BULLETIN NO. 490 NOVEMBER, 1921

New York Agricultural Experiment Station.

GENEVA, N. Y.

CONTROL OF APPLE RED BUGS BY DUSTING

P. J. PARROTT, HUGH GLASGOW, AND G. F. MACLEOD

PUBLISHED BY THE STATION

BOARD OF CONTROL

GOVERNOR NATHAN L. MILLER, Albany.
COMMISSIONER BERNE A. PYRKE, Albany.
IRVING ROUSE, Rochester.
FRANK M. BRADLEY, Barker.
CHARLES C. SACKETT, Canandaigua.
CHARLES R. MELLEN, Geneva.
JOHN B. MULFORD, Lodi.
C. FRED BOSHART, Lowville.
PETER G. TEN EYCK, Albany.

OFFICERS OF THE BOARD

CHARLES R. MELLEN,
President.

WILLIAM O'HANLON,
Secretary and Treasurer.

STATION STAFF

ROSCOE W. THATCHER, D. Agr., *Director.*

†ALBERT R. MANN, A.M.,
Agricultural Economist.
GEORGE W. CHURCHILL, *Agriculturist.*
REGINALD C. COLLISON, M.S.,
Chief in Research (Agronomy).
†T. LYTTLETON LYON, Ph.D.,
Chemist (Agronomy).
JAMES E. MENSCHING, M.S.,
Associate in Research (Agronomy).
JAMES D. HARLAN, B.S.,
Assistant in Research (Agronomy).
WILLIAM P. WHEELER,
Chief in Research (Animal Industry).
ROBERT S. BREED, Ph.D.,
Chief in Research (Bacteriology).
HAROLD J. CONN, Ph.D.,
Chief in Research (Soil Bacteriology).
†WILLIAM A. STOCKING, JR., M.S.A.,
Bacteriologist.
GEORGE J. HUCKER, M.A.,
Associate in Research (Bacteriology).
ARCHIE H. ROBERTSON, B.S.,
Assistant in Research (Bacteriology).
FRED C. STEWART, M.S.,
Chief in Research (Botany).
†DONALD REDDICK, Ph.D., *Botanist.*
WALTER O. GLOYER, M.A.,
Associate in Research (Botany).
MANCEL T. MUNN, M.S.,
Associate Botanist.
ELIZABETH F. HOPKINS, A.B.,
Assistant Botanist.
LUCIUS L. VAN SLYKE, Ph.D.,
Chief in Research (Chemistry).
RICHARD F. KEELER, M.S.,
Associate in Research (Chemistry).
RUDOLPH J. ANDERSON, Ph.D.,
Chief in Research (Biochemistry).
†LEONARD A. MAYNARD, Ph.D.,
Biochemist.
WALTER L. KULP, M.S.,
Assistant in Research (Biochemistry).
ARTHUR W. CLARK, B.S.,
Associate Chemist.
MORGAN P. SWEENEY, A.M.,
WILLIAM F. WALSH, B.S.,
Assistant Chemists.
MILLARD G. MOORE, B.S.,
NATHAN F. TRUE, A. B.,
LEON R. STREETER, B.S.,
Assistant Chemists.
ARTHUR C. DAHLBERG, M.S.,
Associate in Research (Dairying).
JAMES D. LUCKETT, M.S.A.,
Editor and Librarian.
LAURA G. COLLISON, A.B.,
Assistant Editor and Librarian.
PERCIVAL J. PARROTT, M.A.,
Chief in Research (Entomology).
†GLENN W. HERRICK, B.S.A.,
Entomologist.
HUGH GLASGOW, Ph.D.,
FRED Z. HARTZELL, M.A. (Fredonia),
Associates in Research (Entomology).
CLARENCE R. PHIPPS, B.S.,
GUY F. MACLEOD, B.S.,
Assistants in Research (Entomology).
ULYSSES P. HEDRICK, Sc.D.,
Vice Director; Chief in Research (Horticulture).
†ROLLINS A. EMERSON, Sc.D., *Geneticist.*
†WM. H. CHANDLER, Ph.D., *Pomologist.*
FRED E. GLADWIN, B.S. (Fredonia),
ORRIN M. TAYLOR,
GEORGE H. HOWE, B.S.A.,
RICHARD WELLINGTON, M.S.,
Associates in Research (Horticulture).
THOMAS O. SPRAGUE, B.S.,
HAROLD B. TUKEY, M.S.,
FRED R. CLARK, M.S.,
Assistants in Research (Horticulture).
JAMES S. LAWSON, Phm.B.,
Museum Preparator.
JESSIE A. SPERRY, *Director's Secretary.*
FRANK E. NEWTON,
WILLARD F. PATCHIN,
LENA G. CURTIS,
MAE M. MELVIN,
MAUDE L. HOGAN,
K. LORAINE HORTON,
Clerks and Stenographers.
ELIZABETH JONES,
Computor and Mailing Clerk.

Address all correspondence, not to individual members of the staff, but to the NEW YORK AGRICULTURAL EXPERIMENT STATION, GENEVA, N. Y.

The Bulletins published by the Station will be sent free to any farmer applying for them.

† Members of the faculty of the New York State College of Agriculture affiliated with this Station.

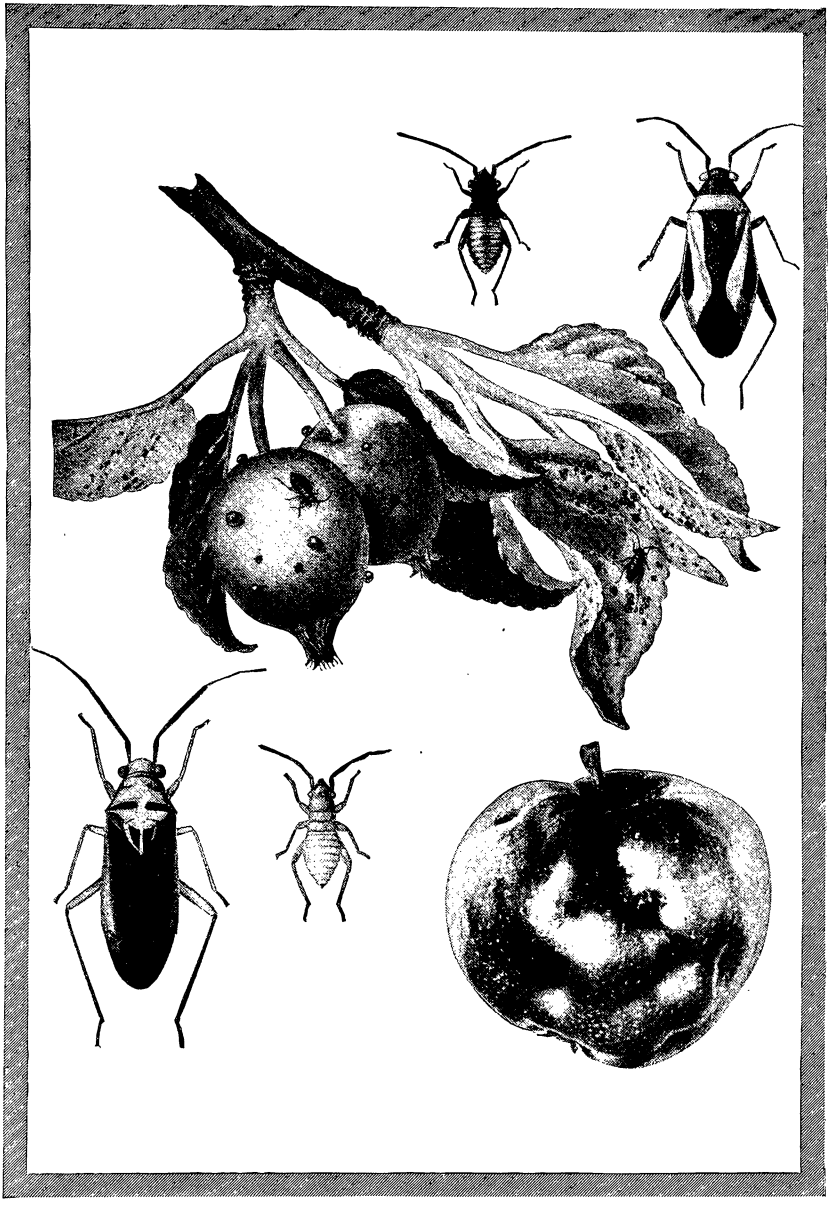

PLATE I.— APPLE RED BUGS: UPPER, DARK RED BUG; LOWER, BRIGHT RED BUG

BULLETIN No. 490

CONTROL OF APPLE RED BUGS BY DUSTING

P. J. PARROTT, HUGH GLASGOW, AND G. F. MACLEOD

SUMMARY

This bulletin deals with experiments with spraying mixtures and with certain insecticidal materials in powdered form which had as their object the determination of the value of dusting in protecting apple orchards from injuries by red bugs.

Apple plantings in this State are subject to attack by two species of plant bugs, *viz.*, the bright red bug (***Lygidea mendax*** Reuter) and the dark red bug (***Heterocordylus malinus*** Reuter). The insects cause premature dropping of young fruits and knotty, deformed apples. For the prevention of injuries to the apple crop, chief dependence has heretofore been placed on spraying mixtures containing nicotine sulfate.

The red bug population was found to vary greatly with individual trees, ranging from a few specimens to a thousand or more individuals per tree. In the orchards under experiment, ***mendax*** was responsible for the bulk of the damage to the apple crop. Both ***malinus*** and ***mendax*** frequently occurred on the same tree or in the same orchard, one or the other species being the dominant form, but two orchards heavily infested with the insects showed almost complete segregation of the two species.

Apple trees frequently support a large population of red bugs without conspicuous injuries to the crop, indicating that they obtain subsistence largely from the foliage. The insects display marked partiality for tender leaves of terminal growth, water-sprouts, etc.

Measured by the number of red bugs dislodged from the trees and the percentage killed by the treatments, dusting preparations containing 0.25, 0.50, 1.0, and 2.0 per cent nicotine, respectively, were toxic to the insects. Effective results were also obtained with spraying mixtures at standard strengths. Nicotine sulfate at rates of $\frac{1}{4}$ and $\frac{1}{2}$ pint to 100 gallons of either soap or lime-sulfur solution showed considerable toxicity to the insects. Dusting and spraying preparations with the larger amounts of nicotine gave,

on an average, more uniform results and displayed higher killing power than those containing smaller amounts.

In a dusting experiment in a 20-year-old Baldwin orchard a larger percentage of the red bugs was killed by a 5-pound dosage per tree than by a 2-pound dosage per tree.

The results of the experiments as a whole indicate that both dusting and spraying mixtures should be used in rather liberal amounts and carefully applied in order to destroy the majority of the insects. Prevailing conceptions of dosage requirements for typical bearing orchards in this State tend to underestimate the amount of material necessary to accomplish effective results.

The comparative effectiveness of the various dusting and spraying mixtures at different dosages is indicated by the accompanying summary:

INSECTICIDAL AND OPERATING EFFICIENCY OF VARIOUS DUST AND SPRAY MIXTURES

NAME OF MATERIAL	AMOUNT PER TREE	INSECTICIDAL EFFICIENCY	EFFICIENCY RATING OF OPERATION
		Per cent	*Per cent*
Dust, 0.25 per cent nicotine	5 lbs.	92.8	70.8
Dust, 0.5 per cent nicotine	2 lbs.	78.8	36.7
Dust, 0.5 per cent nicotine	5 lbs.	91.4	91.4
Dust, 1.0 per cent nicotine	2 lbs.	73.3	39.4
Dust, 1.0 per cent nicotine	5 lbs.	100.0	70.1
Dust, 2.0 per cent nicotine	5 lbs.	100.0	91.6
Soap and nicotine ($\frac{1}{4}$ pint)	15 gals.	91.4	56.2
Soap and nicotine ($\frac{1}{4}$ pint)	25 gals.	97.4	83.8
Soap and nicotine ($\frac{1}{2}$ pint)	15 gals.	96.5	85.7
Soap and nicotine ($\frac{1}{2}$ pint)	25 gals.	96.8	86.4
Soap and nicotine (1 pint)	25 gals.	94.3	.....
Lime-sulfur and nicotine ($\frac{1}{4}$ pint)	15 gals.	80.6	45.3
Lime-sulfur and nicotine ($\frac{1}{4}$ pint)	25 gals.	80.4	50.6
Lime-sulfur and nicotine (1 pint)	$7\frac{1}{2}$ gals.	95.4	85.1
Lime-sulfur and nicotine (1 pint)	15 gals.	99.4	93.7
Lime-sulfur and tobacco dust (40 lbs. to 100 gals.)	15 gals.	99.7	90.9
Lime-sulfur and tobacco dust (40 lbs. to 100 gals.)	25 gals.	97.9	92.0
Tobacco dust	8 lbs.	93.9	88.2

The cost of treatment per tree for both spraying and dusting is variable, depending on labor, machinery, size of tree, weather conditions, kind and cost of insecticides, and general management.

The average quantity of spraying and dusting mixtures used and the cost of treatment per tree for labor and material in treating 20-year-old trees with power outfits, not including interest on investment and depreciation of machinery, were as follows:

SPRAYING AND DUSTING FOR APPLE RED BUGS, WILSON ORCHARD, ONTARIO COUNTY, NEW YORK.

NAME OF MATERIAL	AMOUNT PER TREE	COST OF TREATMENT
Lime-sulfur with nicotine (1 pint)	5.72 gals.	18 cts.
Lime-sulfur with nicotine (1 pint)	7.69 gals.	24 cts.
Lime-sulfur with nicotine (1 pint)	15 gals.	48 cts.
Dust, 0.25 per cent nicotine	2 lbs.	21 cts.
Dust, 0.25 per cent nicotine	5 lbs.	53 cts.
Dust, 0.5 per cent nicotine	2 lbs.	25 cts.
Dust, 0.5 per cent nicotine	5 lbs.	63 cts.
Dust, 1.0 per cent nicotine	2 lbs.	34 cts.
Dust, 1.0 per cent nicotine	5 lbs.	84 cts.
Dust, 2.0 per cent nicotine	2 lbs.	50 cts.
Dust, 2.0 per cent nicotine	5 lbs.	125 cts.

No appreciable differences were observed between ***mendax*** and ***malinus*** with respect to susceptibility to either dusting or spraying mixtures, the nymphs and adults alike proving very sensitive to treatment.

The experiments have clearly shown that there are at least two essential factors in securing effective control of red bugs, ***viz.***, materials with adequate insecticidal properties, and contact of the material with the insects. In both dusting and spraying operations the reduction in red bug population was not generally as large as was expected from the known killing powers of the insecticides. The discrepancy between the potential properties of the materials and the results actually obtained was primarily due to faulty distribution because of insufficient dosage, size of trees, denseness of growth, wind, etc., all of which may exert an unfavorable influence on the success of the undertaking.

Temperatures ranging from 44° to 87° F. and moisture on the foliage apparently exerted no appreciable influence on the killing properties of dusting mixtures. Strong air currents rendered uni-

form distribution of materials difficult of accomplishment. Dusting operations were most satisfactorily conducted during periods when the air was still.

Dosage cost for dusting is higher than for spraying, due chiefly to the high nicotine content of the dust mixtures. Dusting requires less time than spraying and this effects economies in time and labor. Considering the needs of average growers and prevailing prices for material and labor, the apple red bugs can be more efficiently and economically controlled by spraying than by dusting. In large commercial orchards dusting could doubtless be used to great advantage in a supplementary capacity to the usual spraying operations.

Tobacco dust which was ground until 50 per cent of the material passed thru a 100-mesh sieve possessed marked insecticidal properties. Promising results were also obtained with the material in combination with either soap or lime-sulfur solution.

Derris and soap displayed a high rate of toxicity against red bugs.

Of vital importance in furthering an extensive employment of dusting for the control of sucking insects is the need of more economical materials which function efficiently as contact insecticides.

INTRODUCTION

Since the introduction of dusting as a method of treatment to combat orchard pests there has been much speculation as to the susceptibility to dusting mixtures of the common sucking insects such as aphids, scales, red bugs, etc. The frequent and widespread demand for information thruout the leading fruit-growing areas of the State prompted a detailed study of the susceptibilities of the foregoing insects to insecticides in powdered and liquid forms. Since information of practical value has been collected relative to apple red bugs, it is deemed desirable to bring the more important results of this study to the attention of orchardists because of their interest in the problem and the urgent need for guidance in the new system of treatment.

It should also be stated that this study represents one of a number of projects under investigation which have as their object the determination of the practicability of dusting for the general treatment of fruit trees.

RED BUGS IN RELATION TO APPLE CULTURE

Apple orchards in this State are subject to attack by two species of very active, reddish plant-bugs. A bright red species (*Lygidea mendax* Reuter) hatches about blossoming time; while the associated form (*Heterocordylus malinus* Reuter), which is darker in color, appears a little earlier. Both species have one generation, reaching maturity and disappearing late in June or early July. Slingerland and Crosby[1] have presented with considerable detail the life history and habits of the insects. (See Plate I.)

The presence of the insects in an orchard may be detected by the appearance of reddish brown spots or stippling on the young, terminal leaves, which are the chief source of food of the nymphs until the blossoms drop and the fruits are formed. While the insects attack apples and injure them severely, the nymphs feed extensively on the tender leaves of terminal growth, suckers, and water-sprouts tho many fruits are present. Under certain conditions apple trees may apparently be more seriously infested than is indicated by the general appearance of the crop. The condition of the foliage furnishes a very reliable guide to the approximate degree of infestation of the trees.

Apples punctured by the insects usually display shallow dimples or funnel-shaped pits, and if these are numerous the fruit is considerably deformed. Extensive feeding on young apples may cause premature falling and, during certain seasons, this is apparently a source of great loss to growers. In addition to the foregoing injuries, Knight [2] has called attention to another form of damage in which the growth of the affected apple causes a rupture of the skin, resulting in irregular scars or russeted areas. (See Plates II and III.)

Spraying with lime-sulfur at summer strength, to which nicotine sulfate is added in either the blossom-pink or calyx treatments or both, is the common method of combating red bugs. For extensive infestation it has been considered advisable to give an extra drenching spray of nicotine sulfate, 1 pint to 100 gallons of water, to which has been added 4 or 6 pounds of soap.

Experience has demonstrated that the insects may be efficiently combated by the foregoing sprays and these were used in our experiments in order to furnish a basis for comparing the relative efficiency of dusting preparations.

---

[1] *Cornell Univ. Agr. Exp. Sta. Bul. 291. 1911.*
[2] *Cornell Univ. Agr. Exp. Sta. Bul. 396. 1918.*

STATION STUDIES ON CONTROL OF APPLE RED BUGS

OUTLINE OF EXPERIMENTS

The purpose of this project was to obtain data on the following points:

1 Merits of dusting as compared with spraying in controlling red bugs.
2 Killing properties of mixtures with high and low ratios of nicotine.
3 Effectiveness of 2- and 5-pound dosages of dusting mixtures.
4 Relative susceptibility to treatment of nymphs and adults of both species of red bugs.
5 Comparative costs of spraying and dusting operations.
6 Insecticidal properties of tobacco dust and derris.
7 Influence of applications on apple crop.
8 Red bug population of apple trees.
9 Life histories of insects in relation to spraying practices.
10 Nicotine content of commercial dust mixtures.

DESCRIPTION OF SPRAYING AND DUSTING MIXTURES

The following spraying mixtures and dusting preparations were used:

1 Lime-sulfur, $2\frac{1}{2}$ gallons; nicotine sulfate, $\frac{1}{4}$ pint; powdered lead arsenate, 3 pounds; water, 100 gallons.
2 Lime-sulfur, $2\frac{1}{2}$ gallons; nicotine sulfate, 1 pint; powdered lead arsenate, 3 pounds; water, 100 gallons.
3 Soap, 6 pounds; nicotine sulfate, $\frac{1}{4}$ pint; water, 100 gallons.
4 Soap, 6 pounds; nicotine sulfate, $\frac{1}{2}$ pint; water, 100 gallons.
5 Soap, 6 pounds; nicotine sulfate, 1 pint; water, 100 gallons.
6 Soap-derris mixture, 10 pounds to 100 gallons water.
7 Superfine tobacco dust, 40 pounds; lime-sulfur, $2\frac{1}{2}$ gallons; powdered lead arsenate, 3 pounds; water, 100 gallons.
8 Tobacco dust (undiluted).
9 Sulfur-lead-arsenate dust (90–10) with 0.25 per cent nicotine.
10 Sulfur-lead-arsenate dust (90–10) with 0.5 per cent nicotine.
11 Sulfur-lead-arsenate dust (90–10) with 1 per cent nicotine.
12 Sulfur-lead-arsenate dust (90–10) with 2 per cent nicotine.

On page 28, analyses are given which show the nicotine content of a number of commercial dusting mixtures. Owing to the vari-

ability of the proprietary preparations with respect to this constituent, we made our own mixtures using nicotine sulfate (40 per cent nicotine) with sulfur-lead-arsenate dust (90–10) as the carrier, according to the following formulas:

Dust, 0.25 per cent nicotine, 0.87 lb. nicotine sulfate to 99.12 lbs. sulfur-lead-arsenate dust.

Dust, 0.5 per cent nicotine, 1.75 lbs. nicotine sulfate to 98.25 lbs. sulfur-lead-arsenate dust.

Dust, 1 per cent nicotine, 2.5 lbs. nicotine sulfate to 97.5 lbs. sulfur-lead-arsenate dust.

Dust, 2 per cent nicotine, 5 lbs. nicotine sulfate to 95 lbs. sulfur-lead-arsenate dust.

Samples of the foregoing mixtures weighing 50 grams each were screened with the results shown in Table 1.

TABLE 1.— ANALYSES SHOWING PHYSICAL PROPERTIES OF THE DUSTING MIXTURES.

MATERIALS	MATERIAL PASSING THRU 50-MESH SIEVE BUT NOT 100-MESH		MATERIAL PASSING THRU 100-MESH SIEVE BUT NOT 200-MESH		MATERIAL PASSING THRU 200-MESH SIEVE		TOTAL WEIGHT OF SAMPLE	MATERIAL LOST IN SHAKING
	Grams	*Per cent*	*Grams*	*Per cent*	*Grams*	*Per cent*	*Grams*	*Grams*
Dusting sulfur	.65	1.2	3.5	7.0	43.2	91.7	50	2.65
Sulfur-lead-arsenate dust (90–10)	.20	.4	3.3	7.3	44.1	92.2	50	2.40
Dust, 0.25 per cent nicotine	.20	.4	4.6	9.6	42.6	89.9	50	2.60
Dust, 0.5 per cent nicotine	2.40	5.1	7.2	15.3	37.3	79.6	50	3.10
Dust, 1.0 per cent nicotine	2.90	6.3	5.6	12.2	37.1	81.1	50	4.40
Dust, 2.0 per cent nicotine	4.80	9.8	8.7	17.8	35.2	72.5	50	1.30

The tobacco dust was the ordinary commercial product guaranteed to contain 1 per cent nicotine. Before using in the experiments it was ground in a ball machine until 50 per cent of the material passed thru a 100-mesh sieve.

The derris-soap compound was a commercial preparation assumed to contain approximately 0.5 pound of powdered derris root and 6 pounds of soap per gallon.

METHODS OF OBTAINING AND TABULATING DATA

In various tables containing data obtained in the experiments, certain computations are grouped under the headings *Insecticidal*

Efficiency and *Efficiency Rating of Operation.* It is desirable to make clear at the outset the meaning that these terms are intended to convey. This perhaps can best be done by describing the procedure followed in securing and tabulating the data.

After placing a large canvas sheet beneath a tree a definite amount of material, either as a dust or as a spray, was applied. In the case of a dusting preparation which possessed high killing properties the red bugs began to drop immediately — most of them dead. A varying percentage were alive and active. A small number were semi-paralyzed, some of them succumbing, while others recovered. With liquid insecticides similar results were obtained except that the majority of the insects did not begin to drop until the spray had dried on the foliage. In falling, some of the red bugs would drop into the fruit clusters or on the leaves, and in order to dislodge them the trees were jarred vigorously in order that all insects affected by the treatment could be counted. It is obvious that the dislodging of the insects was the direct result of the treatment and, on the basis of the number of living and dead specimens recorded, the rate of effectiveness of a particular insecticide was determined and expressed under the heading *Insecticidal Efficiency.*

In all the operations of this character with individual trees to the number of 60 or more, no treatment, even with the most efficient insecticide, killed or brought to the ground all of the red bugs that were on a tree. An essential consideration in our efforts was to secure an accurate knowledge of the total red bug population. In order to determine within fairly close limits the number that escaped the first treatment a second application was made of either the nicotine and soap mixture at standard strength, using 15 to 25 gallons per tree, or 2 per cent nicotine dust at the rate of 10 to 25 pounds per tree, after which the tree was again jarred. Special pains were taken to make thoro treatments and no attempt was made to economize in material. The influence on the insects of successive treatments is shown in Table 2.

So far as Treatment 1 is concerned it is obvious that the insects brought down by Treatments 2 and 3 should be classed as *living insects.* In the case of materials of demonstrated effectiveness, the question at once arises if the immunity of these insects was due to the inefficiency of the insecticide or to the influence of some

circumstance of the experiment such as small dosage, poor distribution, air currents, denseness of tree growth, etc. If the result is not really due to any inherent weakness of the mixture, then the second and third counts should be excluded in determining the insecticidal efficiency of the material. For example, with an insecticide of proved efficiency the escape of the insects as expressed in the second count could hardly be ascribed to poor killing properties but rather to poor spraying as a result of careless work, high trees, strong winds, etc.; the operation in its entirety and not the material producing the result.

TABLE 2.— EFFECT OF REPEATED TREATMENTS ON RED BUG POPULATION.

NUMBER OF TREE	TREATMENT 1, INSECTS DISLODGED		TREATMENT 2, INSECTS DISLODGED		TREATMENT 3, INSECTS DISLODGED	
	Number of insects	Percentage of population	Number of insects	Percentage of population	Number of insects	Percentage of population
1.....	89	77.4	24	20.8	2	1.8
2.....	1,040	96.1	41	3.7	1	0.2
3.....	478	97.8	11	2.2	0	0.0

Take another example. With a tree of large size 2 pounds of a dust with needed toxic properties will not prove as effective as 10 pounds of the same material. Experience has shown that the dust is effective, but the determining factor is that the smaller amount is not sufficient to cover the foliage satisfactorily. Misleading and erroneous conclusions would be drawn as to the comparative effectiveness of certain materials if the failure to control the insects was ascribed to poor killing properties of the insecticide.

These illustrations show that a distinction should be made between limitations in insecticidal efficiency and failure to destroy the insects which are due to other factors involved in the task of treating a tree.

Under the heading *Efficiency Rating of Operation* there is included computations which are the sum of Counts 1 and 2, the red bugs in the latter count being classed as living insects. These computations are intended to show particularly the influence of faulty spraying or dusting, *viz.*, failure to hit the insects, on the effectiveness of the treatment.

DESCRIPTION OF EXPERIMENTS

I. TESTS WITH SPRAYING AND DUSTING MIXTURES

The experiments were conducted on June 1 and 2, 1920, in a 19-year-old orchard of Charles S. Wilson at Hall. The planting, which consists chiefly of such varieties as Greening, Hubbardston, and Baldwin, had suffered for successive years, and at the time of the operations over 90 per cent of the terminal growth of many of the trees was damaged. In Plat I, 10 Greening trees were dusted with a 90–10 mixture containing 0.5 per cent nicotine. The mixture was applied at the rate of a little more than 5 pounds per tree and with one tree (Tree 1) a special effort was made to secure a thoro application of the material. In Plat II, 17 Greening trees were dusted, using from 85 to 90 pounds of a 90–10 mixture with 1.0 per cent nicotine. In Plat III, 15 trees were sprayed with 200 gallons of a derris-soap mixture composed of 10 pounds of the stock material to 100 gallons of water. Tree 2 of this plat was sprayed very thoroly. One tree (Tree 3) was sprayed with 25 gallons of soap and nicotine at standard strength. All applications were made during bright, warm periods when no air was stirring. Beneath the trees that received special attention canvas fumigation sheets were spread in order that the red bugs could be collected as they fell. Following the first count the trees were shaken vigorously and the condition of the insects, whether dead or alive, recorded. The effectiveness of the different treatments is indicated in Tables 3 and 4.

TABLE 3.— EFFECT OF DUST AND SPRAY APPLICATIONS ON RED BUGS.

TREATMENT	AMOUNT PER TREE	INSECTS DISLODGED BY TREATMENT		INSECTICIDAL EFFICIENCY
		Number living	Number dead	
				Per cent
Tree 1, Dust, 0.5 per cent nicotine...	5 lbs.	74	403	84.5
Tree 2, Derris-soap mixture.....	13⅓ gals.	5	600	99.2
Tree 3, Soap and nicotine.....	25 gals.	14	462	97.0
Tree 4, Check.....	.....	*317	*14	.....

*The insects were dislodged by jarring the tree.

TABLE 4.— INFLUENCE OF DUST AND SPRAY APPLICATIONS IN PREVENTING INJURIES TO FRUIT.

TREATMENT	NUMBER OF APPLES	NUMBER OF INJURED APPLES	PERCENTAGE OF INJURED APPLES
Dust, 0.5 per cent nicotine	717	41	5.4
Dust, 0.5 per cent nicotine	1,682	84	4.7
Dust, 1.0 per cent nicotine	1,349	201	12.9
Dust, 1.0 per cent nicotine	2,280	198	7.9
Dust, 1.0 per cent nicotine	595	26	4.2
Dust, 1.0 per cent nicotine	2,857	149	4.9
Dust, 1.0 per cent nicotine	1,266	72	5.4
Derris-soap mixture	1,533	98	6.0
Derris-soap mixture	1,372	226	14.1
Derris-soap mixture	1,702	114	6.3
Soap and nicotine	1,228	15	1.2
Check, no treatment	1,120	997	47.1

SUMMARY

TREATMENT	PERCENTAGE INJURED APPLES	PERCENTAGE SOUND APPLES
Dust, 0. 5 per cent nicotine	5.0	95.0
Dust, 1.0 per cent nicotine	7.1	92.9
Derris-soap mixture	13.2	86.8
Soap and nicotine	1.2	98.8
Check	47.1	52.9

II. TESTS WITH SPRAYING AND DUSTING MIXTURES CONTAINING DIFFERENT RATIOS OF NICOTINE

Experimental operations were conducted during 1921 in the orchard described in the preceding tests. Plats I, II, III, and IV, each containing 40 Greening trees, were dusted with a 90–10 mixture containing 0.25, 0.5, 1.0, and 2.0 per cent nicotine, respectively. The preparations were applied at the rate of 5 pounds per tree at daybreak when there were, for the most part, no appreciable air currents. In Plat V, 40 trees of the same variety were sprayed at the rate of $7\frac{1}{2}$ gallons of lime-sulfur containing nicotine sulfate, and a similar number of trees (Plat VI) were treated with the spraying mixture at the rate of 15 gallons per tree. The applications were made with the latest models of spraying and

dusting machinery and all the rows were treated from two sides. (See Plates IV and V.) The effectiveness of the different treatments is indicated in Tables 5 and 6.

TABLE 5.— EFFECT OF DUST AND SPRAY APPLICATIONS ON RED BUGS.

MATERIAL	AMOUNT PER TREE	INSECTS DISLODGED				INSECTICIDAL EFFICIENCY	EFFICIENCY RATING OF OPERATION
		Treatment 1		Treatment 2			
		Living	Dead	Living	Dead		
		Number	*Number*	*Number*	*Number*	*Per cent*	*Per cent*
Dust, 0.25 per cent nicotine	5 lbs.	9	80	0	24	89.9	70.8
Dust, 0.25 per cent nicotine	5 lbs.	2	44	.....	.....	95.7	.....
Dust, 0.50 per cent nicotine	5 lbs.	52	988	0	41	95.0	91.4
Dust, 0.50 per cent nicotine	5 lbs.	80	576	.....	.....	87.9	.....
Dust, 1.0 per cent nicotine	5 lbs.	0	155	0	66	100.0	70.1
Dust, 1.0 per cent nicotine	5 lbs.	0	132	.....	.....	100.0	.....
Dust, 2.0 per cent nicotine	5 lbs.	0	356	0	17	100.0	95.5
Dust, 2.0 per cent nicotine	5 lbs.	0	329	0	25	100.0	92.9
Dust, 2.0 per cent nicotine	5 lbs.	0	53	0	6	100.0	89.9
Dust, 2.0 per cent nicotine	5 lbs.	0	59	0	8	100.0	88.1
Lime-sulfur and nicotine	7½ gals.	16	344	0	44	95.6	85.1
Lime-sulfur and nicotine	15 gals.	1	477	0	11	99.8	97.5
Lime-sulfur and nicotine	15 gals.	2	199	0	21	99.0	89.6
Lime-sulfur and nicotine	15 gals.	1	209	.....	.....	99.5	.....
SUMMARY							
Dust, 0.25 per cent nicotine	5 lbs.	.....	.....	.....	.....	92.8	70.8
Dust, 0.50 per cent nicotine	5 lbs.	.....	.....	.....	.....	91.4	91.4
Dust, 1.0 per cent nicotine	5 lbs.	.....	.....	.....	.....	100.0	70.1
Dust, 2.0 per cent nicotine	5 lbs.	.....	.....	.....	.....	100.0	91.6
Lime-sulfur and nicotine	7½ gals.	.....	.....	.....	.....	95.6	85.1
Lime-sulfur and nicotine	15 gals.	.....	.....	.....	.....	99.4	93.6

PLATE II.— YOUNG APPLES AND FOLIAGE INJURED BY RED BUGS.

PLATE V.—SPRAYING MACHINE IN OPERATION WITH SHEET IN POSITION TO CATCH DISLODGED INSECTS.

TABLE 6.— INFLUENCE OF DUST AND SPRAY APPLICATIONS IN PREVENTING INJURIES TO FRUIT.

Row and Tree	Condition of apples with respect to injuries				Number pitted apples	Number scarred apples	Number sound apples	Total number apples	Percentage pitted apples	Percentage scarred apples	Percentage injured apples	Percentage sound apples
	Picked fruit		Dropped fruit									
	Number pitted	Number scarred	Number pitted	Number scarred								
Check												
3–35	17	4	5	0	22	4	65	91	24.20	4.40	28.6	71.4
3–36	36	12	3	0	39	12	99	150	26.00	8.00	34.0	66.0
Dust, 0.25 per cent Nicotine												
9– 6	30	6	3	2	33	8	955	996	3.30	0.90	4.2	95.8
9– 7	9	4	1	3	10	7	598	615	1.60	1.20	2.8	97.2
9– 8	6	1	3	3	9	4	745	758	2.15	0.95	3.1	96.9
9– 9	7	5	3	3	10	8	1,221	1,239	0.84	0.66	1.5	98.5
9–15	14	1	0	1	14	2	466	482	2.97	0.42	3.4	96.6
9–17	3	0	3	1	6	1	360	367	0.86	0.14	1.0	98.0
Dust, 0.50 per cent Nicotine												
18–18	19	2	3	1	22	3	809	834	2.64	0.36	3.0	97.0
18–22	44	10	7	3	51	13	1,149	1,213	4.23	1.07	5.3	94.7
18–29	3	0	2	0	5	0	850	855	0.60	0.00	0.6	99.4
18–30	12	2	5	0	17	2	180	199	7.70	0.90	8.6	91.4
18–33	35	6	6	0	41	6	706	753	5.50	0.80	6.3	93.7
18–34	12	3	5	1	17	4	853	874	2.03	0.47	2.5	97.5
Dust, 1.0 per cent Nicotine												
3–20	11	3	0	3	11	6	466	483	2.36	1.24	3.6	96.4
3–22	1	0	0	0	1	0	319	320	0.10	0.00	0.1	99.9
3–25	0	0	0	0	0	0	101	101	0.00	0.00	0.0	100.0
3– 2	17	0	3	0	20	0	824	844	2.40	0.00	2.4	97.6
3–11	19	4	3	2	22	6	629	657	3.40	0.90	4.3	95.7
Lime-sulfur and Nicotine (7½ gals. per tree)												
12– 6	2	1	2	0	4	1	220	225	1.84	0.46	2.30	97.7
12–14	27	3	2	0	29	3	822	854	3.39	0.36	3.80	96.2
12–32	12	7	6	0	18	7	991	1,016	1.80	0.70	2.50	97.5
12–33	8	3	2	3	10	6	751	767	1.30	0.79	2.10	97.9
12–35	10	7	2	1	12	8	1,005	1,025	1.17	0.78	1.95	98.1
Lime-sulfur and Nicotine (15 gals. per tree)												
6–15	15	2	2	2	17	4	859	880	1.95	0.45	2.4	97.6
6–16	3	4	2	0	5	4	1,058	1,067	0.47	0.43	0.9	99.1
6–17	3	4	1	2	4	6	771	781	0.53	0.77	1.3	98.7
6–18	7	2	0	0	7	2	630	639	1.20	0.30	1.5	98.5
6–29	0	0	0	0	0	0	153	153	0.00	0.00	0.0	100.0
6–32	0	1	0	0	0	1	174	175	0.00	0.60	0.6	99.4
6–37	3	1	0	0	3	1	137	141	2.12	0.68	2.8	97.2

TABLE 6.— SUMMARY.

TREATMENT	PERCENTAGE INJURED APPLES	PERCENTAGE SOUND APPLES
Untreated trees	31.3	68.7
Dust, 0.25 per cent nicotine	2.9	97.1
Dust, 0.50 per cent nicotine	4.4	95.6
Dust, 1.0 per cent nicotine	2.1	97.9
Lime-sulfur and nicotine (7½ gals. per tree)	2.4	97.6
Lime-sulfur and nicotine (15 gals. per tree)	1.4	98.6

Cost of labor and materials in dusting and spraying orchard.— In this experiment records were kept of the actual time required to load the machines and to apply the different mixtures to the trees in the various plats. The data are given in Tables 7 and 8.

The prices for the insecticidal materials were estimated as follows: Lime-sulfur solution, 20 cents per gallon; powdered lead arsenate, 25 cents per pound; nicotine sulfate (Black Leaf 40), $13.75 per gallon; soap, 10 cents per pound; sulfur-lead-arsenate dust (90–10), $8.50 per 100 pounds; 90–10 dust with 2 per cent nicotine, $25.00

TABLE 7.— TIME REQUIRED TO LOAD MACHINE AND TO DUST TREES USING MATERIAL AT THE RATE OF 2 POUNDS AND 5 POUNDS, RESPECTIVELY, PER TREE.

MATERIAL USED	TIME REQUIRED TO FILL HOPPER, *Minutes*	TIME EXPENDED IN APPLYING 100 LBS. DUST, *Minutes*	TOTAL TIME REQUIRED TO APPLY 100 lbs. DUST, *Minutes*	NUMBER OF TREES TREATED	TIME PER TREE, *Minutes*	TOTAL TIME FOR TWO MEN, *Minutes*
2 POUND RATE						
Dust, 100 lbs...	2.00	25.0	27.00	50	0.540	1.180
Dust, 100 lbs...	2.00	24.0	26.00	50	0.520	1.060
Average.....	2.00	24.5	26.50	50	0.530	1.120
5 POUND RATE						
Dust, 100 lbs...	1.50	11.0	12.50	20	0.624	1.248
Dust, 100 lbs...	2.00	10.0	12.00	20	0.600	1.200
Average.....	1.75	10.5	12.25	20	0.612	1.224

TABLE 8.— TIME REQUIRED TO LOAD MACHINE AND TO SPRAY TREES USING 5, 7, AND 15 GALLONS OF SPRAYING MIXTURE, RESPECTIVELY, PER TREE.

MATERIAL USED	TIME TO FILL TANK, *Minutes*	TIME TO REACH ORCHARD, *Minutes*	TIME TO APPLY MIXTURE, *Minutes*	TIME TO RETURN TO FILLING STATION, *Minutes*	TOTAL TIME REQUIRED TO APPLY 300 GALS, *Minutes*	NUMBER OF TREES SPRAYED	TIME REQUIRED FOR SPRAYING ONE TREE, *Minutes*	TOTAL TIME FOR THREE MEN, *Minutes*	AMOUNT OF MATERIAL APPLIED PER TREE, *Gallons*
				5 GALLON RATE					
Spray, 300 gals.	9.00	5.00	33.00	5.00	52.0	51.00	1.019	3.057	5.88
Spray, 300 gals.	9.00	5.00	37.00	6.00	57.0	58.00	0.980	2.940	5.17
Spray, 300 gals.	8.50	7.00	38.00	3.50	57.0	49.00	1.190	3.570	6.12
Average	8.83	5.66	36.00	4.83	55.3	52.66	1.063	3.156	5.72
				7 GALLON RATE					
Spray, 300 gals.	8.50	6.00	34.00	4.00	52.5	40.00	1.310	3.930	7.50
Spray, 300 gals.	9.50	5.00	34.50	5.00	54.0	38.00	1.420	4.260	7.89
Average	9.00	5.50	34.25	4.50	53.2	39.00	1.340	4.090	7.69
				15 GALLON RATE					
Spray, 300 gals.	9.00	7.00	32.00	3.00	51.0	20.00	2.550	7.650	15.00
Spray, 300 gals.	8.50	7.50	31.00	4.00	51.0	21.00	2.230	6.690	14.28
Average	8.75	7.25	31.50	3.50	51.0	20.50	2.390	7.170	14.64

TABLE 9.— AVERAGE COST OF TREATMENT PER TREE FOR DUSTING AND SPRAYING MATERIALS AT DIFFERENT DOSAGES.

MATERIAL	AMOUNT PER TREE	TIME PER TREE, *Minutes*	COST OF MATERIALS PER TREE	COST OF TIME PER TREE	TOTAL COST PER TREE	COST OF MATERIALS PER GALLON OR POUND
Lime-sulfur, lead arsenate, nicotine (1 pt.)	5.72 gals.	3.156	$0.1699	$0.01578	$0.1857	$0.0297
Lime-sulfur, lead arsenate, nicotine (1 pt.)	7.69 gals.	4.09	0.2284	0.02045	0.2489	0.0297
Lime-sulfur, lead arsenate, nicotine (1 pt.)	15.00 gals.	7.17	0.4455	0.03585	0.4814	0.0297
Lime-sulfur, lead arsenate, nicotine ($\frac{1}{2}$ pt.)	5.72 gals.	3.156	0.1270	0.01578	0.1428	0.0211
Lime-sulfur, lead arsenate, nicotine ($\frac{1}{2}$ pt.)	7.69 gals.	4.09	0.1623	0.02045	0.1828	0.0211
Lime-sulfur, lead arsenate, nicotine ($\frac{1}{2}$ pt.)	15.00 gals.	7.17	0.3165	0.03585	0.3524	0.0211
Lime-sulfur, lead arsenate, nicotine ($\frac{1}{4}$ pt.)	5.72 gals.	3.156	0.0961	0.01578	0.1119	0.0168
Lime-sulfur, lead arsenate, nicotine ($\frac{1}{4}$ pt.)	7.69 gals.	4.09	0.1292	0.02045	0.1497	0.0168
Lime-sulfur, lead arsenate, nicotine ($\frac{1}{4}$ pt.)	15.00 gals.	7.17	0.2520	0.03585	0.2879	0.0168
Lime-sulfur, lead arsenate, tobacco dust (40 lbs.)	5.72 gals.	3.156	0.1184	0.01578	0.1342	0.0207
Lime-sulfur, lead arsenate, tobacco dust (40 lbs.)	7.69 gals.	4.09	0.1592	0.02045	0.1797	0.0207
Lime-sulfur, lead arsenate, tobacco dust (40 lbs.)	15.00 gals.	7.17	0.3105	0.03585	0.3464	0.0207
Soap, nicotine (1 pt.)	5.72 gals.	3.156	0.1327	0.01578	0.1485	0.0232
Soap, nicotine (1 pt.)	7.69 gals.	4.09	0.1784	0.02045	0.1989	0.0232
Soap, nicotine (1 pt.)	15.00 gals.	7.17	0.3480	0.03585	0.3839	0.0232
Dust (90–10) 2 per cent nicotine	2 lbs.	1.12	0.5000	0.0056	0.5056	0.2500
Dust (90–10) 2 per cent nicotine	5 lbs.	1.224	1.2500	0.00612	1.2560	0.2500
Dust (90–10) 1 per cent nicotine	2 lbs.	1.12	0.3350	0.0056	0.3406	0.1675
Dust (90–10) 1 per cent nicotine	5 lbs.	1.224	0.8375	0.00612	0.8436	0.1675
Dust (90–10) 0.5 per cent nicotine	2 lbs.	1.12	0.2526	0.0056	0.2582	0.1263
Dust (90–10) 0.5 per cent nicotine	5 lbs.	1.224	0.6315	0.00612	0.6376	0.1263
Dust (90–10) 0.25 per cent nicotine	2 lbs.	1.12	0.2112	0.0056	0.2168	0.1056
Dust (90–10) 0.25 per cent nicotine	5 lbs.	1.224	0.5280	0.00612	0.5341	0.1056

per 100 pounds; 90–10 dust with 1 per cent nicotine, $16.75 per 100 pounds; 90–10 dust with 0.5 per cent nicotine, $12.63 per 100 pounds; and 90–10 dust with 0.25 per cent nicotine, $10.56 per 100 pounds.

Labor was charged for at the rate of 30 cents per hour, allowing for two men to operate the dusting machine and for three men for the spraying outfit.

With the foregoing figures as a basis, the estimated cost of dusting and spraying 20-year-old Greening apple trees is as presented in Table 9. It should be noted that the computations do not include use of teams, depreciation of machinery, or interest on the investment.

III. COMPARATIVE EFFECTIVENESS OF SMALL AND LARGE DOSAGES OF DUSTING MIXTURES

With such insects as aphids and red bugs, effective results from dusting will depend on the thoro coating of the insects, since the substances applied kill by direct contact. The preceding tests have demonstrated that red bugs are relatively easy to kill. They have also made quite clear that, notwithstanding the sensitiveness of the insects to treatment, the problem of the grower is to reach a fairly large percentage of the creatures with the dust or spray which is not so simple a matter as it may first appear. The task is, of course, chiefly that of mastering practical difficulties. One of the essential factors in securing thoro treatment is the application of adequate amounts of material. As no data were available relative to the dosage requirements of bearing apple trees, this series of tests was undertaken to determine the extent of protection afforded by dusting mixtures applied in amounts of 2 and 5 pounds, respectively, per tree. The trees selected for treatment were 20-year-old Baldwins which had made a vigorous growth and carried rather dense foliage. Nicotine was applied at rates of 0.5, 1.0, and 2 per cent in combination with 90–10 sulfur-arsenate of lead mixture. The dusting machine was directed completely around each tree so that the material could be applied from all sides. In applying materials in 2-pound lots, considerable difficulty was experienced in encircling the trees before the exhaustion of the material. At occasional moments slight air currents prevailed. The effectiveness of the different treatments is indicated in Table 10.

TABLE 10.— EFFECT OF DUST APPLICATIONS ON RED BUGS.

TREATMENT	AMOUNT PER TREE	INSECTS DISLODGED				INSECTICIDAL EFFICIENCY	EFFICIENCY RATING OF OPERATION
		Treatment 1		Treatment 2			
		Number living	Number dead	Number living	Number dead		
	Pounds					*Per cent*	*Per cent*
Dust, 0.5 per cent nicotine	5	52	988	0	41	95.0	91.4
Dust, 0.5 per cent nicotine	5	80	576	.....	....	87.8	.....
Dust, 0.5 per cent nicotine	2	20	53	1	169	72.6	21.9
Dust, 0.5 per cent nicotine	2	5	43	.....	37	89.6	50.5
Dust, 0.5 per cent nicotine	2	28	80	.....	133	74.1	33.2
Dust, 1.0 per cent nicotine	5	0	155	0	66	100.0	70.1
Dust, 1.0 per cent nicotine	5	0	132	.....	.....	100.0	.....
Dust, 1.0 per cent nicotine	2	23	87	.....	58	79.1	51.8
Dust, 1 0 per cent nicotine	2	37	163	.....	195	81.5	41.3
Dust, 1.0 per cent nicotine	2	22	32	.....	74	59.3	25.0
Dust, 2.0 per cent nicotine	5	0	356	0	17	100.0	95.4
Dust, 2.0 per cent nicotine	5	0	329	0	25	100.0	92.9
Dust, 2.0 per cent nicotine	5	0	53	.....	6	100.0	89.8
Dust, 2.0 per cent nicotine	5	0	59	.....	8	100.0	88.1
SUMMARY							
Dust, 0.5 per cent nicotine	2	.....	.....	.....	.....	78.8	36.7
Dust, 0.5 per cent nicotine	5	.....	.....	.....	.....	91.4	91.4
Dust 1.0 per cent nicotine	2	.....	.....	.....	.....	73.3	39.4
Dust, 1.0 per cent nicotine	5	.....	.....	.....	.....	100.0	70.1
Dust, 2.0 per cent nicotine	5	.....	.....	.....	.....	100.0	91.6

IV. NICOTINE IN LIME-SULFUR AND SOAP: GROUND TOBACCO AS A DUST AND IN LIME-SULFUR

In considering materials for combating such insects as aphids, capsids, etc., it may be pointed out that there is not a wide range of available substances with desirable insecticidal properties. At present nicotine sulfate is widely used and is the most effective constituent of both dusting and spraying mixtures which function as contact insecticides. A serious drawback to its extensive employment by many growers is its high cost.

A means of effecting economy is to employ dilutions with the minimum amount of nicotine necessary to secure satisfactory control. The preceding experiments have indicated the relative efficiency of dusting mixtures with varying nicotine content. As there was need of similar data for spraying mixtures, this series of experiments was undertaken to determine the effectiveness of lower ratios of nicotine than are commonly employed in spraying operations against the red bugs. Nicotine sulfate was used in combination with both lime-sulfur and soap at standard strengths. The applications were

made on 20-year-old Baldwins, vigorous growing trees with rather heavy foliage.

Provision was also made in these operations for a test with finely ground tobacco as a possible substitute for nicotine sulfate. It was applied at the rate of 8 pounds per tree and was also used at the rate of 40 pounds in 100 gallons of lime-sulfur solution as employed for summer applications on apple trees. The effectiveness of the different treatments is indicated in Table 11.

TABLE 11.— EFFECT OF DUST AND SPRAY APPLICATIONS ON RED BUGS.

MATERIAL	AMOUNT PER TREE	INSECTS DISLODGED				INSECTICIDAL EFFICIENCY	EFFICIENCY RATING OF OPERATION
		Treatment 1		Treatment 2			
		Number living	Number dead	Number living	Number dead		
						Per cent	*Per cent*
Soap and nicotine sulfate, ½ pt.	15 gals.	12	127	0	87	91.4	56.2
Soap and nicotine sulfate, ½ pt.	25 gals.	14	527	0	88	97.4	83.8
Soap and nicotine sulfate, ½ pt.	15 gals.	8	221	0	29	96.5	85.7
Soap and nicotine sulfate, ½ pt.	25 gals.	7	215	0	27	96.8	86.4
Soap and nicotine sulfate, 1 pt.	25 gals.	36	594	.....	.....	94.3	.....
Lime-sulfur and nicotine sulfate, ½ pt.	15 gals.	39	162	1	156	80.6	45.3
Lime-sulfur and nicotine sulfate, ¼ pt.	25 gals.	21	86	0	63	80.4	50.6
Lime-sulfur and nicotine sulfate, 1 pt.	7½ gals.	17	349	0	44	95.4	85.1
Lime-sulfur and nicotine sulfate, 1 pt.	15 gals.	1	478	0	11	99.8	97.6
Lime-sulfur and nicotine sulfate, 1 pt.	15 gals.	2	202	0	21	99.0	89.8
Lime-sulfur and nicotine sulfate, 1 pt.	15 gals.	1	209	.....	.....	99.5	.....
Lime-sulfur and tobacco dust.	15 gals.	1	331	0	32	99.7	90.9
Lime-sulfur and tobacco dust.	25 gals.	4	185	0	12	97.9	92.0
Tobacco dust	8 lbs.	12	186	0	13	93.9	88.2

V. COMPARATIVE SUSCEPTIBILITY TO TREATMENT OF *H. malinus* AND *L. mendax*

As previously noted, apple trees in this State are infested with two species of red bugs, *viz.*, *L. mendax*, bright red in color, which hatches about the period of blossoming; and *H. malinus*, dark red in color, which makes its appearance somewhat earlier. Both forms may frequently be found on the same tree, when it will usually be observed that the nymphs of *malinus* are more advanced in their development than those of the associated species. It should also be noted that the relative numbers of the two insects may vary with different orchards, either one or the other being the dominant form.

In view of the lack of data on the comparative effectiveness of dusting and spraying mixtures against both species, two orchards were selected which were much infested and showed almost complete segregation of the two insects. In the older orchard, consisting chiefly of Baldwins and Greenings about 35 years of age, *malinus* was the dominant species. In the treatment of this planting the lack of efficient dusting and spraying machinery compelled the use of large amounts of materials in order to secure a fairly satis-

TABLE 12.— COMPARATIVE SUSCEPTIBILITY OF RED BUG NYMPHS TO DUSTING AND SPRAYING MIXTURES.

NUMBER OF TREE	MATERIAL	AMOUNT PER TREE	AGE OF TREE, YEARS	NUMBER OF INSECTS DISLODGED			
				Total number of nymphs	Number living	Number dead	Per-centage killed
			H. MALINUS				
1	Dust, 0.5 per cent nicotine.	25 lbs.	35	934	61	873	93.5
2	Dust, 0.25 per cent nicotine	25 lbs.	35	135	24	111	82.2
3	Soap and nicotine (1 pint).	25 gals.	35	248	44	204	82.2
4	Soap and nicotine (1 pint)	25 gals.	35	739	19	720	97.4
			L. MENDAX				
5	Dust, 0.5 per cent nicotine.	5 lbs.	20	1040	52	988	95.
6	Dust, 0.5 per cent nicotine.	5 lbs.	20	656	80	576	87.8
7	Dust, 0.25 per cent nicotine	5 lbs.	20	89	9	80	89.9
8	Dust, 0.25 per cent nicotine	5 lbs.	20	46	2	44	95.6
9	Soap and nicotine (1 pint)	25 gals.	20	630	36	594	94.3

TABLE 13.— COMPARATIVE SUSCEPTIBILITY OF RED BUG ADULTS TO DUSTING MIXTURES.

NUMBER OF TREE	MATERIAL	AMOUNT PER TREE, POUNDS	AGE OF TREE, YEARS	NUMBER OF INSECTS DISLODGED			
				Total number of adults	Number living	Number dead	Per-centage killed
			H. MALINUS				
1	Dust, 2.0 per cent nicotine.	25	35	56	0	56	100
2	Dust, 2.0 per cent nicotine.	25	35	16	0	16	100
3	Dust, 2.0 per cent nicotine.	25	35	13	0	13	100
4	Dust, 2.0 per cent nicotine.	25	35	34	0	34	100
5	Dust, 2.0 per cent nicotine.	25	35	44	0	44	100
			L. MENDAX				
6	Dust, 2.0 per cent nicotine.	5	20	356	0	356	100
7	Dust, 2.0 per cent nicotine.	5	20	329	0	329	100
8	Dust, 2.0 per cent nicotine.	5	20	53	0	53	100
9	Dust, 2.0 per cent nicotine.	5	20	59	0	59	100

factory coating of the tops of the trees. In the younger planting, consisting of the same varieties of apples, *mendax* was the more numerous species. The effects of the different treatments on the nymphs and adults of both species are shown in Tables 12 and 13.

VI. THE RED BUG POPULATION OF APPLE TREES

As a rule relatively few red bugs are observed, even with careful inspection of apple trees, and for that reason injuries to the crop

TABLE 14.— RED BUG POPULATION OF APPLE TREES.

NUMBER OF TREE	NUMBER OF INSECTS ON TREE	NUMBER OF TREE	NUMBER OF INSECTS ON TREE
1	113	31	6
2	46	32	2
3	1081	33	1
4	657	34	2
5	221	35	1045
6	132	36	633
7	490	37	37
8	225	38	355
9	210	39	177
10	410	40	363
11	226	41	234
12	629	42	779
13	258	43	72
14	249	44	17
15	358	45	29
16	170	46	35
17	264	47	62
18	101	48	79
19	211	49	93
20	243	50	34
21	85	51	5
22	241	52	49
23	168	53	56
24	388	54	208
25	128	55	569
26	63	56	68
27	373	57	630
28	355	58	605
29	59	59	200
30	67	60	131

Mean	246.61 ± 21.42
Standard deviation	245.99 ± 15.15
Coefficient of variability	99.75 ± 10.63
Range	1 — 1081

have quite generally been assumed to be due to the activities of comparatively small numbers of the insects. By means of the methods which have been previously described, it proved possible to dislodge the insects and thus determine quite accurately the red bug population of a goodly number of trees. With both fruit growers and investigators, much interest naturally inheres in such a study and, because of a lack of data showing the extent and variation of infestation, the records of 60 trees were tabulated, as shown in Table 14.

It will be of interest to the reader to note the number of red bugs collected from individual trees. In Table 14 it will be observed that the population varied from 1 to 1081 specimens. This is a very large variation, and the exact causes for it are not clearly understood. As a measurement of this variation, the coefficient of variability and the standard deviation are the best indices. A coefficient of variability of practically 100 is marked, to say the least. This might indicate that we are confronted with the question of heterogeneity of population, but since no correlation can be found between the number of insects per tree and the age, vigor, and variety of the tree, we are compelled to conclude that the data are homogenous and represent normal variations. Perhaps with much greater numbers this point would be more clearly shown.

VII. LIFE HISTORIES OF THE APPLE RED BUGS IN RELATION TO SPRAYING PRACTICES

In conducting the field experiments collections of both species of red bugs were made at repeated intervals during the period of activity of the insects. An examination of the material shows

TABLE 15.— LIFE HISTORY OF *H. malinus* AS REPRESENTED BY COLLECTIONS OF SPECIMENS FROM MAY 4 TO JUNE 14, 1921.

STAGE OF INSECT	DATE OF COLLECTIONS										TOTAL NUMBER INSECTS
	May 4	May 5	May 14	May 16	May 17	May 18	May 24	May 31	June 10	June 14	
First nymphal instar	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Second nymphal instar	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	3
Third nymphal instar	1,119	392	.....	.....	.....	.....	.....	.....	.....	.....	1,511
Fourth nymphal instar	167	46	1	2	11	8	.....	.....	.....	.....	235
Fifth nymphal instar	.....	.....	.....	1	7	10	2	.....	.....	.....	20
Adult	.....	.....	.....	.....	.....	.....	.....	114	53	5	172

TABLE 16.— LIFE HISTORY OF *L. mendax* AS REPRESENTED BY COLLECTIONS OF SPECIMENS FROM APRIL 22 TO JUNE 14, 1921.

STAGE OF INSECT	DATE OF COLLECTION																TOTAL NUMBER INSECTS
	April 22	May 4	May 5	May 14	May 16	May 17	May 18	May 19	May 20	May 24	May 26	May 27	May 31	June 7	June 10	June 14	
First nymphal instar	6	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8
Second nymphal instar	....	163	8	48	9	2	3	4	....	....	....	....	....	....	....	....	237
Third nymphal instar	....	....	....	752	1,753	498	623	943	525	6	....	....	....	....	....	....	5,100
Fourth nymphal instar	....	....	....	....	7	9	47	116	271	951	153	62	....	....	....	....	1,616
Fifth nymphal instar	....	....	....	....	....	....	....	....	....	41	5	3	35	316	....	....	400
Adult	....	....	....	....	....	....	....	....	....	....	....	....	....	435	16	2	453

that a complete series of nymphs and adults of both species were secured with the exception of the first instar nymphs of *malinus*. The life histories of the insects and the comparative number of individuals at different stages of development for given periods, as revealed by a study of the collections, are shown in Tables 15 and 16.

As previously indicated, our observations of the insects, as well as experimental operations, were largely confined to the Greening and Baldwin varieties of apples. Chart I clearly shows the time of appearance of the different instars of both species of insects in relation to spraying practices. The dates especially noted refer to the period of time when the bulk of the insects are in the stage of development designated.

During the two seasons that we have conducted the experiments, the bright red bug (*L. mendax*) has been the more abundant and destructive of the two species. Observations of this insect during the season of 1921 showed that it was susceptible to treatment at three of the regular spraying periods. While the calyx application is obviously the logical treatment to combat the insect, much benefit might be obtained under certain conditions from the addition of nicotine sulfate to the pink application or to the two weeks' application.

During the past season, at the time of the pink application, less than 50 per cent of the species had hatched. While it is evident that the insect could not be exterminated at this time, the addition of nicotine sulfate might be warranted, especially where a severe outbreak was expected and the use of tobacco extract was also contemplated in the calyx treatment. In this event the pink application should be deferred as long as possible, since the number of the insects that will have hatched would increase with an appreciable postponement of the operation.

By the time the calyx application was applied the bulk of the insects were in the second and third nymphal instars and all the eggs had hatched. According to our observations during 1920 and 1921 this was the most favorable period for control measures. Careful spraying and dusting at this time resulted in an almost complete destruction of the insect.

In case large numbers of the insects escape the calyx application or the presence of the creatures is not discovered until after this treatment, the experiments show clearly that a large amount of protection could be secured for the following season by the addition of nicotine sulfate to the two weeks' application.

CHART I.— RELATION OF USUAL TIME FOR SPRAYING APPLE ORCHARDS TO DATES OF APPEARANCE OF RED BUGS IN VARIOUS STAGES.,

PERIOD FOR SPRAYING	*H. malinus*	DATE	*I. mendax*
Delayed dormant application (Green tip)		April 2	
		" 3	
		" 4	
		" 5	
		" 6	
		" 7	
		" 8	
		" 9	
		" 10	
		" 11	
		" 12	
		" 13	
		" 14	
		" 15	
Pink application		" 16	
		" 17	
		" 18	
		" 19	
		" 20	
		" 21	
		" 22	....First instar
		" 23	
		" 24	
		" 25	
		" 26	
		" 27	
		" 28	
Full bloom		" 29	
		" 30	
		May 1	
		" 2	
		" 3	
Petals dropping		" 4	...Second instar
	Third instar	" 5	
		" 6	
		" 7	
		" 8	
		" 9	
Calyx application		" 10	
		" 11	
		" 12	
		" 13	
		" 14	
		" 15	
		" 16	
	Fourth instar	" 17	....Third instar
		" 18	
		" 19	
		" 20	
		" 21	
		" 22	
		" 23	
	Fifth instar	" 24	...Fourth instar
		" 25	
		" 26	
		" 27	
Two weeks' application		" 28	
		" 29	
		" 30	
	Adult	" 31	....Fifth instar
		June 1	
		" 2	
		" 3	
		" 4	
		" 5	
		" 6	
		" 7	
		" 8	
		" 9	.....Adult
		" 10	
		" 11	
		" 12	
		" 13	
	Last of adults	" 14	
		" 15	..Last of adults

It is obvious that this treatment would be too late to afford a very appreciable amount of protection to the apple crop for the current season. The insects at this period were in the fourth and fifth nymphal instars and proved almost as vulnerable to treatment as the younger forms. The value of the application as a preventive measure, to avoid a serious attack for the succeeding season, would be almost as great as the calyx spray. This statement does not apply with equal certainty to *H. malinus*.

VIII. THE INFLUENCE OF MIXING AND STORAGE ON THE NICOTINE CONTENT OF DUST MIXTURES

During the course of the experiments with dusting mixtures assumed to contain definite ratios of nicotine, it was considered desirable to know the extent of variation in the amount of this constituent in the different preparations. Samples from nine lots which had been stored for known periods of time were analyzed, with the results shown in Table 17.

TABLE 17.— ANALYSES OF DUST MIXTURES SHOWING NICOTINE CONTENT.

NUMBER OF SAMPLE	MATERIAL CONTAINING NICOTINE	ASSUMED NICOTINE CONTENT	TIME IN STORAGE	AMOUNT OF NICOTINE FOUND	VARIATION FROM ASSUMED CONTENT
		Per cent	*Days*	*Per cent*	*Per cent*
1	Sulfur and lead arsenate (90–10)	0.5	108	0.559	+0.059
2	Sulfur and lead arsenate (90–10)	1.0	224	0.772	—0.228
3	Sulfur and lead arsenate (90–10)	1.0	108	0.554	—0.446
4	Sulfur and lead arsenate (90–10)	1.0	108	0.556	—0.444
5	Sulfur and lead arsenate (90–10)	1.0	108	1.030	+0.030
6	Sulfur and lead arsenate (90–10)	2.0	224	2.990	+0.990
7	Sulfur and lead arsenate (90–10)	2.0	108	1.640	—0.360
8	Sulfur and lead arsenate (90–10)	2.0	224	1.800	—0.200
9	Calcium hydrate	2.2	14	1.800	—0.400

The analyses show plainly the variations from the assumed original nicotine content. The apparent explanations for these results are disappearance of nicotine by volatilization and imperfect mixing. We have been informed that the loss of nicotine in such preparations as were used in our experiments is normally rather small, and such being the case, the analyses are chiefly of value in showing the lack of uniformity because of faulty mixing. Attention is especially directed to Samples Nos. 3, 4, and 5 which were obtained from difierent bags of the same shipment and which were supposed to be uniform in strength. The analysis of Sample No. 6 suggests

that a mistake was made in weighing the different constituents of the preparation before grinding or that the mixing was not thoro, which is probably the correct explanation. The deficiency of nicotine in Sample No. 9 indicates either faulty compounding or the disappearance of this constituent thru volatilization.

SUMMARY AND CONCLUSIONS

In the experiments described in this bulletin, spraying and dusting mixtures containing nicotine sulfate were toxic to apple red bugs. The nymphs and adults of both species of red bugs proved very sensitive to treatment. The number of insects in these stages on bearing apple trees were reduced to a large extent by thoro applications of effective mixtures.

In contact with the red bugs, dusting preparations carrying nicotine produced almost instant dislodgment, the larger percentage of the insects dropping quickly to the ground in a paralyzed state from which they rarely recovered.

Dusting mixtures containing 0.25, 0.50, 1.00, and 2.00 per cent nicotine showed marked insecticidal properties. The preparations with the highest amounts of nicotine displayed, on the average, greater killing power and gave more uniformly effective results.

In the treatment of 20-year-old Baldwin trees the dusting mixture used at the rate of 5 pounds per tree was more effective than at a 2-pound dosage. As demonstrated with spraying mixtures, these results show that the amount of protection secured by the treatment depends to a large extent on the degree of thoroness of the application. To destroy the bulk of the red bugs dusting mixtures should be used in liberal amounts and applied carefully to insure thoro distribution and to avoid wasting of materials.

The effectiveness of dusting preparations was uninfluenced, at least to an appreciable extent, by temperatures ranging from 44° to 87° F., by slight dampening by dews or showers, or by freedom of foliage from moisture. Strong air currents made thoro dusting difficult, caused wasteful use of materials, and tended to render applications less effective.

Dusting was most satisfactorily accomplished when the air was still or only slight air currents prevailed. While the data at present do not justify definite conclusions as to the actual merits of the

practice, preference developed during the course of the experiments for the heated portions of the day as the more desirable time for applying dusting materials.

Effective dusting mixtures against red bugs require a larger nicotine content than spraying mixtures, which makes the dosage cost for dusting higher than that for spraying. However, dusting requires less time than spraying and thus effects great economies in time and labor. At prevailing prices for materials dusting is more expensive than spraying.

Derris and tobacco dust applied either in dry state or with lime-sulfur, displayed a high rate of toxicity against red bugs.

Thoro applications of efficient dusting and spraying mixtures protected both foliage and fruit from important injury. As compared with the condition of untreated trees, there was not only a marked reduction in the percentage of affected apples and leaves but the injuries as a rule were of a less severe type.

In view of the data presented, it is concluded that apple red bugs may be effectively controlled by thoro dusting with sulfur and arsenate of lead containing 0.50, 1.0, and 2.0 per cent nicotine.

Dusting apple orchards for sucking insects, it should be noted, is in its first phase and future efforts will doubtless reveal the desirability of modifications in present field practices as well as in the selection and compounding of materials. In attempting to combat red bugs by dusting, it is suggested, tentatively, that in the employment of formulas with low ratios of nicotine somewhat larger amounts be applied than in the case of mixtures with a higher nicotine content. Preparations containing 0.25 per cent nicotine are probably too weak to obtain uniformly satisfactory results, and those with 0.5 per cent or more nicotine should be applied with care to secure effective control of the insects and to avoid high dosage cost. If possible the operations should be undertaken on bright, warm days when the air is still, dusting the trees from opposite sides.

ACKNOWLEDGMENTS

Acknowledgments are due Messrs. Wilson and Jones, Hall, New York, and Mr. S. Malone, Hopewell, New York, who permitted the use of their orchards and assisted in various ways to further the experiments.