of methylene blue by means of a fine glass tube. Some of the larvæ were left as checks while others were dipped in a light lubricating oil. Larvæ not treated with the oil remained a beautiful blue while those treated, rapidly faded out, becoming white or yellowish white in three to five minutes. Since it was impossible to remove the oil from the tracheæ, the larvæ were then opened with a pair of scissors. The tissues and body fluids immediately turned blue on contact with the air.

Exp. 2. Same as Experiment 1 but when larvæ had become white, some of its body fluids were carefully removed by a capillary tube. A drop of this blood placed on a piece of filter paper or on a glass slide assumed a blue color in a few minutes.

Exp. 3. Same as Experiment 1 but olive oil used instead of a lubricating oil. Results exactly similar were obtained.

Exp. 4. Larvæ injected with methylene blue and then with olive oil. Although the larvæ died in a few hours, it remained blue both before and after death.

Exp. 5. Heavy lubricating oil, so viscous that it was unable to penetrate the tracheæ, was used to cover over a larva previously injected with methylene blue. Larva moved about for four hours, retaining its blue color, after which it was buried under a thicker layer of the oil with the result that it lost its blue color and was stupified within one hour. The oil was then removed as well as possible, but although the larvæ again assumed a bluish color, it did not survive the treatment.

Exp. 6. Injected larvæ dipped in toluene and removed; decolorized in six minutes. Injected larvæ dipped in carbon tetrachloride and removed; decolorized in six minutes. Injected larvæ dipped in xylene and removed; decolorized in seven minutes. Injected larvæ dipped in nitrobenzene and removed; decolorized in seven minutes. Injected larvæ dipped in nicotine and removed; decolorized in six minutes. Injected larvæ dipped in ether and removed; redipped, decolorized in thirty minutes.

Exp. 7. Injected larvæ placed in small vial with vapor of nicotine. Larvæ dead in four hours but color had not faded. Larvæ kept twelve hours but blue color did not fade.

Exp. 8. Experiment 7 repeated, using nitrobenzene and xylene with similar results.

Exp. 9. Injected larvæ placed in water, which did not enter the tracheæ. Started at 9.15 a. m., decolorized 9.28 a. m. Removed and excess water absorbed with filter paper. Larvæ again blue in color at 9.32 a. m. Larvæ were returned to the water at 9.40 a. m. and left until 2.10 p. m. They turned blue at once upon removal to the air.

Exp. 10. Injected larva placed in soap solution 1-500 in such manner that only the right spiracles were in contact with the soap. Removed and placed in pure water until colorless. Removed from water, dried, and left half of larva assumed a blue color while the right side remained colorless. Heart not beating and larva in stupor. Placed completely in soap solution and color faded out but did not reappear when larva was again dried and exposed to the air.

Exp. 11. Injected larva placed in soap solution until color had disappeared. Removed at 9.40 a. m. and color not having reappeared by 10.02 a. m. it was placed in distilled water and thoroughly washed until 10.20 a. m. Removed but color did not reappear by 10.37 a. m.

Exp. 12. One injected larva dipped in light lubricating oil so as to fill tracheæ of cephalic portion and another dipped to fill tracheæ of caudal end. Removed, heart beating and larvæ did not lose its blue color. Placed in water until stupefied and heart had ceased to beat. Larvæ now colorless were removed to the air and dried, when the portion with oil filled tracheæ remained colorless while the other half of the larvæ assumed a bright blue color. Later the larvæ revived, the heart started beating and the whole larvæ became blue.

Exp. 13. Injected larva placed in soap solution becoming colorless. Removed, carefully washed in distilled water and rolled on filter paper to remove as much as possible of the soap solution from the tracheæ. Within an hour, a bluish color developed in the vicinity of each spiracle, until after ten hours, the larva was irregularly blue over the entire body.

These experiments show that a contact insecticide containing oil or soap may penetrate the tracheæ of the insect; thus preventing normal oxidations from taking place in the insect's body with the result that the insect dies from their mechanical action alone. In order to insure death in this manner, it is necessary that all the tracheæ be filled with the spray. The vapor of the insecticide such as nicotine may produce death by chemical action without materially influencing the intake of oxygen. For small insects such as plant lice, an insecticide killing in a mechanical way alone will give good results, since all or nearly all the tracheæ will be filled. For larger insects, such as the tarnished plant bug (*Lygus pratensis* L.) filling all of the tracheæ becomes unlikely, hence it would be necessary to add to the spray an insecticide capable of killing in a chemical manner, thus insuring death, even if only one trachea is filled. Field experiments with sprays containing free nicotine have shown that the efficacy of such sprays is sometimes increased 50 per cent. by the addition of soap. These experiments were conducted during the past summer by S. A. Graham and will be reported by him elsewhere.

A further point, however, which has a decided bearing upon this question, arose in the study of the effect of laundering processes upon the destruction of active stages of the clothes louse (*Pediculus corporis*). In these experiments it was shown that the clothes louse was able to close its tracheæ quickly enough to keep out soap solutions, lubricating oils, xylene, and in seven cases out of twelve, even ether was prevented from entering. A few experiments have shown that the hog louse (*Hæmatopinus suis*) and the dog louse (*Hæmatopinus piliferus*) possess a similar power of keeping ether out of their tracheæ, but are not as successful in general as the clothes louse. The dog flea (*Pulex serraticeps*), mealy bugs (*Pseudococcus* sp.), soft scale (*Coccus* sp.), houseflies (*Musca domestica*), angumois grain moth, larvæ and adults (*Sitotroga cerealella*), tussock moth larvæ (*Notolophus leucostigma*) and pea aphid (*Macrosiphum pisi* Kalt) were all unable to prevent the penetra-

tion of ether, but this does not mean that some of these might not be able to shut out heavy oils or soap solutions. This whole question is interesting and if the parasitic lice, ticks, etc., should be found to possess this ability of closing the tracheæ rapidly, it will have considerable bearing upon the type of dips which would prove most effective. A similar cause may be an explanation of the difficulty of killing such insects as the tarnished plant bug. It is hoped to give this problem further attention at some future date.

THE CALIFORNIA PISTOL CASE BEARER¹

COLEOPHORA SACRAMENTA HEINRICH

By W. M. DAVIDSON, *U. S. Bureau of Entomology, Sacramento, Cal.*

Coleophora sacramenta Heinrich, Insec. Insci. Mens. II p. 145, 1915.

Coleophora sacramenta Hein.; Essig, E. O. Injurious & Beneficial Insects of California; Suppl. Monthly Bull. IV, 4. 1915.

INTRODUCTION

Since the year 1908, observations on the habits and biology of this insect have been made by agents of the Bureau of Entomology, Deciduous Fruit Insect Division, under the direction of Dr. A. L. Quaintance. The material in this paper has been arranged from notes made by Mr. J. R. Horton, Bureau of Entomology, formerly in the Deciduous Fruit Insect Division, by Mr. P. R. Jones, formerly of the Bureau of Entomology, Deciduous Fruit Insect Division, and by the writer. The greater part of the observations were made at San José, Cal., during the years 1910-1912, while some points in the life-history were subsequently checked up in 1916 at Walnut Creek, California.

RELATED INSECTS

The California Pistol Case Bearer belongs to a group of moths (Elachistidæ) of which a number are injurious to deciduous fruit trees. Among these are the Cigar Case Bearer (*Coleophora fletcherella* Fernald) the Western Cigar Case Bearer (*C. volckei* Volck) and the Eastern Pistol Case Bearer (*C. malivorella* Riley). The last named which attacks pomaceous fruit trees in the East is very similar to *C. sacramenta* in appearance and habits. According to Lowe² there are some minor differences; the larvæ of *C. malivorella* pupate on the twigs and branches, not on the leaves as in the case of *C. sacramenta*; the egg and pupal instars of *malivorella* in New York are passed in from 10 to 14 days, whereas those of *C. sacramenta* in California require a period of some 25 days.

¹ Published with the permission of the Secretary of Agriculture.

² Lowe, V. H. Bulletin 122, N. Y. Agr. Exp. Sta., Geneva, N. Y.