duction to the plant pathologists, who are familiar with his many scientific achievements. Some of the members of the American Association of Economic Entomologists, however, may not be so fortunate as to know Dr. Orton personally, and to them I take pleasure in introducing Dr. W. A. Orton, President of the American Phytopathological Society who will preside this morning.

PRESIDENT W. A. ORTON: As retiring president of the Phytopathological Society, I wish to express our appreciation of the invitation from the Entomologists which has brought us together today and to express our convictions that such meetings ought to come more frequently. Perhaps they should have come earlier. It has even been suggested that we in this country have made a mistake in developing two branches of plant pest study and control separately and independently of each other. At any rate, each passing year reveals new points of contact.

We shall discuss today only one phase of the problem of control wherein similar methods are used to combat both insects and diseases. "A Symposium on Dusting as a Means of Controlling Injurious Insects and Plant Diseases" is to be presented.

The first paper will be given by Mr. P. J. Parrott, Geneva, N. Y.

CONTROL OF SUCKING INSECTS WITH DUST MIXTURES¹

By P. J. PARROTT, *Geneva, N. Y.*

The efficient protection of bush and tree fruits involves several factors—the prevention and control of plant diseases, the repression of leaf- and fruit-eating insects, and the destruction of certain haustellate species which are commonly classified as scales, aphids, capsids, etc. It is self-evident that no system aiming to afford protection to fruit plantings satisfactorily meets practical necessities which does not secure adequate control of all three categories of parasites. In considering the merits of dusting as related to orchard management in New York, there has been a great lack of experimental data regarding the value of dusting in combating such insects as San Jose scale, blister mite, green apple aphid, rosy aphid, leafhoppers and redbugs. Although apple scab and codling moth usually levy the largest tribute, the shrinkage in yields due to attacks of sucking insects is by no means insignificant and during some seasons the accumulative losses reach impressive proportions. Certainly, no grower in this state is properly conducting

¹Condensed from a paper presented to the joint meeting of the Association and the American Phytopathological Society at Chicago, Dec. 31, 1920. Typical tests have been selected to illustrate the nature of the investigation and the average results secured.

his orchard operations who fails to make provisions for the control of these pests. Likewise, the neglect of pear psylla, thrips, or the green bug is likely to be attended with serious consequences as is usually manifested by the reduced yields and impaired vitality of the trees. Similar considerations hold true for the grape leafhopper, the currant aphid and four-lined plant-bug, the potato aphid and leafhopper, and the onion thrips. In view of the importance of this class of insects and of the need for information as to their susceptibility to dusting preparations, the Geneva Station began a serious investigation of the problems during the past season. My contribution to this symposium, therefore, deals largely with the more important results of this inquiry.

TESTS WITH VARIOUS FRUIT INSECTS

A series of experiments are here described which were designed to ascertain the effectiveness of dusting mixtures on a number of common sucking insects. The objects which we hope to attain, and which we succeeded in attaining in part, were: (1), Data on the susceptibility of various insects to dusting preparations with definite ratios of nicotine; (2), some knowledge of the efficiency of dusting for the control of certain species under field conditions; and (3), information as to the importance of accessory factors in the effectiveness of dusting operations.

CONDITIONS OF THE TESTS

The following species of insects were used in the experiments: The green apple aphid (*A. pomi* De Geer), the rosy aphid (*A. sorbi* Kalt.), the grain aphid (*A. avenæ* Fab.), the apple leafhoppers (*E. rosæ* L. and *E. unicolor* Gillette), the apple redbug (*Lygidea mendax* Reuter), the pear psylla (*Psylla pyricola* Forster), the currant aphid (*Myzus ribis* L.), the four-lined leaf-bug (*Poecilocapsus lineatus* Fab.), and the potato aphid (*M. solanifolii* Ash.) The dusting preparations were applied with "hand dusters," "hand blowers," or orchard power outfits. A mixture of superfine sulfur, 90 percent. and powdered lead arsenate, 10 percent. was the carrier of the nicotine. In many of the experiments provision was also made for application of liquid insecticides at standard strengths.

SUSCEPTIBILITY OF INSECTS TO DUSTING PREPARATIONS

The Apple Redbug

Experiments with apple redbugs were conducted on June 1 and 2 in an 18-year-old orchard composed chiefly of such varieties as Greening, Hubbardston and Baldwin. This planting had suffered serious injuries for successive years, and at the time of the test over 90 percent. of the

terminal growth of many of the trees was damaged. In Plat I ten Greening trees were dusted with a preparation containing 0.5 percent. nicotine. A little more than fifty pounds of dust were applied and one tree (Tree 1) was very thoroughly dusted. In Plat II seventeen Greening trees were dusted, using from eighty-five to ninety pounds of material. One Greening tree (Tree 2) was given an application of two and one-half gallons of lime-sulfur diluted with one hundred gallons of water to which was added one pint of nicotine sulfate. To insure thorough treatment, twenty-three gallons of the mixture were applied. In the treatment of the individual trees much care was exercised to make thorough applications without any attempt to economize on materials. Fumigation sheets were spread on the ground beneath each tree in order that the redbugs could be collected as they fell. After the first count the trees were shaken quite violently at repeated intervals and after each operation the condition of the insects, whether dead or alive, recorded. The effectiveness of the different treatments is indicated in Tables I and II.

TABLE I—EFFECTS OF DUSTING ON REDBUGS

Condition of Insects	Tree 1 Dusted	Tree 2 L. S. and Nicotine Sulfate	Tree 4 Check
Dead	437	594	14
Living	132	36	317
Total	569	630	331
Percent. living	23.2	5.7	96.7

TABLE II—INFLUENCE OF DUSTING FOR REDBUGS IN PREVENTING INJURIES TO FRUITS

Treatment	No. of Apples	No. Apples Injured	Percent. Injured
Dust, 0.5 percent. nicotine	717	41	5.7 Average
	1682	84	4.9 5.3
Dust, 1.0 percent. nicotine	1349	201	14.9
	2280	198	8.6
	595	26	4.4
	2857	149	5.2
	1266	72	5.7 7.4
Lime-sulfur and nicotine	1228	15	1.2
Check	1120	997	89.0

Redbugs proved very sensitive to nicotine, dusting preparations carrying this ingredient producing almost instant paralysis upon coming in contact with the insects. No difference in rapidity of action or in effectiveness was discerned between the dusting preparations which contained respectively 0.5 and 1.0 percent. nicotine.

The Apple Aphids

The conditions under which the experiments with aphids were carried out may be briefly described as follows: Apple buds infested with newly hatched nymphs of *avenæ*, *pomi* and *sorbi*, principally the former species,

were thoroughly dusted with preparations containing 0.5, 1.0 and 2.0 percent. nicotine. As previous experiments had indicated that there was very little difference between the three species with regard to their susceptibility to the dust, and since the majority of the nymphs belonged to *avenæ*, the counts were made without any attempt to distinguish the different species. The effects of the dusting on the aphids are given in Table III.

TABLE III—RESULTS OF DUSTING AGAINST APPLE APHIDS

Treatment	No. of Buds	Original No. of Aphids	Average No. Aphids per Bud	Percent. dead after 4 Days
Dust 0.5 percent. nicotine.....	40	121	3.02	91.7
Dust 0.5 percent. nicotine.....	32	80	2.5	98.7
Check	32	81	2.56	27.1
Check	17	38	2.2	65.5
Dust, 1 percent. nicotine.....	37	89	2.4	87.6
Dust, 2 percent. nicotine.....	50	107	2.14	97.2
Check	18	42	2.3	47.8
Dust, air-slaked lime.....	53	127	2.4	78.6
Lime-sulfur and nicotine.....	58	120	2.03	97.5
Check	14	25	1.78	60.0

At the time of the opening of the apple buds the extent of infestation by aphids may be greatly influenced by such factors as driving rains, sleet storms, high winds and low temperatures. The reduction in the number of insects on the checks by natural means was considerable in some instances, and it is reasonable to suppose that similar influences operated on the sprayed and dusted series. A study of the data shows that, on the whole, dusting compared quite favorably with spraying in insecticidal efficiency. It should also be noted that a heavy application of air-slaked lime resulted in a loss of 78.6 percent. of the aphids.

One of the interesting results of the season's activities with aphids is that different species are apparently not equally susceptible to dust mixtures with the same nicotine content. The fact that some aphids are more resistant than others was most clearly demonstrated in some tests with *M. solanifolii* and *S. lanigera*, which proved very much less susceptible to treatment than the common apple species, such as *pomi*, *avenæ* or *sorbi*.

The Apple and Grape Leafhoppers

In the experiments against the apple redbugs, to which attention has previously been called, the nymphs of *Empoasca unicolor* and *Empoasca rosæ* proved very susceptible to dust mixtures containing 0.5 and 1.0 percent. nicotine and fell completely paralyzed in large numbers on the collecting sheets. As the control of these species was not contemplated when the work was undertaken, no attempt was made to determine the effectiveness of the treatment in protecting apple trees.

In an experiment with grapes, an application of dehydrated copper sulfate and lime containing 2.0 percent. nicotine destroyed eighty percent. of the nymphs of the leafhopper.

Since the foregoing species are apparently quite vulnerable, a problem deserving serious attention is the value of this system of treatment in combating such insects in commercial plantings of apple and grape.

The Pear Psylla

During the past summer a special effort was made to ascertain the comparative effectiveness of various spraying mixtures and dusting preparations in controlling psylla nymphs. As the results, in general, were quite similar one experiment is selected as typical. On June 3, 1920, a plat of thirty Bartlett trees, about fifteen years old, was sprayed with bordeaux mixture (4-4-100) to which was added 6 pounds of paste lead arsenate and 1 pint nicotine sulfate. Four gallons were applied on the average to each tree. An adjoining plat of sixty trees of the same variety was dusted on the following day with a mixture composed of 50 pounds sulfur, 10 pounds lead arsenate, 5 pounds nicotine sulfate, and 30 pounds powdered tobacco. About $2\frac{2}{3}$ pounds were applied on the average to each tree. Before treatment the nymphs on fifty tagged spurs on each plat were counted, and on the day following the operation each of these spurs was re-examined and the nymphs present recorded. The data are given in Table V.

TABLE V—COMPARATIVE EFFECTIVENESS OF SPRAYING AND DUSTING AGAINST PSYLLA NYMPHS

Material	Nymphs per Spur before Treatment	Nymphs per Spur After Treatment	Nymphs Killed
	No.	No.	Percent.
Bordeaux mixture and nicotine sulfate	42.57	0.30	99.4
Sulfur and nicotine sulfate	41.58	15.92	61.7

In this experiment, as with other similar efforts, the dust mixture killed a goodly percentage of nymphs; but, as compared with spraying, the treatment proved considerably less effective. The nymphs secreted in the axils of the leaves and fruits and, heavily coated with honey dew, displayed the greatest resistance. It was under such conditions that the inferiority of dusting to spraying was most marked.

In experiments with hibernating adults, spraying proved very much superior to dust mixtures as measured by the number of adults dislodged from the trees and the percentage killed by the treatment.

The Currant Aphis and Four-Lined Bug

Mixtures containing 0.5 and 2.0 percent. nicotine produced complete paralysis of currant aphids. With the opening of currant buds it became increasingly difficult to do effective dusting because of the interference of the dense foliage.

Nymphs of the four-lined bug proved very much more resistant to nicotine than the apple redbug or certain species of aphids. Preparations containing 2.0 percent. nicotine caused paralysis, from which none recovered. As with the aphids, dense foliage produced by the new growth made it very difficult to secure effective control by dusting.

PRINCIPAL FINDINGS AND DISCUSSION OF RESULTS

Dusting mixtures containing nicotine were toxic to aphids, redbug, leafhoppers of the apple, the currant aphid and four-lined plant-bug.

The degree of susceptibility to dusting preparations varied with different species. Mixtures with 0.5 percent. nicotine were fatal to the apple aphid and redbug and to the currant aphid. Preparations at this strength also reduced nymphs of the four-lined plant-bug to a state of inactivity, although the insects ultimately recovered with few fatalities. Dusting with mixtures containing 2.0 percent. nicotine was fatal to the nymphs. Mixtures containing less than 2.0 percent. nicotine gave very poor control of the potato aphid. The nymphs of the pear psylla displayed considerable resistance to preparations containing from 0.5 to 2.0 percent. nicotine. Mixtures with 0.5 percent. nicotine destroyed only a small percentage of hibernating adults, and preparations with 1.0 percent. nicotine were less effective than spraying mixtures composed of nicotine sulfate and soap in the usual proportions.

Air currents, denseness of tree growth, low temperatures and exudates of insects, such as wax and honeydew, exerted a greater adverse influence on the efficiency of dusting preparations than on that of spraying mixtures. These results suggest that while certain principles of procedure apply equally well to both systems of orchard treatment, the field technique required for effective dusting differs in important particulars from standard spraying practices. In its present stage of development dusting displays defects both as to methods of application and machinery which will probably be overcome by the corrective processes of experience. A study of present dusting methods shows also that a distinction should be made between obvious limitations of dusting materials and machinery and failures which arise from attempting to dust under conditions that are unfavorable for effective work. In the foregoing experiments operations which proved promising when no breeze was stirring and when the trees had open tops would not infrequently yield quite different results when strong air currents prevailed and the tree growth was dense. The inefficiency of dusting was most marked with the pear psylla and the woolly aphid, as the honey dew and waxy secretions of these insects were repellent to the materials. It was also noted that during periods of low temperature dusting was less effective than when high temperatures prevailed.

Our experiments show clearly that, while dusting has possibilities, it is not wise with our present knowledge and experience to encourage too great expectations as to the practicability of combating common sucking insects by this system of treatment. Growers who possess dusting machinery and do not consider present prices for contact insecticides prohibitive, might well conduct an experiment against the apple redbug. To attempt very large operations against other species of sucking insects would expose the growers to the risk of great expenditures for materials and large losses in fruit yields through inefficient control.

If the data make one point clear it is that dusting for sucking insects is in its first phase. While many failures have been noted in our experiments, we should be ignoring the history of scientific progress if we relied too much on early negative indications. The conservative as well as the constructive view to take is that conditions have passed the stage where dusting is considered wholly impracticable to one where it may be regarded as having possibilities under certain conditions. It remains to be seen whether this system of treatment will enter the realm of practical fulfillment of all the requirements and needs of the commercial orchard. It will take time and money, but it is well worth doing and needs to be taken up by those with special aptitude and necessary funds and equipment.

Improvements in Machine Construction

The conspicuous results obtained by dusting are speed of operation and economy in labor. It is presumed that dusting machinery is in the experimental stage and, if so, improvements will unquestionably be made that will meet the requirements of different field crops and various bush and tree fruits. It is also not unreasonable to hope that for the treatment of large trees outfits will be available which will insure satisfactory distribution of materials without sacrificing speed.

With such pests as redbugs and aphids, effective results will depend on the thorough coating of the insects. In dusting large trees it has been difficult to obtain satisfactory control without incurring large expense for dosage, which appears excessive in comparison with the cost of labor or for like materials used in spraying. In considering the items that enter into this expense, the fact stands out clearly that contact insecticides in powder form now prepared and sold by commercial companies are expensive and almost prohibitive for large operations. On the other hand, with existing types of orchard dusting outfits there is danger of applying excessive amounts to insure thorough treatment, and every pound in excess of actual requirements for effective work multiplies rapidly the cost of the operation. It is evident, then, that

while seeking to reduce the cost of insecticides encouragement should also be given to improving machinery which will insure both thorough and economical distribution and thus produce maximum benefits with minimum dosage. I merely wish to emphasize the practical bearing of this phase of the problem. I have not attempted to suggest modifications, but the improvement of machinery to meet the requirements of different crops needs serious attention.

Chemical Assistance in the Investigation of Dust Mixtures

In considering materials for dusting to combat such insects as aphids, capsids, etc., it should be noted that there is not a wide range of available substances with desirable insecticidal properties. At present nicotine sulfate is widely used, and is certainly the most effective constituent of dust mixtures which function as contact insecticides. A serious drawback to its extensive employment for this purpose is its high cost, and besides it has not always been available in sufficient quantities for commercial operations. The situation reveals a great need of more knowledge concerning the insecticidal properties of other substances, as there are doubtless various organic compounds equal to nicotine in value.

What is true of organic substances holds equally well with inorganic compounds. There is probably a large range of chemical agents which could be prepared in commercial quantities as soon as their properties are known and a need created for them.

Mention is made of these facts in order to focus attention on the promising field that awaits investigation and to emphasize the great need of cooperation between entomologists and chemists. Entomology is greatly handicapped by a lack of chemical assistance. In plans for the development of efficient dusting preparations it is not sufficient to have expert assistance in the quest for new insecticides only. It is also highly important to have technical knowledge relative to the physical condition of the materials used and of the influence of the physical properties on the effectiveness of the substance as an insecticide, since this is dependent upon factors other than its mere chemical composition. The difficulties that beset the dusting problem plead loudly for more constructive efforts along these lines and for a sharpening of the weapons of the entomologist.

CONCLUSION

In conclusion, this symposium, attracting as it does workers from the fields of phytopathology and entomology, constitutes a significant step, probably more important than is generally realized. The discussions should bring up new points of view and yield keener analyses of methods

and policies, and to that extent should promote a sane solution of the problem of dusting for the control and suppression of crop pests. The task is admittedly not a simple one. It is the usual experience, however, that difficulties lessen as we approach them with open minds, show a disposition to be fair, and a determination to reach the result which the facts rather than our predilections require. The collection and tabulation of existing experimental data will form the foundation upon which subsequent progress will be built. We may hope, therefore, that the future will bring order out of the chaos of conflicting opinions which exist with respect to a large field of significant data. The program may seem ambitious, but responsibility for action largely rests with the scientific workers in the two branches of effort. Ours is the task to create a stimulus and arouse an interest which shall bear fruit in practical endeavor.

PRESIDENT W. A. ORTON: Mr. T. J. Headlee will now discuss his experiences with Dusting to control Sucking and Biting Insects, with special reference to the plum curculio and the codling moth.

DUSTING AS A MEANS OF CONTROLLING INJURIOUS INSECTS¹

By THOMAS J. HEADLEE, Ph.D., *New Brunswick, N. J.*

Late in the year 1912 the writer reached the conclusion that the development of powdered arsenate of lead and of finely divided sulfur had reached a point where further experiments on the relative value of dusts and sprays for control of insects injurious to apple and peach should be undertaken. In cooperation with Mr. F. H. Pough of the Union Sulfur Company and Mr. C. D. Vreeland of the Vreeland Chemical Company, a plan for attacking this problem was worked out and at the Cleveland Meetings of this society this plan was gone over and modified by Mr. F. M. Blodgett, Dr. Reddick and Dr. Whetzel of the Cornell Agricultural Experiment Station. This plan involved similar tests in certain of the Experiment Stations of the United States east of the Rocky Mountains, selected from the standpoint of the fruit growing industry. This plan included a test of a dust composed of finely divided sulfur and powdered arsenate of lead as compared with the same materials delivered in suspension in water and as compared with the standard commercial liquid treatments for the crop in question. The idea of

¹Paper 18 of the Technical Series, N. J. Agricultural Experiment Stations, Department of Entomology.