BULLETIN No. 453. DECEMBER, 1918.

New York Agricultural Experiment Station.

GENEVA, N. Y.

EXPERIMENTS FOR THE CONTROL OF THE GRAPE ROOT-WORM

F. Z. HARTZELL.

PUBLISHED BY THE STATION.

BOARD OF CONTROL.

GOVERNOR CHARLES S. WHITMAN, Albany.
COMMISSIONER CHARLES S. WILSON, Albany.
IRVING ROUSE, Rochester.
FRANK M. BRADLEY, Barkers.
CHARLES C. SACKETT, Canandaigua.
ALFRED G. LEWIS, Geneva.
JOHN B. MULFORD, Lodi.
C. FRED. BOSHART, Lowville.
PARKER CORNING, Albany.

OFFICERS OF THE BOARD.

COMMISSIONER CHARLES S. WILSON, *President.*

WILLIAM O'HANLON, *Secretary and Treasurer.*

STATION STAFF.

WHITMAN H. JORDAN, SC.D., LLD., *Director.*

GEORGE W. CHURCHILL, *Agriculturist and Superintendent of Labor.*

REGINALD C. COLLISON, M.S., *Agronomist.*

JAMES E. MENSCHING, M.S., *Associate Chemist (Agronomy).*

†WILLIAM W. BAER, B.S., *Assistant Chemist (Soils).*

JAMES D. HARLAN, B.S., *Assistant Agronomist.*

WILLIAM P. WHEELER, *First Assistant (Animal Industry).*

ROBERT S. BREED, PH.D., *Bacteriologist.*

HAROLD J. CONN, PH.D., *Associate Bacteriologist.*

JOHN BRIGHT, M.S., *Assistant Bacteriologist.*

FRED C. STEWART, M.S., *Botanist.*

WALTER O. GLOYER, M.A., *Associate Botanist.*

MANCEL T. MUNN, M.S., *Assistant Botanist.*

LUCIUS L. VAN SLYKE, PH.D., *Chemist.*

†RUDOLPH J. ANDERSON, B.S.,
ARTHUR W. CLARK, B.S.,
JOHN C. BAKER, PH.D., *Associate Chemists.*

MORGAN P. SWEENEY, M.A.,
OTTO MCCREARY, B.S.,
RICHARD F. KEELER, A.B.,
WILLIAM F. WALSH, B.S.,
WALTER L. KULP, M.S., *Assistant Chemists.*

GEORGE A. SMITH, *Dairy Expert.*

FRANK H. HALL, B.S., *Vice-Director; Editor and Librarian.*

PERCIVAL J. PARROTT, M.A., *Entomologist.*

HUGH GLASGOW, PH.D.,
*FRED Z. HARTZELL, M.A., (Fredonia), *Associate Entomologists.*

HAROLD E. HODGKISS, B.S.,
BENTLEY B. FULTON, M.S., *Assistant Entomologists.*

ULYSSES P. HEDRICK, SC.D., *Horticulturist.*

ROY D. ANTHONY, M.S.A.,
*FRED E. GLADWIN, B.S. (Fredonia),
ORRIN M. TAYLOR, *Associate Horticulturists.*

†GEORGE H. HOWE, B.S.A.,
JOSEPH W. WELLINGTON, B.S.,
WILLIAM C. STONE, M.S.,
EDWARD H. FRANCIS, M.A., *Assistant Horticulturists.*

F. ATWOOD SIRRINE, M.S., (Riverhead), *Special Agent.*

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, *Computer 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.

---

* Connected with Grape Culture Investigations. † In military service.

CONTENTS.

BULLETIN No. 453.

EXPERIMENTS FOR THE CONTROL OF THE GRAPE ROOT-WORM.

F. Z. HARTZELL.

SUMMARY.

The grape root-worm has been the most destructive pest of vineyards in the Chautauqua and Erie grape region during the past two decades.

Previous to the studies herein described, the chief method of control sought the destruction of the adults by arsenical sprays alone or in combination with bordeaux mixture. Two applications during the latter part of June or early July were usually advised.

Owing to the failure of this system of treatment in the hands of many grape growers, the field tests discussed in this bulletin were conducted to determine the causes of failure, and on the basis of this knowledge to devise efficient and practical methods of combating the pest.

Trials of sprays were made in vineyards, the plats being nearly an acre in extent, and no plat was less than five rows wide. The plats to be compared were in the same section, and, with one exception, they were placed parallel to each other. It was necessary to have the plats of the width mentioned in order to avoid error due to the influence of the several treatments on the beetles.

Spraying was accomplished by means of either horsepower or gasoline engine outfits fitted with three cyclone nozzles on a side. The nozzles were set to cover the foliage properly, and, once adjusted to a row, were operated without further change.

It was found that a comparison of yields of plats gave inaccurate data regarding the effect of treatment on the grape root-worm; therefore the numbers of eggs deposited by the beetles on the several plats were compared as measures of the efficiency of the applications. This necessitated taking a sample in each plat. Usually

ten vines were selected in each plat, and the eggs counted. The selection of the vines was made in such a manner as to avoid systematic error of infestation.

Efforts were made to avoid errors in the collection of the data, and the probable error of the mean was calculated for each plat. The probable error of the difference in the number of eggs between two plats was used to determine the degree of certainty that could be placed in the results. Since the number of observations upon which each mean was calculated was rather small, an indirect method of calculating the probable error has been used.

In the field tests during 1910 it was learned that molasses was very attractive to the beetles. Its use with arsenate of lead made a combination destructive to the insects. The development of a practical method of using the sweetened spray and comparative tests of this material with bordeaux mixture and poison were the chief objects of the experiments since 1910.

Two sprayings with bordeaux mixture and arsenate of lead, thoroly applied at the proper time, have given effective control of the grape root-worm. The effectiveness of the spraying is more pronounced when the treatment is continued over several seasons. Failures to combat the beetle satisfactorily are largely attributed to delay in making the applications, allowing too long an interval between the first and second applications, and lack of thoroness due to poor spraying apparatus, dense foliage or spraying in windy weather.

Poison was found to be of importance in the bordeaux mixture.

The use of molasses and arsenate of lead applied at a time when rains did not occur for several days, followed in a week or ten days with bordeaux mixture and arsenate of lead, proved more efficient in controlling the grape root-worm than two applications of the latter mixture.

The addition of molasses destroys the adhesiveness of the arsenate of lead, thus necessitating the precaution of applying the material at a time when the weather conditions indicate that no rain is to be expected for several days. A supplementary treatment should be made in about one week with bordeaux mixture and poison to protect vines from invading beetles.

Two gallons of molasses in each 100 gallons of spray produced better results than one gallon.

A combined spray for the grape leaf-hopper and the grape root-worm was not found practical, owing to the fact that, during the seasons when the tests were made, the periods for effective control of the two insects did not coincide. However, the use of nicotine sulphate with bordeaux mixture and arsenate of lead did not injure Concord grape foliage in any instance.

Glucose was not found to be as effective as molasses with arsenate of lead.

Arsenite of zinc when used either alone or with molasses severely injured grape foliage.

The adults of ***Fidia viticida*** were found to fly with the wind.

During certain seasons the numbers of grape root-worm larvæ were greatly reduced thru the activities of Carabid beetles.

On the basis of the experiments described, two methods of control are recommended: (1) Molasses, 2 gallons, arsenate of lead, 6 pounds, and water 100 gallons, followed in about one week with an application of bordeaux mixture (8–8–100) and arsenate of lead 6 pounds; (2) two applications of bordeaux mixture (8–8–100) and arsenate of lead, 6 pounds at an interval of about ten days. The first system of treatment is especially recommended when the beetles are present in excessive numbers, but the second is advised for general vineyard spraying when beetles are not abundant.

INTRODUCTION.

The grape root-worm (*Fidia viticida* Walsh) has been the most serious pest of vineyards in the Chautauqua and Erie region of New York and Pennsylvania. This bulletin is a detailed account of control experiments conducted against this insect for six seasons. In the beginning of the investigation it was aimed to test chiefly the value of bordeaux mixture and arsenate of lead for the control of the root-worm, but owing to the favorable results obtained with sweetened poison against other insects, tests were also made with this material. During 1910 and 1911 the results with molasses and poison were very favorable, while in 1912 and 1913 the sweetened spray proved much less efficient. In succeeding years, principally during 1914 and 1915, efforts have been directed toward ascertaining the causes of the failures and the conditions under which the foregoing spraying mixtures could be most profitably used. In the course of these investigations supplementary experiments were made both in the field and laboratory, the results of which, because of their practical importance, are presented in this bulletin.

Owing to the fact that biometrical methods have not generally been employed in considering the evidence of field experiments, and as it was desirable to resort to statistical analysis in the interpretation of our data, the application of some of the principles of biometry in this study is briefly considered.

PART I. LIFE CYCLE, HABITS AND IMPORTANCE OF THE GRAPE ROOT-WORM.

LIFE HISTORY AND HABITS.

The grape root-worm is not a worm according to zoological classification, but is the larva of a beetle. The adults (Plate I, fig. 1, Plate II, fig. 2; and Fig. 1) are robust in appearance, and are grayish-brown in color. The beetles vary in size, but average about one-fourth inch in length. In Chautauqua County, N. Y., they appear on the foliage of the grape during the latter part of June or early July, the time depending upon weather conditions. The feeding of the beetles, which produces characteristic chainlike markings on the leaves (Plate II, fig. 3), is most active for about two weeks after emergence. After feeding about a week, the sexes mate, and soon afterwards the females begin laying eggs. Oviposition continues until early August, altho certain belated females may deposit eggs until near the end of that month. The eggs (Plate I, fig. 2) are deposited under the loose bark of the entire vine, except the roots, the majority being placed on the canes. From these eggs, in about two weeks, hatch cream-colored grubs, which are about .04 of an inch in length. These drop to the ground soon after hatching, and burrow until they find the roots of the vine upon which they feed. They are voracious feeders during the late summer and autumn, and usually attain full growth by the last of October (Fig. 2 and Plate I, fig. 3). About this time they burrow to a depth of a foot or more, and form circular cells

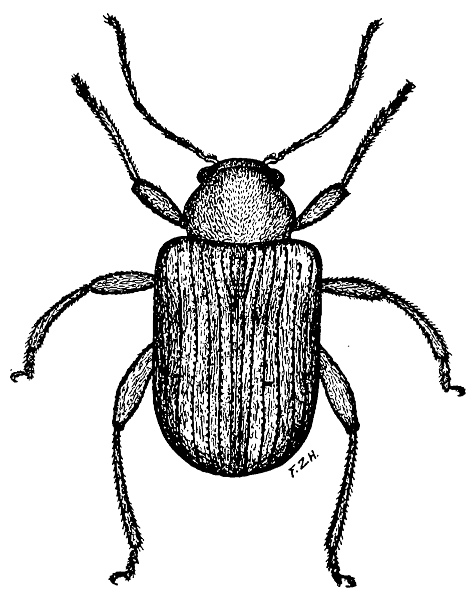


Fig. 1.— ADULT GRAPE ROOT-WORM.
(Much enlarged.)

in which they pass the winter. In the early part of May the grubs leave their winter quarters and crawl nearer the surface. The full grown larvæ seldom feed during the spring — altho undeveloped larvæ do feed — and the early part of June the majority of grubs form cells from four to eight inches beneath the surface of the soil where they change to pupæ (Fig. 3 and Plate I, fig. 4) the first beetles emerging about June 25 in a normal year. The time of appearance of the first adults, which is determined by conditions of season and soil, may be as early as June 17 and as late as July 14. The majority of the beetles usually emerge about a week after the appearance of the first individuals, but during certain seasons there

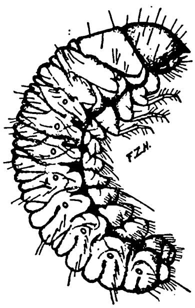


Fig. 2.— Larva of Grape Root-Worm.
(Much enlarged.)

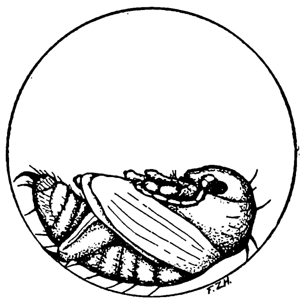


Fig. 3.— Pupa of Grape Root-Worm.
(Much enlarged.)

may be a longer interval. The adults, after mating and laying eggs, die in the latter part of July and early August, altho occasional beetles may be found as late as the second week of September. Rarely an individual will require two seasons to reach the adult state, in which event pupation takes place the second season. A diagrammatic representation of the normal life history is shown in Fig. 4.

ECONOMIC IMPORTANCE.

In the early literature of this species, mention is made of serious damage to vines by the beetles destroying the foliage, but our observations record only a single instance of serious injury to grape foliage. In this case damage was due to the pulling out of a seriously infested section in the spring, so that the beetles emerging during July were forced to concentrate on the nearest vines. The most serious injury to the growth of the vine is caused by the feeding of the larvæ on the small, fibrous rootlets and on the bark and cambium layer of the roots. They channel the older roots and, when present in sufficient numbers, girdle them (Plate III). These grubs thus kill the portions

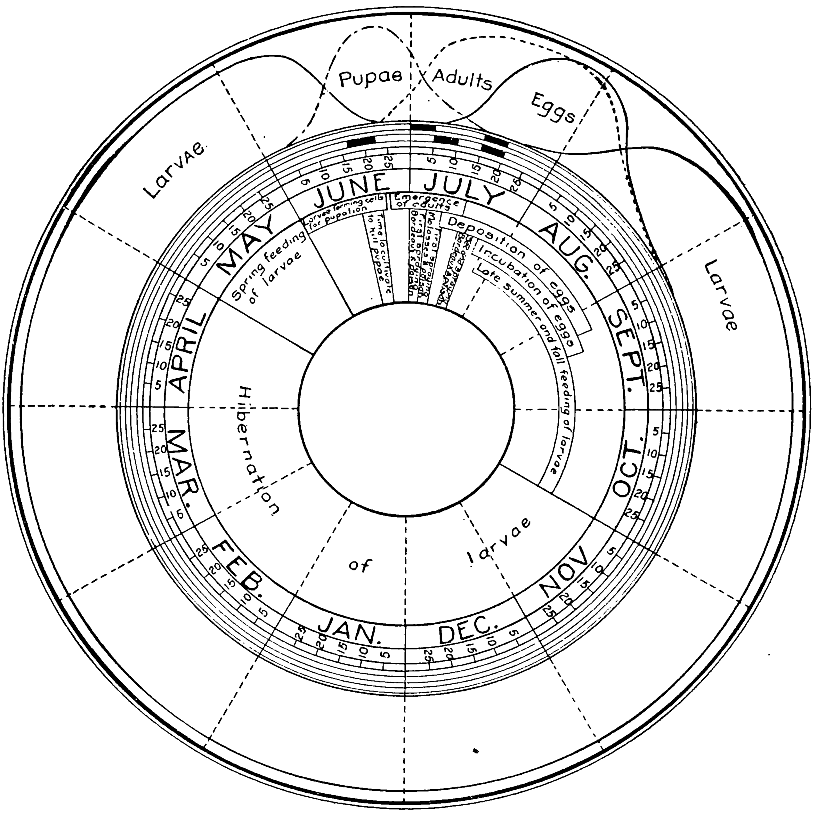


Fig. 4.— Diagram Showing the Seasonal History of the Grape Root-Worm during a Normal Season.

of the roots where absorption of food and water takes place, and also destroy the channels which conduct this material to the main trunk. Often the entire root system is destroyed with a consequent loss of the vine, but *the more usual effect* is to seriously weaken the vine, so that it succumbs to disease or, if it does eke out an existence, produces little or no profit to the owner (Plate V). Occasionally a vineyard is practically destroyed by the beetle, but this is exceptional (Plate IV). The greatest damage that has been done recently in western New York is the weakening of the vines on thousands of acres which has reduced their productive value, and has resulted in great financial losses to owners of such plantings.

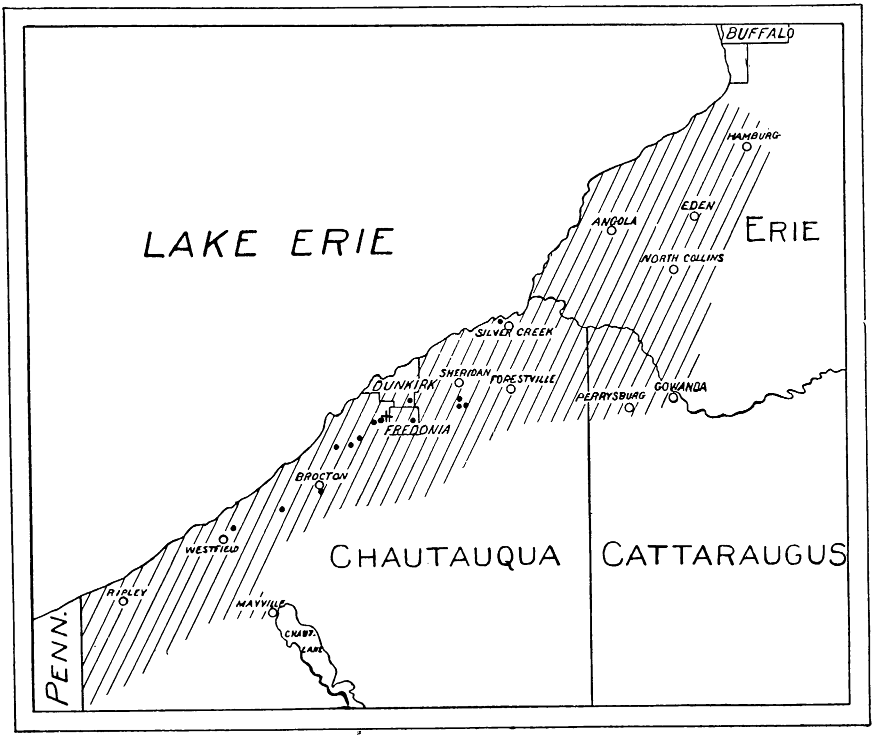


Fig. 5.— Map Showing the New York Portion of the Chautauqua and Erie Grape Region.

The shaded part indicates the area in which grapes are grown commercially but the proportion of tillable soil planted to vineyards varies in different portions of the area. Dots represent the location of co-operative experiments for the control of the grape root-worm. Cross indicates location of Vineyard Laboratory and Station vineyards.

It is estimated that the vineyards in Chautauqua, Cattaraugus and Erie counties total 35,000 acres and over all this area the grape root-worm is present in varying numbers. A map of the Chautauqua and Erie grape belt in New York is shown in Fig. 5. During periods when these insects are very numerous the vineyards suffer considerably from their depredations. It is impossible to state the exact money loss that has occurred in the 16 years from 1900 to 1916, during which time the root-worm has been known to cause serious damage in these vineyards, but it is known that this insect has been an important factor in the decline of the vineyards. If they were present in only 20,000 acres in sufficient numbers to cause a yearly loss of only $5.00 per acre for the 16 years mentioned, it would mean a loss of $1,600,000, or $100,000 annually, to the vineyardists of Chautauqua, Cattaraugus and Erie counties. The actual loss, no doubt, has been several times this sum.

This insect was the cause of so much damage in Ohio vineyards during the 90's, that many growers pulled out their vines, and engaged in other lines of farming.[1] The injuries to vines in Erie County, Pa., has been very serious, for the root-worm seemed to have caused damage here earlier than in Chautauqua County and, since the acreage is large, the monetary loss must have been considerable.

The reasons for the difficulty in estimating the exact amount of grape root-worm injury are the following: (1) Most vineyards have declined because of the destruction of humus without subsequent additions; (2) no system of fertility has been practiced in most of the vineyards which would replace plant food used by the growing vines and this has allowed a decline; (3) the lack of cover crops on the steep hillsides, especially on the shale soils, has allowed much washing of the soil to take place, and many vineyards which formerly were profitable are now in such poor condition that the financial returns are small. How much weight should be given to each of these causes it is impossible to say at present, for each one, together with the root-worm injury, has had an important share in causing the general decline in production which has been so apparent for nearly two decades.

HISTORY OF REMEDIAL MEASURES.

The study of any important pest of a cultivated crop is seldom the result of the investigations and observations of any one person, and generally many workers contribute a share to the solution of the problem. Each worker usually takes up the study where it

[1] Felt, E. P. Grapevine root-worm. N. Y. State Mus. Bul. 72, pp. 9-11. 1903.

was discontinued by his immediate predecessors. The knowledge of the life habits and methods of control of the grape root-worm (*Fidia viticida* Walsh) which we now possess is no exception to this rule.

This insect has been known to science and to vineyardists for more than forty years, and when the author began his investigations in June, 1909, much had been accomplished by other investigators in solving the riddle of the life history and control of this pest. Notwithstanding, the grape root-worm remained the most serious insect enemy of the Chautauqua County vineyards, and grape growers were pessimistic regarding their ability to control it by the methods then recommended. The fact that many growers reported failure to control this enemy, therefore, made necessary experiments to test the practicability of the various methods of control which were advocated and, if possible, to improve them if they were found inadequate. In justice to other workers who have labored with this insect, we will state that much of the failure of the growers to control the pest arose from improper applications of sprays and especially the lack of appreciation of the proper time to make the treatments. Another important cause of failure was the fact that sprayings were not continued over a sufficient number of seasons to secure the cumulative effects that accrue from proper spraying for several consecutive seasons.

The life cycle of the grape root-worm was first investigated and described by F. M. Webster [2] in 1895, who found the insect in injurious numbers near Cleveland, Ohio. From these life history studies it was evident that the most successful method of control would be the prevention of egg deposition on the vines by the adults, and the most practical method to secure this was by killing the adults or by repelling them from the vines. The next step was to devise efficient sprays and ascertain the time of maximum effectiveness of the applications. His remedial recommendations were arsenical sprays to kill the adults. The extensive experiments of Slingerland,[3] Craig,[3] Johnson,[4] and Felt [5] during the seasons of 1902 to 1904 showed that, while in some instances unsatisfactory results were secured, spraying with arsenate of lead and bordeaux mixture

[2] Webster, F. M., Ohio Agr. Expt. Sta. Bul. 62. 1895.
[3] Slingerland, M. V., and Craig, J., Cornell Agr. Expt. Sta., Bul. 208. 1902.
[4] Slingerland, M. V., and Johnson, F., Cornell Agr. Expt. Sta., Bul. 224. 1904.
[5] Felt, E. P., N. Y. State Mus. Bul. 59, 1902, and Bul. 72. 1903.

proved to be an efficient method of preventing oviposition by the adults. Felt also recommended cultivation during June to kill the pupæ as well as collecting the adults by beetle catchers.[6] The experiments of Johnson and Hammar,[7] 1906–1909, also proved that arsenate of lead with bordeaux mixture will control the pest if the remedy is continued over several seasons.

When the author began the entomological work at Fredonia, in June, 1909, the root-worm beetles were rather scarce in all vineyards which it was possible to visit in the short period between emergence and the proper time to spray, and so attention was directed to life history studies of this and other insects that attack the grape. During that season, talks with numerous growers all pointed to the fact that most of them doubted the efficacy of the bordeaux-arsenate of lead spray for the control of the grape root-worm. The existing situation pointed clearly to the fact that well planned and long-term field experiments were necessary before any definite progress could be made in the solution of such a difficult problem. The experiments soon revealed the fact that considerable variation in effectiveness is to be expected with most spray materials used against the grape root-worm. Bordeaux mixture and arsenate of lead in combination are usually effective when properly applied, but dense foliage and wind often make it extremely difficult, even for expert workers, to thoroly spray a vineyard. Under such conditions the number of beetles may not be sufficiently decreased in one season to encourage the average grower to continue the practice. The failure to overcome these difficulties largely accounts for the reluctance of vineyardists to resort to spraying in an effort to keep the pest under control.

A mixture of glucose and arsenate of lead was used in Chautauqua County against the rose chafer with excellent success during the early part of June, 1910. Similar experiments against the grape root-worm seemed to produce rather poor results; for which reason molasses was substituted for glucose in all subsequent experiments.

During six seasons, from 1910 to 1915 inclusive, experiments were conducted with both the bordeaux mixture-arsenate of lead and molasses-arsenate of lead combinations; also with other insecticides with the object of securing the most efficient control of the

[6] Felt, E. P., N. Y. State Mus., Bul. 72, pp. 34–38. 1903.
[7] Johnson, F., and Hammar, A. G., U. S. Bur. Ent., Bul. 89. 1910.

grape root-worm. In the course of these efforts it was learned that the effectiveness of molasses and arsenate of lead depended to a large extent upon the condition of the weather following the spraying. Rains were found to wash much of the material from the foliage, which subsequent studies showed was due to the fact that molasses practically destroys all the adhesive properties of arsenate of lead. In spite of this reaction it was considered desirable to test still further the poison bait since, under certain conditions, it possesses desirable properties.

The dispersion of the adults during the period of oviposition proves also to be an additional disturbing factor in the control of this pest. It was found that vines sprayed with molasses and arsenate of lead were frequently freed from the beetles which were present at the time of spraying, but if rains followed the application within a week, the arsenical was washed off the foliage, thus leaving the vines exposed to attack. Frequently beetles reinvaded such a planting and in spite of the treatment would lay many eggs. To provide against this contingency it was found necessary to supplement the sweetened spray by a treatment, about one week after the application, with bordeaux mixture and arsenate of lead to repel all immigrating beetles. This work features prominently in the experiments of 1914 and 1915.

PART II. METHODS OF EXPERIMENTATION AND COLLECTING OF DATA.

OBJECT OF FIELD TESTS.

The first aim of the field trials with the insecticides, which are later described with considerable detail, was to compare the number of eggs laid by the beetles in a plat treated with a certain combination with the number deposited in the plats receiving no treatment, or sprayed with various miscellaneous mixtures. Then again it was desirable to determine the practicability of using the various mixtures under field conditions considered from the standpoint of their action in the sprayers, and possibility of uniformly covering the foliage to insure control of the pest. The ultimate object in all of these activities was to determine which system of treatment gave the best results against the root-worm.

NATURE OF EXPERIMENTS.

All the experiments described in this bulletin, except the tests dealing with the question of adhesiveness, were made in commercial vineyards, and the material was applied with fixed nozzles attached to either a horse-power sprayer or a gasoline engine outfit (Plates VII and VIII). A few of the tests were carried out in the Station vineyards, but the majority of the trials were conducted in vineyards of private owners. In the latter the experiments were made on a co-operative basis. The Station contributed the spraying materials and assistance in the application of the spray, while the grower furnished the sprayer, team, driver and mixing receptacles. In a few instances the owner furnished the spraying materials but asked for direction in the application of the materials. Because of the expressed desire to determine on their own premises the worth of the different mixtures, these vineyardists permitted the writer to plan the necessary test plats.

SIZE, SHAPE AND LOCATION OF PLATS.

The usual size of the sprayed plats was approximately one acre. To be exact, in the majority of cases, it was the area of the vineyard that was sprayed with the contents of a 100-gallon spray tank. The check plat was usually as large as a single sprayed plat. On the Station vineyard the plats were occasionally only one-half acre in extent. The width of the plats varied in the different vineyards owing to the variation in the lengths of the rows. In the Chautauqua and Erie grape belt the vineyards are divided into sections, each row averaging nearly fifty vines and of a length of four hundred to five hundred feet, depending on the distance between vines. Frequently the rows were shorter or longer than the measurements given. Naturally, the longer the rows the less the number necessary to furnish the desired area, and thus the widths of the acre plats varied slightly. The writer deems it necessary to have plats at least five rows wide but even wider plats are desirable. The object of having moderately wide plats is to avoid — at least as far as possible — the attractive or repellent effects of the material of one plat on the beetles of a neighboring plat. On the other hand, if the plats are too wide, the variation in the infestation from one side of the section to the other may introduce a systematic error.

THE QUESTION OF CHECK PLATS.

The idea of a check or control test or, as it might be called, a blank test in an experiment is in common use in chemistry, field tests of fertilizers, and spraying for fungous diseases and insect pests of plants. Since such experiments usually consist of a comparison between treated and untreated portions of the material, the check is an essential part of the experiment. A blank test to be of greatest worth must not be influenced even in the smallest degree by the other portions of the experiments, or its value is decreased. In a chemical experiment or a test of fertilizers, especially on level ground, this desideratum is usually attained satisfactorily because exterior conditions influence all plats alike. The greatest difficulty to be considered in such experiments is the variability of the chemicals, or the soil. With certain plant diseases, like powdery mildew of the grape, if the disease has become established before treatment is applied, one can determine the uniformity of the infection and treat certain plats, leaving others, having the same amount of the fungus, untreated. With all these apparently uniform conditions some variation in results is unavoidable in plats treated alike, due to a number of causes, such as impurity of fungicidal materials, lack of uniformity in the plats, errors in determination of the results, etc. The economic entomologist, who is experimenting in the control of flying insects, has to contend with all these factors, and in addition he is confronted with another difficult problem; as the insects may move from treated plats to the untreated plats in case a repellent is used, or from the untreated plats to treated plats when a strongly attractive substance is applied near enough to the check plat to exert such an influence. If the material is neutral, so far as attractive or repellent properties are concerned, but is toxic, then as the insects die off in the sprayed plats those on the check plats would have a tendency to spread into the sprayed plats. In any event, the number remaining on the check plat at the end of the experiment would not be the same as at the beginning. Thus the value of the blank test is marred, and conclusions drawn from such experimental data are incorrect to the degree that the disturbing influences exist, unless due allowance has been made for them. These difficulties are hard to overcome, and one of the problems confronting the author has been to provide for satisfactory checks in the efforts to secure control of the grape root-worm.

If bordeaux mixture and arsenate of lead are used on one plat and the spray applied so thoroly that scarcely a leaf remains uncovered, and the adjoining plat is untreated, the beetles, if they are repelled by the material, will leave the sprayed vines, and fly to the checks. In the Chautauqua region this is even more apt to occur if the untreated plat is to the east of the treated plat, owing to the insects flying with the wind and to the prevailing winds being from the west and southwest. In such an instance the difference between the number of eggs on the two plats would not be a true index of the destruction of the beetles on the sprayed plat, but would only indicate to what extent they were driven to the check plat. On the other hand, if molasses and arsenate of lead were used on one plat, and the beetles were attracted to this material, and there is good evidence that this is true, the adjoining unsprayed plat would suffer diminution in numbers. Even tho all such migrating insects were poisoned before they laid eggs, the difference in number of eggs in the two plats would not truly indicate the efficiency of the molasses spray.

While we are convinced that, on the warmer days at least, the molasses does attract the beetles, the proof that the bordeaux mixture repels the insects is not so positive. When foliage sprayed with the latter mixture and unsprayed foliage are placed together in a cage with a number of the beetles, the insects feed on the unsprayed leaves, and avoid those that have been treated. Examinations for six years of the ground beneath vines sprayed with this mixture have revealed only two dead beetles, even tho at times sheets have been placed under the vines to facilitate observation of the dead insects. At the same time dead beetles were found in considerable numbers under the vines sprayed with molasses and arsenate of lead in the same vineyards. As a rule the beetles disappeared from the vines properly sprayed with either mixture, provided, in the case of the molasses spray, suitable weather followed the application. The apparent repellent effect of the bordeaux mixture and arsenate of lead was most marked on vines whose foliage was most thoroly covered. What becomes of those beetles from the bordeaux-sprayed vines? The facts would seem to indicate that they were repelled and flew to the unsprayed vines or to those sprayed with the molasses-arsenate of lead combination. On the other hand, some observations that make the author reluctant to accept this conclusion are as follows: (1) In all the experiments conducted during the past five seasons, in every vineyard in which a low egg count was secured on the vines sprayed with bordeaux mixture, no matter how severe the infestation previous to spraying, the count on the check plat was lower than in a similarly infested vineyard which had received no spraying; (2) in all vineyards where the spraying was not properly applied, on account of poor apparatus or heavy foliage, or was applied too late in the season, the number of eggs on the check plat was high; (3) in 1914 a vineyard in which no spraying had been done and where the surrounding vineyards had not been sprayed, and one also in which the amount of feeding would not indicate that more beetles were present than in many of the vineyards in which experiments have been conducted, the egg count was likewise high, and was — mark the point — about the same as was secured in the improperly sprayed vineyards.

Weighing everything, we believe the following conclusions are warranted: (1) The bordeaux mixture and arsenate of lead in combination have a decided influence on the unsprayed adjoining vines, either thru killing a considerable number of the insects which might migrate to the sprayed plants or by a repellent action exerted over a considerable space. (2) The egg-counts on the various check plats minimize the effects of spraying both on the plats sprayed with molasses and poison and those sprayed with bordeaux mixture and poison.

SPRAYING APPARATUS USED IN VINEYARD EXPERIMENTS.

In commercial vineyards in western New York, the vines are planted in rows, and are trained on wire trellises (Plate VI). The rows are rarely closer than eight, and seldom more than ten feet apart. The various types of vineyard sprayers in common use have been built to meet these demands. All spraying can be done automatically; i. e., the nozzles are arranged so that the spray is delivered to the vines without the necessity of a person directing the nozzles as is done in orchard spraying. Generally the operator need only to drive and see that the nozzles are not clogged with foreign material. To avoid this difficulty usually requires little work if the tank was clean when filled, and if the spray materials have been properly strained. With an abundant water supply near the vineyard and proper equipment for filling the tank, it is possible to spray thoroly from eight to ten acres of vines in ten hours.

TYPES OF SPRAYERS.

Sprayers adapted for vineyard work may be classified in several ways: viz., two-wheeled and four-wheeled, engine, compressed air and horse power (Plates VII and VIII), the latter frequently being listed under the caption "geared" or "traction-sprayer." The two-wheeled outfits are better adapted to ordinary vineyard conditions than four-wheeled machines, because of the ease of turning at the ends of the rows. Most vineyardists desire to plant as much ground as possible, leaving only sufficient room at the ends of the rows to turn with the ordinary vineyard machinery and wagons. This space is generally too small for the longer four-wheeled sprayers, altho some of the latter are now being constructed to allow short turning. These four-wheeled outfits have one distinct advantage in that they are easier on the necks of the horses than many of the two-wheeled rigs.

The gasoline engine sprayer is an excellent outfit for vineyards because the required pressure can be maintained independently of the progress of the machine, and this is a very important consideration, especially when the foliage is dense. Fairly high pressures are required for efficient spraying against the grape leaf-hopper. With the "geared" sprayer slow driving usually allows the pressure to decrease. Again, the use of engine sprayers is warranted and is highly desirable on farms where both vineyards and tree fruits are to be sprayed, since the one outfit will serve both purposes. The disadvantage of the engine sprayer where vineyards alone are to be sprayed is the fact that they are more complicated and more likely to get out of order than geared sprayers. This is especially true when we must depend on a poor grade of farm help. The additional first cost and the expense for gasoline and oil should also not be overlooked. Good "geared" sprayers are less liable to get out of order and for ordinary vineyard spraying are more satisfactory in the hands of most grape growers. It is for this reason that fewer coöperative vineyards have been sprayed with gasoline engine sprayers than with "traction" sprayers. All outfits should have pumps that can be readily packed, and the intake should be such as will avoid allowing gritty particles to enter the pump, thus making the packing live longer. In fact, the ideal sprayer for vineyards has not been built at this date, and a grower who is planning to buy an outfit should examine carefully the merits of the various machines, and select the one that most nearly suits his conditions.

PRESSURE.

A pressure of 100 to 150 pounds per square inch has been used in practically all experimental work. This has proved sufficient to produce a driving spray that would coat uniformly both foliage and fruit, at least all that was possible to cover with fixed nozzles. It is doubtful whether higher pressures than those given are necessary. A pressure under 100 pounds will give poor results.

NOZZLES.

The nozzles should deliver a spray coarse enough to thoroly cover the foliage without producing large drops or dripping (Plate IX, fig. 2). The very fine mist-like spray usually recommended is very difficult to force to the under portions of the vines, especially if a light wind is blowing, which usually occurs in regions bordering on the Great Lakes. For this reason most vineyardists are using the cyclone type of nozzles which are fitted with steel discs (Plate II, fig. 1). These discs can be secured with apertures of different sizes which allow the vineyardist to vary the fineness of the spray according to circumstances. In general, the rule is to use as fine a spray as can be properly applied under the weather conditions at the time of spraying. The attention of growers should be called to the various types of cyclone nozzles which have a sieve in the interior. We have found these excellent for vineyard spraying as they prevent clogging, thus avoiding the stopping of the team in the rows where the horses are apt to break off shoots and fruit while the driver is cleaning the nozzles. These nozzles, however, should be examined a number of times especially at the beginning of spraying, for the sieve may become fouled and thus the pressure in the nozzle will be greatly decreased. As the examinations can be made at the ends of the rows, much loss of time and injury to vines can be avoided.

ARRANGEMENT OF THE NOZZLES.

In commercial vineyards the trellises vary in height, but are seldom higher than five feet or lower than four feet. Spraying to control the grape root-worm necessitates the covering of the upper surfaces of all the foliage with the spray material. Such a standard of thoroness is perhaps never completely attained, but in practice sufficiently thoro spraying consistent with the cost of application can certainly be secured by means of three stationary cyclone nozzles on each side of the sprayer. Thruout this bulletin, where spraying experiments are described, this arrangement of the nozzles is to be assumed unless otherwise specified. The elevation and direction of the nozzles will vary with the height of the vines, the direction of the wind and the arrangement of the vines on the trellis. With the Chautauqua or arm system of training, in which the vines are not more than five feet in height, the lower nozzle should be not over eighteen inches, the middle nozzle about forty-two inches and the upper one between five and six feet above the ground. The upper nozzle should be carried from the sprayer about one foot by means of a pipe, so as to insure thoro treatment of the highest foliage. The proper arrangement and direction to point the nozzles are shown in Plate VIII, fig. 2. All nozzles should be connected in such a manner as to allow independent and quick adjustment in height and direction.

It often becomes necessary to make numerous changes in the same vineyard owing to varying heights of vines, and especially on account of the wind, which frequently necessitates a change in direction of the nozzles on each return trip if the best results are to be secured. *It is always best to spray during a calm* period, but where a large acreage is to be treated it often happens that a part of the spraying must be done under less favorable conditions if the work is to be completed at the proper time.

THE METHODS OF DETERMINING THE RESULTS OF EXPERIMENTS.

LACK OF CORRELATION BETWEEN YIELD AND EFFECTIVENESS OF TREATMENT.

The method of arriving at a true estimate of the efficiency of the various practices of spraying should be one that yields exact results under different conditions of soil, fertilizer and cultivation. These variations in a vineyard do not influence the results of a system of spraying, and therefore the data secured should be free from such disturbing factors. Any method of collecting data that does not avoid such influences is logically wrong. We believe that one of the most uncertain methods in attempts to secure exact data regarding the effects of spraying operations for the control of the grape root-worm is to measure or weigh the crop from sprayed and unsprayed vineyards, because it is very difficult to find a vineyard in which uniformity exists regarding (1) the soil, (2) previous cultivation, (3) fertilization, especially manuring, in the past, (4) present cultivation, and (5) present fertilization. Each of these factors influences the yield to a more or less marked extent. These considerations carry greater weight when we realize that, in order to get exact results, rather large areas must be used as plats, the reason being that the movement of the beetles, especially at the period of dispersion, is apt to cause considerable variation unless the plats are of fair size. When plats of one-half acre or more are used, the variations in the yield of the several plats, *even should there be no variation in infestation by the grape root-worm*, is apt to be very large because of the foregoing factors. This fact is illustrated by the data secured in the Lowell vineyards during 1910, as shown in Table I.

TABLE I.— NUMBER OF EGGS OF *Fidia viticida* AND YIELDS OF THE SEVERAL PLATS DURING 1910 IN VINEYARD OF S. J. LOWELL, FREDONIA.

Plat.	Material used.	Average number of eggs per vine.	Yield per acre.
	Section 1:		*Lbs.*
3	Not sprayed	81.2	2,904
4	Arsenate of lead, 6 lbs., glucose, 20 lbs., water, 100 gals.	87.6	2,118
5	Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	38.4	1,694
	Section 2:		
1	Not sprayed	140.4	1,089
2	Arsenate of lead, 6 lbs., glucose, 20 lbs., water, 100 gals.	88.4	1,331
3	Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	22.8	1,997

The two sections were widely separated. In each section the soil and vines appeared to be as uniform as one is apt to find in most vineyards. The plats were approximately one acre each, and the infestation by the grape root-worm was quite uniform before spraying. The results of successful control would not show in the yields until the second or third season following the treatment. A study of the data in Section 1 emphasizes the following facts: (1) There was a wide but rather uniform variation in yield as one passed from plat 3 to plat 5; (2) the vines showing the smallest deposition of eggs also gave the poorest yield. Since there was no injury to the vines from the material applied, and especially since bordeaux mixture is known to have an invigorating effect on grapes, this section is a striking example of the unreliability of data from yields of different plats. Section 2 illustrates the same facts, altho here the vines showing the smallest number of eggs produced the highest yields, regardless of the fact that the effect of the treatments could not affect the yield until another season. Experiments which chanced to have such coincidences would be liable to bias an experimenter unless he had a sufficient number of tests to bring out the fallacy, as is clearly apparent in Section 1.

Unfortunately, the experiments for the control of *Fidia viticida* cannot be continued over more than a few years in the same vineyard owing to the changing conditions in the number of insects due to several reasons mentioned previously (page 271), and so the yields do not tend to become equal in the several plats receiving the same treatment, as is true in a fertilizer experiment continued over a period of years. The realization of these conditions has caused the author to abandon the practice of weighing the crop on plats sprayed to control the grape root-worm.

NUMBER OF EGGS DEPOSITED AN INDEX OF THE EFFECTIVENESS OF TREATMENT.

Inasmuch as the act of spraying is undertaken to prevent oviposition by the beetles, so that the roots of the vines may be protected from the larvæ that would hatch from the eggs, the most logical and practical method of determining the effects of the various mixtures on the insects is to count the number of eggs on sprayed and unsprayed vines.

MANNER OF SELECTING SAMPLES AND ESTIMATING NUMBER OF EGGS DEPOSITED.

It is an impossible task to count all the eggs laid on the plats, and so a sample is taken by selecting on each plat a certain number of average vines of approximately the same vigor, age, and variety, and having — as near as can be judged from the condition before the spraying was done — the same degree of infestation as the vines in the other plats, and the eggs are estimated as described subsequently. The vines are selected on the row extending thru the middle of the plat in order that the influence of the adjoining plats may be reduced to a minimum, and to avoid bias in selection, consecutive vines are taken. Owing to the fact that systematic errors of sampling extending lengthwise with the plat may be present, the vines counted on all the plats are in the same cross section (Fig. 6).

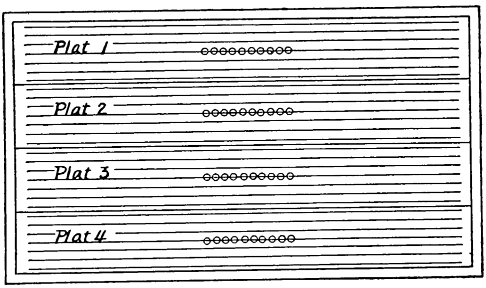


Fig. 6.— Diagram Indicating the Method of Selecting Vines for the Counting of Eggs of Grape Root-Worm.

After a vine has been selected for egg counting, the loose bark is carefully stripped and as each piece is removed, the egg clusters are sought, and the number and size are communicated to the note keeper, who records each observation in the proper column. Here another difficulty confronts the experimenter, for the eggs are small, and, being laid in clusters, are difficult to count except with the aid of a microscope, and to do this would require more time than can be afforded inasmuch as the eggs on several hundred vines are counted each year, and the work must be done in about two weeks, owing to the early hatching of the eggs. Therefore the number in each cluster is estimated as follows: A cluster having ten eggs or less is noted in a column marked "small," one having more than ten and not over thirty eggs is placed in a column headed "medium," and a cluster having more than thirty eggs is designated "large." In estimating the number of eggs we have used the arithmetical mean of the limits of the group except for the large clusters. Thus the numbers of eggs used are five for small clusters and twenty for medium clusters. In deciding upon the number of eggs to be used for the large clusters, we find that while a few clusters may have as many as seventy eggs, the greater number lie between thirty and fifty, and for this reason it was decided that forty eggs would be a fair average. The method of estimating the eggs as just described introduces a few errors which will be discussed in the chapter on errors. In a large number of doubtful clusters, before deciding upon the number of eggs to be used as averages for the different groups of clusters, counts of the individual eggs were made.

In estimating egg clusters, it was possible to note all hatched and parasitized clusters by their appearance, and these were recorded. The clusters found on the canes or new wood were separated from those found on the old wood such as the trunk and arms.

PART III. SOURCES OF UNCERTAINTY IN RESULTS AND STATISTICAL INTERPRETATION OF DATA.

DIFFICULTY OF INTERPRETATION OF DATA.

Since the object of experiments like those described in this bulletin is to secure methods for the control of insects with the idea of recommending them to the farming public, it is very important that the experimenter exercise considerable caution in the interpretation of his results. In fact, the data should have a high degree of precision, if recommendations are to be based upon them, for the average fruit grower, in attempting to follow the method of the experimenter, may not approach very closely the conditions under which the field tests were conducted, and unless the method is one in which considerable latitude is possible, he may suffer financial loss. For these reasons we are compelled to consider the causes of the uncertainty attached to the meaning of the data, and to find methods of increasing to a maximum the extent of reliability in the conclusions deduced from experimental results.

The plan of the ordinary spraying experiment is simple, and it might seem that, after the data have been collected, there could be no difficulty in determining which treatment would prove the better under general field conditions. The element of uncertainty, however, is due to the impossibility of predicting the exact result that would be obtained if the tests were repeated under similar conditions. To put the matter in another form, if a second experiment were made under conditions resembling those obtaining with the first experiment, what reason have we for believing that approximately the same results will be obtained?

FACTORS WHICH CAUSE AMBIGUITY IN THE MEANING OF EXPERIMENTAL RESULTS.

An examination of the data from plats which, apparently, are subjected to the same environment, will show considerable differences between two plats, which might be expected to yield the same results. Further, if we select an unsprayed vineyard which is apparently uniform in all respects, and count the number of eggs on ten consecutive vines, the number of eggs on no two vines will be alike and — of more importance — the differences in the number of eggs on the several vines will vary considerably. Even adjoining vines will differ markedly in the number of eggs. This is clearly shown in Table II, the data of which were taken on ten apparently uniform vines which had not been sprayed.

TABLE II.— VARIATION IN INFESTATION OF TEN PLANTS APPARENTLY UNIFORM AS TO CHARACTER AND EXTENT OF GROWTH.

(Vines grown in same row in the order as listed.)

Vine.	Number of eggs
1	700
2	975
3	555
4	1,085
5	750
6	485
7	435
8	830
9	470
10	420
Average	671

Differences like those just shown and also the ambiguity attached to all experimental data may be due to one of three causes (or to a combination of all of these); namely, lack of homogeneity in the material under experimentation, errors involved in the securing of data and variation due to casual and undetermined factors. Attention is now directed to the problems arising from each of these factors.

HETEROGENEITY OF THE MATERIAL UNDER EXPERIMENTATION.

An analysis of any series of values will not be correct unless the material from which the data were collected was homogeneous; e. i., all the material must belong to the same race or variety and must be affected by the same environment. In technical language, it must belong to the same "universe." It is fundamentally important that the vineyard in which the field tests are to be made be uniform as regards variety of grapes, age and vigor of vines, soil, topography, cultivation and insect infestation before the spraying is done. Obviously, comparisons of results of tests could not be made with any hope of accuracy unless such conditions were approximated.

It may seem trite to mention these facts, but in reality the most difficult phase of experimentation for the control of the grape root-worm, or of any insect pest, is to secure uniform areas, and to detect systematic errors that may be present. Since the data are taken after the experimental treatment has been made, it is only by careful observation that the worker can judge of the extent of the uniformity previous to treatment. After the data have been taken, examination should be made for systematic errors of sampling, and, if possible, the proper correction should be made. The manner of applying the corrections is discussed under systematic errors.

The usual method of overcoming heterogeneity is to duplicate the experiments in other vineyards and during different years. If the results of treatment in a number of vineyards are consistent, we can feel assured that differences are not due to lack of uniformity in the material under experimentation.

ERRORS IN THE SECURING OF DATA.

The difference between the true value of a quantity and the observed value of the same quantity is an error. If a determination is higher than the true value, the error is plus; if lower than the true value, the error is minus. Experimental data may be affected by errors from a number of sources and, as it is important that the experimenter investigate the causes of error that may occur, a brief discussion of the several kinds of error is given.

The errors that might influence our data are grouped into three classes: systematic error, errors of measurement, and error due to normal variation in the material under investigation.

SYSTEMATIC ERROR.

If the values determined thruout an experimental area tend to decrease or increase as one goes from one end of the area to the other, or from one side to another, the material is affected by a systematic error. In field trials for the control of insects, this error is very apt to be present, is one of the causes of heterogeneity, and is one of the chief reasons for the lack of confidence that can be placed in trials in a single set of experiments.

In spraying tests for the control of the grape root-worm, this error was present in a number of the vineyards used, but fortunately in the majority of them the decrease in the number of insects was in the direction of the rows, and was the same on the several plats used. Under such conditions it was a simple matter to neutralize the effects of systematic error. As described on page 278, the vines selected for the counting of the grape root-worm eggs were — except in one vineyard — all taken in the same section across the plats. As this section was usually at right angles to the rows, the vines in one plat averaged the same distance from the end of the row as did those of any other plat, and so any systematic error lengthwise of the vineyard affected all plats alike, and comparisons of averages taken on the different plats would be free from any influence from this source.

When the systematic error extends across the plats, the effect on the data is more serious. This is the form of error that is most liable to affect and vitiate conclusions. In the event of the original infestation being affected with this form of error, comparisons of treatments are unreliable unless the proper corrections can be made, since the beneficial effects of a treatment may appear to be more or less than is really the case, depending on the direction of the decrease of insects.

Another form of systematic error may be introduced by having the plats too narrow or by selecting vines for egg counts which are separated from the remaining vines by missing plants. Competition between plats or plants subjected to a different environment has been found to be the source of important errors in crop experiments.[1] To avoid such error, the plats were never less than five rows in width in all spraying experiments, the central row was always selected for the collection of data, being farthest removed from the influences of adjacent plats, and the vines chosen were in the midst, at least as far as possible, of a uniform stand as regards position and vigor.

There are three general methods of compensating for systematic error: (1) Duplication and reversal of plats of the same size in the same vineyard, and taking of an average between plats treated alike;

[1] Kisselbach, T. A., Studies concerning the elimination of experimental error in comparative crop tests. Neb. Agr. Expt. Sta. Research Bul. No. 13. 1918.

(2) the use of a number of vineyards in which the experiments are repeated; and (3) continuing the experiments either in the same or other vineyards over a series of years. Of these methods we have used the two latter the most extensively. The size of the plats necessary for grape root-worm experiments, the number of trials desired and the fact that the uniform vineyards at our disposal were usually of small acreage have prevented the use of the first method generally, altho it was used in several vineyards during 1914 and 1915. During all our field trials we have taken the greatest pains in selecting the section for egg counts where we believed systematic errors to be very small.

ERRORS OF MEASUREMENT.

In securing the data discussed in this bulletin, the only sources of *error of measurement* were personal errors, such as errors in counting, errors in the recording of data, and errors in estimating.

Errors in counting.— In counting the number of egg clusters of the grape root-worm on a vine, the smallness of the clusters and the liability of their becoming detached from the bark as it is removed, tend to cause some of the clusters to be missed in the counting. This error is cumulative for it tends in one direction only; namely, to indicate a lower number of eggs than was on the vine when the count was made. It is also certain that some men will exercise more care in searching for the eggs than others. We have attempted to avoid the influence of this error in the comparisons of the different plats by using the same men to count the eggs on the plats to be compared, thus probably securing errors in each plat which are proportionate to the number of clusters counted. We assume that each man has a tendency to commit the same proportion of errors on one plat as on another. Thus we hope to have reduced the error in the comparison to a minimum.

Errors in recording data.— The source of this error is the notekeeper's misunderstanding the kind of cluster found by one of the workers, and also thru blunders; in either event, the notekeeper places the data in the wrong column. To avoid these errors, the notekeeper was required to announce the kind of cluster recorded.

Errors in estimating.— There are two errors involved in estimating the number of eggs on a vine: the error in estimating the size of the cluster and the error introduced by assuming that the arithmetical mean of the upper and lower limits of the class multiplied by the number of clusters gives the exact number of eggs in each class.

We believe the errors in estimating the size of the cluster are compensating. In other words we are of the opinion that the chances are even that the number of clusters having more than 10 eggs, which chance to be classified as "small", will equal the number having less than 10 eggs which happen to be classified as "medium." The eggs in all doubtful clusters were counted under the microscope. This not only assisted the judgment of the men but, we believe, it reduced the errors of estimation to a minimum.

The assumption that the arithmetical mean of the two extremes of a class multiplied by the number of clusters in the same class gives the correct number of eggs, perhaps introduces an error because the distribution of the frequencies may be skew, in which event the mean and median do not coincide. We have not investigated this sufficiently to determine the extent of the error, which appears to be small, nor the direction in which it tends.

VARIATION DUE TO CASUAL AND UNDETERMINED FACTORS.

If it were possible to select a vineyard in which no systematic error existed in regard to vines, soil or infestation, and at the same time it were possible to take the data without any errors of measurement, a comparison of the number of eggs on, say, 500 vines, would reveal the fact that few, if any, of the vines would have the same number of eggs; moreover, the range in number of eggs per vine might be relatively large. In other words our homogeneous material would be found to vary. Variation is associated with all living matter, or, stated differently, each living thing possesses individuality. It is this tendency for individual vines to vary that is responsible for much of the uncertainty attached to the data of field tests, even tho the greatest efforts are made to select homogeneous material, and avoid errors. The several factors responsible for the variation found among individuals apparently subjected to the same environment are never completely known either qualitatively or quantitatively, and so are beyond the control of the experimenter. Therefore, in order to use our data for predicting the result if the experiment were repeated, we assume that these factors occur fortuitously — technically speaking, the effects are perfectly random — since they show no regularity or periodicity.

THE MEASUREMENT OF VARIATION.

In order to make comparisons between plats where different numbers of vines have been used for the counting of eggs, it is necessary to reduce all figures to a *per capita* basis which is accomplished by taking the arithmetical mean of the eggs of each lot. Let us suppose that two lots of ten vines each have the same average number of eggs per vine. It may be that in the one lot all the values are closely grouped about the mean, while in the second lot the range of values may be considerable. Surely the means do not tell the whole truth about the distribution of values in the two lots. A measure of the "scatter" or variation in each lot is necessary. Such a measure is given by the *standard deviation,* determined by squaring the deviation of each observation from the mean, summing the deviations squared, dividing by the number of observations and extracting the square root of the quotient. The standard deviation is usually represented by the Greek letter sigma (σ).

PROBABLE ERROR.

Having found a measure of variation, the next problem is to determine to what extent variation vitiates conclusions based on the mean. We desire to know the degree of confidence that can be placed in means when the amount of variation is known. This end is accomplished by calculating the probable error of the mean, the usual formula being

$$\text{Probable error of mean} = \pm\ .6745\ \frac{\text{standard deviation}}{\sqrt{\text{number of variates}}}$$

The probable error is such a value that the chances are even that if a second sample of the same number of observations be taken from the same plat the mean will coincide with the first average within the limits of the probable error. Also "the chances that the true value lies within the range set by ±E, ±2E, etc., are as follows:

± E the chances are even
±2E the chances are 4.5 to 1
±3E the chances are 21 to 1
±4E the chances are 142 to 1
±5E the chances are 1,310 to 1
±6E the chances are 19,200 to 1
±7E the chances are 420,000 to 1
±8E the chances are 17,000,000 to 1
±9E the chances are about 1,000,000,000 to 1.

It is very improbable, therefore, that an error will be many times as large as the probable error. . . . Thus by giving, along with any result, the calculated probable error, the reader may know what degree of confidence is to be placed in the results."[2]

"The probable error of the sum or difference of two quantities A and B, respectively affected with the probable errors $\pm a$ and $\pm b$ is

$$R = \pm \sqrt{a^2 + b^2} \quad ."^{3}$$

Also if a general mean is desired of several quantities affected with the errors r_1, r_2, etc., the formula used is

$$R = \pm \frac{\sqrt{r_1^2 + r_2^2 + \quad . \quad . \quad . \quad . \quad r_n^2},}{n}$$

in which R is the error of the general mean and n the number of values used in calculating the general mean.[4]

The last two formulæ have been used in the calculations in this bulletin, but the first formula has not been employed where the number of observations has been less than ten. A special method of calculating the probable error of a mean has been used where the number of observations has been ten or less, and will be described subsequently.

The question naturally arises regarding the ratio between a difference and its probable error that should be considered as minimum in order that the difference may be deemed significant. We have followed the usual rule of biometricians and have not regarded a difference significant unless it is at least three times as great as its probable error. The chief value of the probable error in our studies and experiments lies in its value for determining the significance of differences between plats to be compared.

THE PROBABLE ERROR OF A MEAN OF A SMALL NUMBER OF OBSERVATIONS.

When the number of observations is comparatively large, the probable error of the mean is calculated in a straightforward manner by the formula given above, and may be safely used in the comparison of averages. However, the experimenter frequently is limited regarding the number of observations that can be made on any one

[2] Davenport, E., Principles of breeding, p. 439. Boston. 1907.

[3] Mellor, J. W., Higher mathematics for students of chemistry and physics, 3d Ed., p. 528. London. 1909.

[4] Mellor, J. W., loc. cit., p. 530.

plat or in any one lot of experimental subjects, because of the labor and expense involved in making the observations. When, as in the present investigations, means must frequently be calculated on ten or less observations, the probable error of the mean determined by the regular formula gives a higher degree of confidence than the data justify. In other words, the probable error is too low. Fortunately, we have an indirect method of calculating the probable error of the mean of a small number of observations.

"Student"[5] has investigated the distribution of means of small samples, and, on the basis of these studies, has calculated a table giving the value of the probability that the mean of a small sample, n, drawn at random from a population following the normal law, will not exceed (in the algebraic sense) the mean of the population by more than z times the standard deviation. The table includes values of n from four to ten, and the values of z range by intervals of .1 from .1 to 3.0. By means of this table of probabilities one is able to determine the probable error of the mean of a small number of observations, and this method has been used for all means of ten or less individuals. Where more than ten vines were used, the probable error was calculated by the usual formula, because in most instances of more than ten vines there have been twenty or more vines in the plat and the differences in the probable errors calculated by the two methods are not marked. In all instances where the number of vines was between ten and twenty the results were failures so far as control was concerned, and so the shorter method of arriving at the probable error is as good as any, since the values were sufficiently large to show that no confidence could be placed in the results. As our method may be rather unusual to some, a concrete example will show the calculation involved.

Illustration.— A comparison of two kinds of treatment for the control of the grape root-worm: (a) Two applications of bordeaux mixture (8–8–100) and arsenate of lead, 6 pounds, at an interval of ten days (Plat III); (b) an application of molasses, 2 gallons, arsenate of lead, 6 pounds, and water, 100 gallons, followed in ten days by an application of bordeaux mixture (8–8–100) and arsenate of lead, 6 pounds (Plat IV). Denson vineyard. 1915.

[5] "Student". The probable error of a mean. *Biometrika* 6:1–25. 1908.
This probability table is also published in Tables for Statisticians and Biometricians by Karl Pearson, p. 36. Cambridge. 1914.

TABLE III. CALCULATION OF PROBABLE ERROR OF THE MEAN BASED ON FEW OBSERVATIONS FOLLOWING "STUDENT" AND COMPARISON WITH PROBABLE ERROR OF MEAN DETERMINED BY ORDINARY METHOD.

Vine.	Plat III. Number of eggs.	Plat IV. Number of eggs.
1	300	45
2	105	25
3	15	30
4	180	40
5	50	70
6	90	70
7	10	60
8	125	30
9	50	30
10	85	35
Mean	101.0	43.5
Standard deviation	82.27	16.29
$z = \frac{\text{mean}}{\text{standard deviation}}$	1.23	2.67
Probability (Student's Table)	.99851	.99999
Corresponding to $\frac{x}{\sigma}$ (Normal Probability Table)	2.795	4.27
Ratio of probable error to the mean $\left(\frac{x}{\sigma} \div .6745\right)$	4.14	6.34
Probable error of mean (Mean ÷ Ratio P. E. to mean)	24.4	6.5
Probable error of mean $\left(E = \pm .6745 \frac{\sigma}{\sqrt{n}}\right)$	17.5	3.5
	Difference	Difference divided by its probable error.
Difference (using modified probable errors)	57.5 ± 25.2	2.29
Difference (using ordinary probable errors)	57.5 ± 17.9	3.21

The data are set forth in Table III. It will be noted that the modified probable errors are considerably larger in both instances, and that in the comparison of the difference between the two treatments the difference is not three times its probable error, thus cautioning the experimenter against drawing certain conclusions from one field trial whereas, when the probable errors calculated by the ordinary formula are used, the difference is 3.21 times the probable error, giving more confidence in the results than is warranted by the data.

The reader may wonder why more vines were not used for egg counts on each plat, thus securing smaller probable errors. If only a few vineyards had been used for experimentation it would have been possible with the same number of men working the same amount of time to have counted the eggs on more vines in each plat. However, conditions in a few vineyards may in all probability be such that the systematic errors present might mask the results, and so to avoid this feature more plats were used with the necessity of using less vines per plat. While this method increases the probable error of each mean, we have used it since we believe that, on the whole, the results are more exact because we have been able to determine the extent of systematic error and to correct the same in a number of the vineyards by using more plats.

In a number of vineyards where no systematic error appeared due to different brands of arsenate of lead used or to irregularities in the amount of infestation, it was possible to combine plats treated similarly, and thus to decrease the probable errors of the means and to insure greater confidence in the results of the experiments.

PART IV. EXPERIMENTS FOR THE CONTROL OF THE GRAPE ROOT-WORM

OBSERVATIONS AND FIELD TESTS DURING 1910.

The grape root-worm was not very numerous during 1910 except in a few restricted areas. Two vineyards were found in which the insect had been destructive during 1909 and a sufficient number of adults were expected to be present for experimentation during 1910; viz., the vineyards of James Barnes, Prospect Station, and the S. J. Lowell vineyards near Fredonia. In the former planting, the number of adults that appeared was considerably below normal, and, altho the vines were sprayed, little can be deduced from the experiment. In the latter vineyards the conditions were favorable for field tests, and these will now be discussed.

EXPERIMENTS IN THE VINEYARD OF S. J. LOWELL, FREDONIA.

The area planted to grapes on this farm consists of two rectangular sections lying parallel but separated for an interval of slightly more than 200 yards by land given to general crops. The soil is Dunkirk silty clay loam[1] and the surface is practically level. There is considerable variation in age and vigor of the vines. However four sections were selected, in each of which the vines were apparently uniform as regards age, vigor and infestation. Owing to the variations between sections it is unsafe to compare one with the other, except that differences may be averaged as is done in the summary of results.

The field trials were to determine the values of (1) bordeaux mixture and arsenate of lead and (2) arsenate of lead and glucose for the control of the grape root-worm. Owing to the apparent failure of the second mixture to decrease the number of beetles, a trial was made of molasses and arsenate of lead. Because of its odor, and perhaps thru the sweet taste, it proved to be more attractive to the insects than ordinary glucose.

The first adult beetles appeared in this vineyard on June 17, but later emergence was very slow, the maximum number appearing

[1] Thruout this bulletin in determining the kind of soil in any vineyard we have used the soil survey map of Chautauqua County prepared by T. M. Morrison, C. C. Engle and G. L. Fuller; advance sheet, Field Operations of Bureau of Soils, 1914. U. S. Dept. of Agr.

about July 4. The first spraying was done July 7, on which date the maximum temperature was 77 degrees F. The day was clear with a very light westerly breeze. Between the first and second sprayings the weather was hot, and rain occurred several times. The second spraying was made on July 23, the maximum temperature being 82 degrees F., and the day was clear with a very light west wind. After the second spraying there were several days before any rain fell.

A Brown "traction" sprayer with four Vermorel nozzles on a side (Plate VII, fig. 2) was used for all applications. About 125 gallons of material was applied to an acre. The results of the experiment are shown in Table IV.

DISCUSSION OF RESULTS.

From Table IV we note that the differences in the number of eggs per vine between plats sprayed with glucose and arsenate of lead and their corresponding check plats, with the exception of one, are significant; i. e., they are more than 3.0 times the probable error of each difference. The odds are even greater when we take the mean of the differences, owing to the reduction of the probable error as shown in the summary.

The plats sprayed with bordeaux mixture and arsenate of lead, when compared with the check plats, show greater differences than do similar comparisons with glucose and arsenate of lead, and the odds that these differences are significant are even greater. This is especially true in the summary where the mean difference is 12 times its probable error. This is overwhelming odds that the difference is significant.

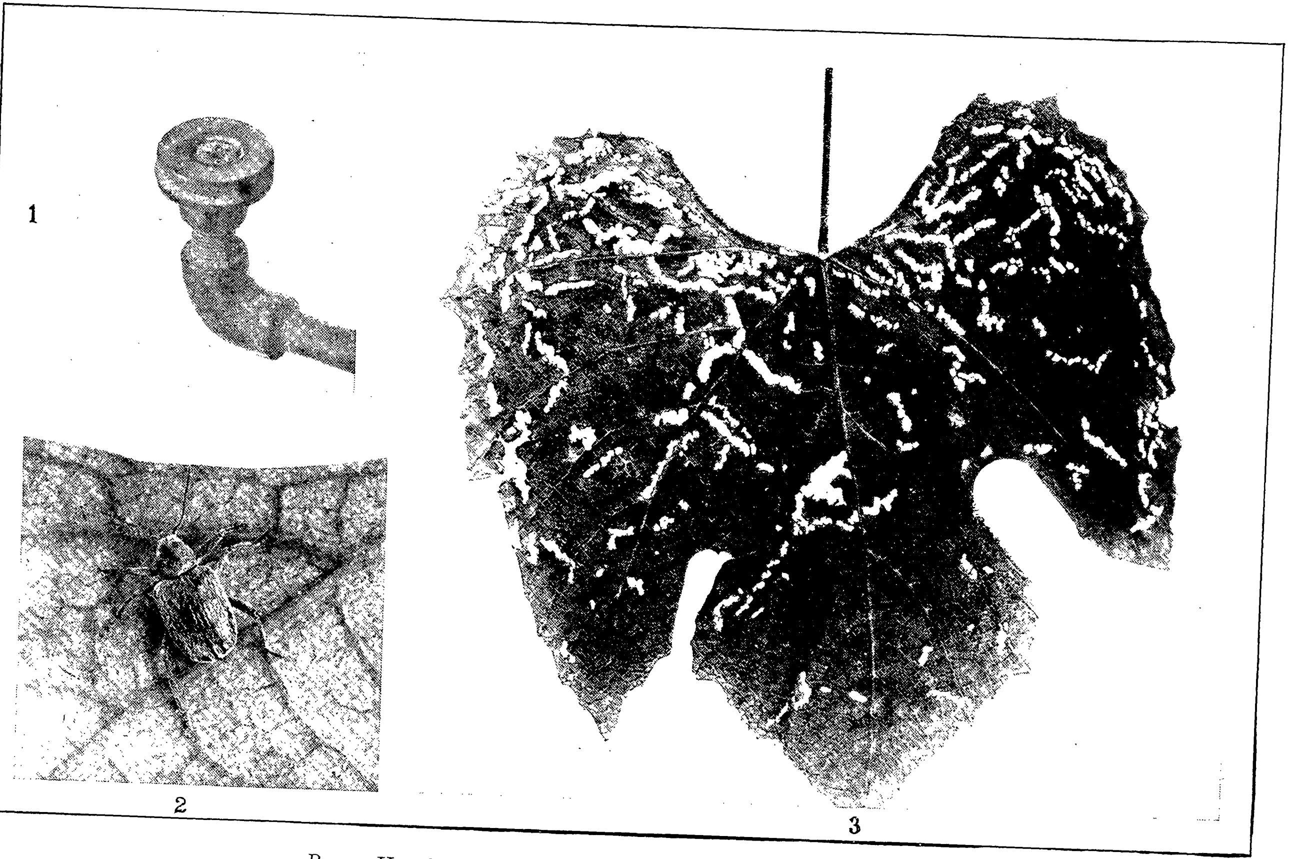
The chief point in these comparisons is the value of the sweetened sprays as compared with the bordeaux mixture and arsenate of lead. In every instance the latter material has shown the better results, and in all comparisons except one the differences are significant.

In order that the differences in the number of eggs laid on plats compared may be shown on the basis of an acre of vineyard, we have calculated the same from the average per vine, using 605 vines per acre as an average.

Altho the results of the experiments during 1910, at least so far as egg counts are concerned, are uniformly in favor of bordeaux mixture and arsenate of lead for the control of the grape root-worm,

1 2 3 4

Plate I.— Life Stages of the Grape Root-worm.
1. Adult × 7; 2, eggs × 8; 3, larva × 5; 4, pupa × 3.


1

2

3

PLATE II.— FEEDING OF ADULT BEETLES ON GRAPE LEAF. NOZZLE.
1. Cyclone type of nozzle; 2, adult on leaf; 3, feeding marks of adults on grape leaf.

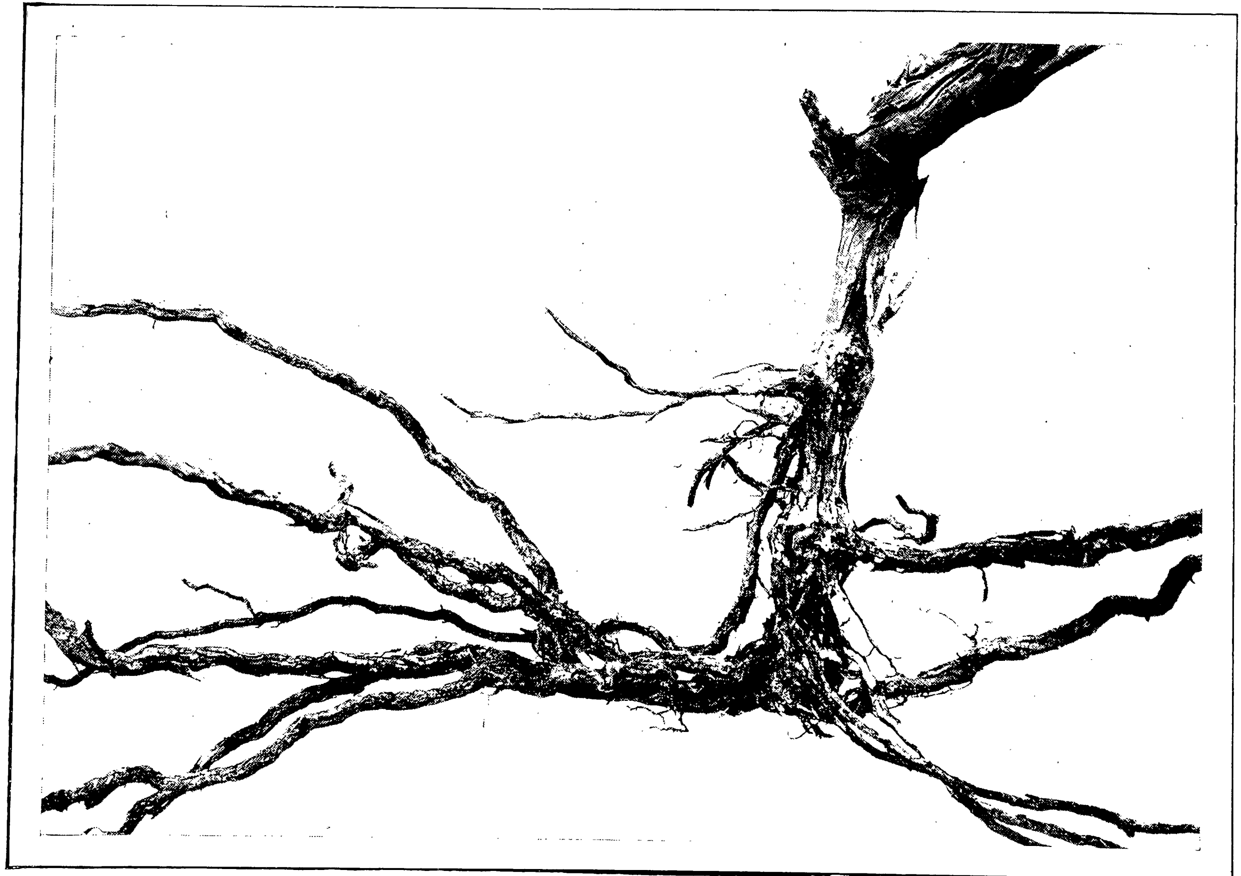


Plate III.— Effect of Feeding by Grape Root-worm on the Roots of Concord Grape.

Plate IV.— Vineyard Injured by Feeding of Grape Root-worm.
Photo taken at Silver Creek, July 23, 1912.

Plate V.— Vines Injured by Feeding of Grape Root-worm.
Fig. 1, photo taken at Ripley, July 1, 1912.
Fig. 2, photo taken at Fredonia, Sept. 15, 1910.

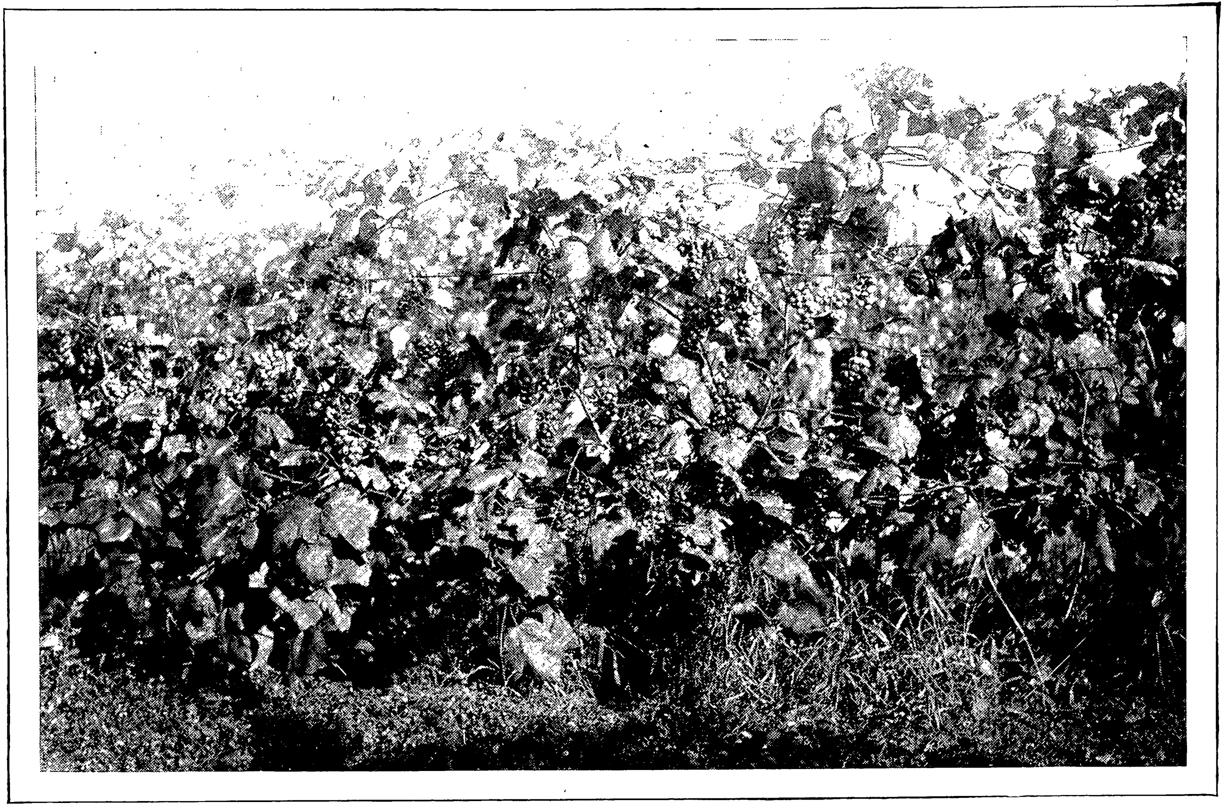


Plate VI.— Vigorous Concord Vine with Fruit in Station Vineyard.
Photo taken at Fredonia, Oct., 1909.

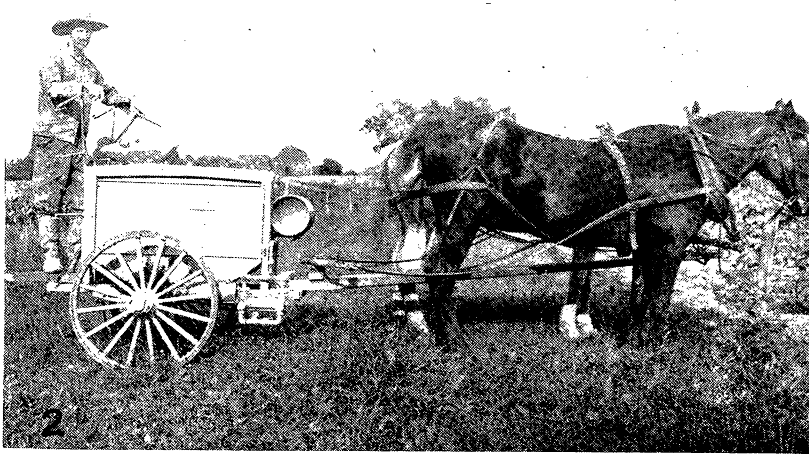
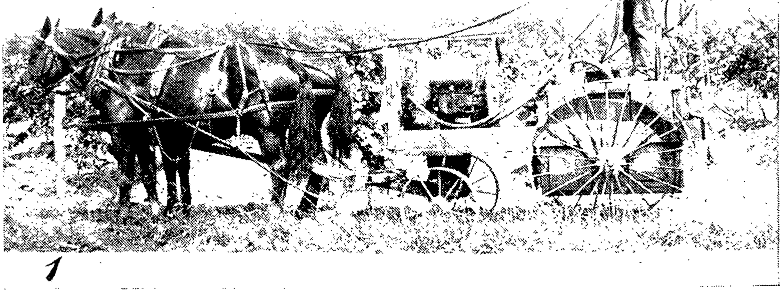


PLATE VII.— TYPES OF HORSEPOWER SPRAYERS.

Fig. 1, Victor sprayer in vineyard of Dr. C. C. Roosa, Silver Creek.
Fig. 2, Brown sprayer in vineyard of S. J. Lowell, Fredonia.



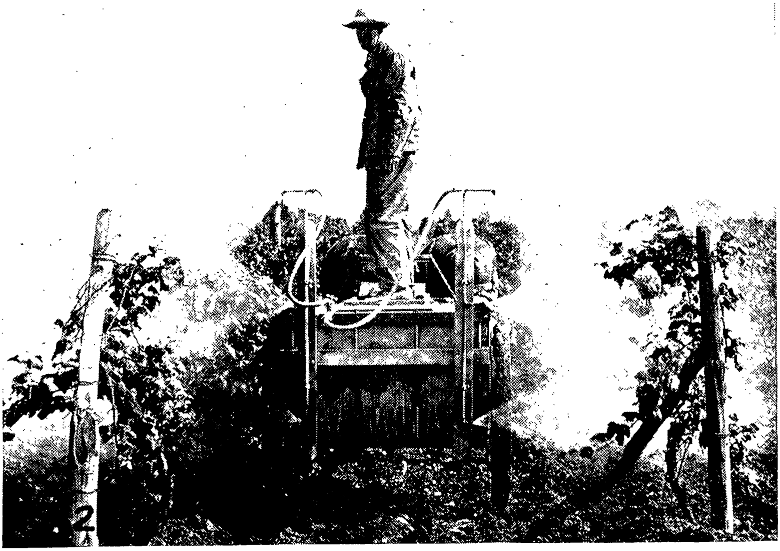
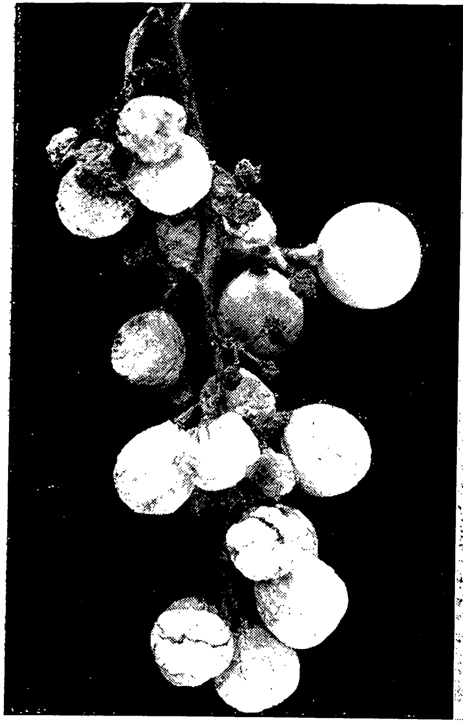


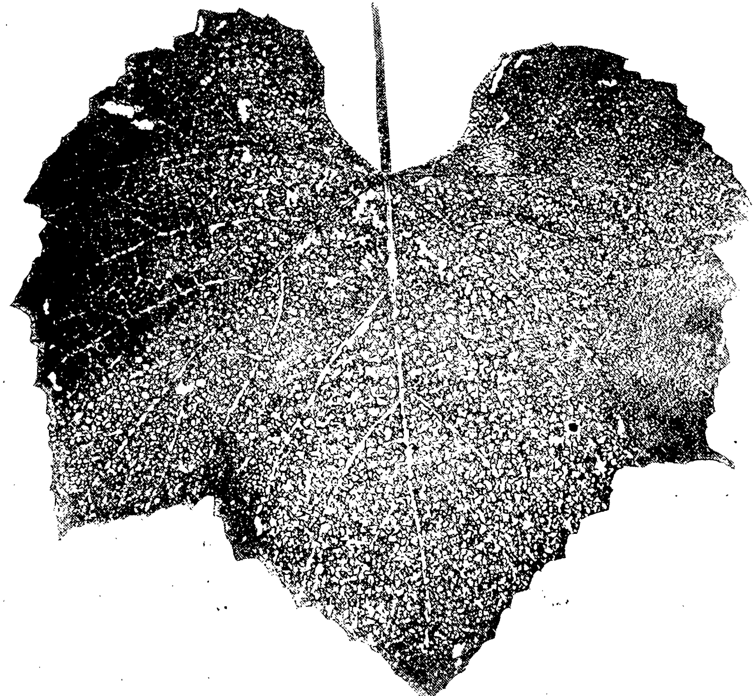
PLATE VIII.— GASOLINE ENGINE SPRAYER AND PROPER ARRANGEMENT OF NOZZLES.

Fig. 1, Friend gasoline engine outfit in vineyards of Wright Bros., Westfield.

Fig. 2, Gasoline engine sprayer showing arrangement of nozzles as used for the Chautauqua system of training in Station vineyards at Fredonia.



1



2

PLATE IX.— INJURY TO CONCORD CLUSTER FROM USE OF ARSENITE OF ZINC. GRAPE LEAF PROPERLY SPRAYED WITH BORDEAUX MIXTURE AND ARSENATE OF LEAD.

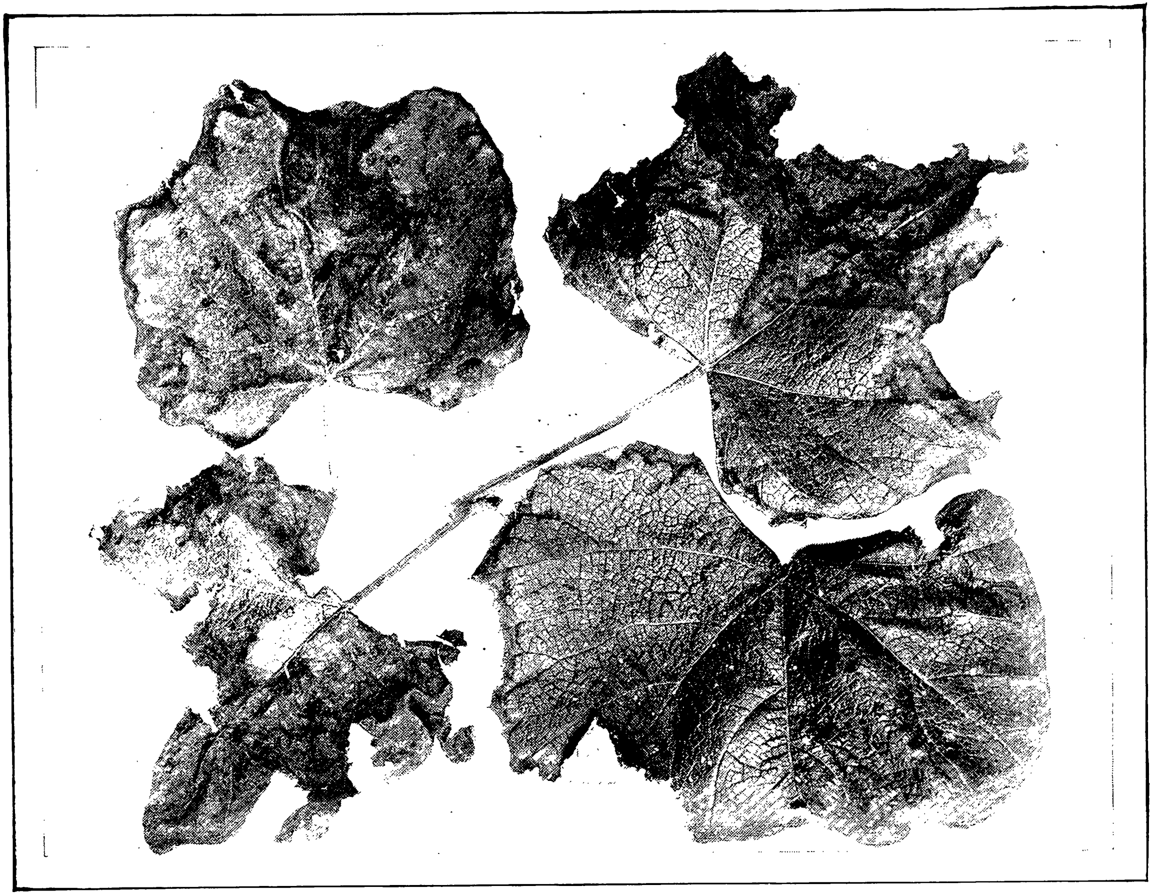


Plate X.— Injury to Concord Grape Foliage Caused by Spraying with Arsenite of Zinc.

there was one fact that caused us to believe that there was merit in the molasses and arsenate of lead spray; viz., dead beetles were found under the sprayed vines within twenty-four hours after the application of the material. On July 23, as soon as the spraying was completed, sheets of cheesecloth were spread and securely fastened under the vines sprayed with the various materials. On the following day, six dead beetles were found on the sheet underneath the vine sprayed with molasses and arsenate of lead, and about one hundred and fifty dead beetles were found on the ground under the vines of one row, but no beetles were found on the sheets spread under the vines sprayed with the other materials, nor were any to be found on the ground. It seemed to us that the possibility of killing the insects instead of driving them to neighboring vines was worthy of further careful consideration. A favorite criticism of the bordeaux-poison spray with grape growers has been that no dead beetles have been found under the sprayed vines, and naturally they are skeptical regarding its efficiency. For this reason the knowledge that the beetles could be killed was hailed with much enthusiasm by both the growers and the writer. It will be noted that the egg counts are not as favorable as could be desired, but we felt that this material required further experimentation to discover and establish its merits, and as far as possible to eliminate its faults. This is one of the objects of the remainder of the experiments that are discussed in this bulletin.

OBSERVATIONS AND FIELD TESTS DURING 1911.

During the season of 1911 the grape root-worm continued to be scarce. However one seriously infested vineyard was brought to our attention. Since the owner furnished all the spraying material, and desired to be rid of the pest which threatened two acres of his vineyard, we acted only in an advisory capacity. However, the owner gave us the opportunity of comparing the relative values of different amounts of molasses in each 100 gallons of liquid but there was no opportunity to secure an unsprayed plat for further comparisons.

EXPERIMENTS IN THE VINEYARD OF JOHN BARNES, FREDONIA.

The portion under experiment was a rectangular area consisting of slightly less than two acres, being the extreme northern end of the

TABLE IV.— DATA SECURED IN EXPERIMENTAL PLATS IN LOWELL VINEYARDS, FREDONIA, N. Y., 1910.

No. of plat.	Spray material used.	Dates of application.	Number of vines used for egg counts.	Mean number of canes per vine.	Mean number of egg clusters per vine.	Mean number of eggs per vine.	Comparisons.	
							Plats compared.	Difference in number of eggs.
	SECTION IA. YOUNG VINES.							
1	Not sprayed........	....	10	1.6	3.5	87 ± 10	1 and 2	47 ± 13
2	Arsenate of lead, 6 lbs.; glucose, 20 lbs.; water, 100 gals........	July 7 and 23	*9	1.6	2.5	40 ± 8	1 " 3	59 ± 12
3	Bordeaux mixture (8-8-100), arsenate of lead, 6 lbs........	"	10	1.7	2.3	28 ± 7	2 " 3	12 ± 11
	SECTION IB. OLDER VINES.							
1	Arsenate of lead, 6 lbs.; glucose, 20 lbs.; water, 100 gals........	July 7 and 23	10	3.0	7.3	161 ± 23	1 and 2	126 ± 37
2	Not sprayed........	....	10	3.3	14.5	287 ± 29	2 " 3	250 ± 30
3	Bordeaux mixture, (8-8-100); arsenate of lead, 6 lbs.; two applications on same day........	July 23	10	2.7	1.7	37 ± 6	1 " 3	124 ± 24
	SECTION IIA.							
1	Not sprayed........	....	10	1.7	6.4	138 ± 19	1 and 2	63 ± 23
2	Arsenate of lead, 6 lbs.; glucose, 20 lbs.; water, 100 gals........	July 7 and 23	10	2.1	4.9	75 ± 14	1 " 3	122 ± 19
3	Bordeaux mixture (8-8-100), arsenate of lead, 6 lbs........	"	10	1.9	1.8	16 ± 4	2 " 3	59 ± 15

SECTION IIB.

1	Bordeaux mixture (8-8-100), arsenate of lead, 6 lbs	July 23	20	2.7	4.7	78 ± 6	1 and 2	55 ± 13
2	Arsenate of lead, 6 lbs.; molasses, 1 gal.; water, 100 gals	"	20	2.7	7.4	133 ± 12	....	....

SUMMARY — COMPARISONS.

TREATMENTS.	Number.	Difference in number of eggs per vine.	Difference divided by probable error.	Difference in number of eggs per acre.
Glucose and arsenate of lead over vines not sprayed	3	79 ± 15	5.3	47,800
Bordeaux mixture and arsenate of lead over vines not sprayed	3	144 ± 12	12.0	87,100
Bordeaux mixture and arsenate of lead over glucose and arsenate of lead	3	65 ± 10	6.5	39,300
Bordeaux mixture and arsenate of lead over molasses and arsenate of lead	1	55 ± 13	4.2	33,300

* One vine was so abnormal in the number of eggs that it was excluded from the average.

vineyard, and having hay fields on both the east and west sides and woodland on the north side. The rows extended north and south, and each plat was 8 rows wide, the vineyard being divided into two plats. The soil is Dunkirk loam, and nearly level. All the vines were uniform in age and vigor, altho they had been weakened by the depredations of the root-worm. The first beetles emerged in this vineyard on June 18, and were present in large numbers by June 26. In fact they were as numerous as in the Lowell vineyards the preceding season.

The owner sprayed the vineyard on June 28, using 6 pounds of arsenate of lead, one gallon of molasses and 100 gallons of water on the west half of the experimental section, and 6 pounds arsenate of lead, two gallons of molasses and 100 gallons of water on the east half of the section. The day was partly cloudy, the maximum temperature being 74 degrees F., with a very light breeze. No rain appeared between the first and second sprayings. The second application was made on July 4, using the same materials on the two plats as in the first application. The day was clear with a maximum temperature of 93 degrees F. and very little wind. A Victor geared sprayer was used for both applications. The following two days, numerous dead beetles were found under the vines in both plats. The first rain appeared on July 10, six days after the second application. By this time the beetles had practically disappeared from the vines. The data are tabulated in Table V.

TABLE V. EFFECTS OF DIFFERENT AMOUNTS OF MOLASSES IN SPRAY: VINEYARD OF JOHN BARNES, FREDONIA, N. Y. 1911.

No. of plat.	Spray Material.	Dates of application.	Number of vines used for egg counts.	Mean number of canes per vine.	Mean number of egg clusters per vine.	Mean number eggs per vine.	Number of eggs per acre.	Difference in number eggs per vine.
1	Arsenate of lead, 6 lbs.; molasses, 1 gal.; water, 100 gals.	June 28 and July 4	25	3.6	5.1	54±7	32,700	18±7
2	Arsenate of lead, 6 lbs.; molasses, 2 gals; water, 100 gals.	June 28 and July 4	20	3.7	3.0	36±2	21,800	

DISCUSSION OF RESULTS.

It should be mentioned that the infestation on the two plats before spraying appeared to be the same, but we must remember that it is possible for a systematic error to have been present, and so too much reliance must not be placed on the results of a single experiment. However, the difference between the numbers of eggs per vine on the two plats indicates that two gallons of molasses used with the poison produced better results than one, but the high probable error of the difference admits the possibility that the results may be due to errors of random sampling. As will be noted in the experiments of 1915, the additional gallon of molasses gave a marked decrease in the number of eggs laid, and thus would tend to show that the results of 1911 are truly indicative of the differences in the materials used for spraying. This point will be treated further in the discussion of the experiments for the six seasons.

Before dismissing the results of 1911, it may be well, in view of later experiments, to mention that this vineyard was sprayed under almost ideal conditions for controlling the root-worm: (1) The weather was bright and warm, (2) no rain appeared until the insects had been poisoned, (3) the location of the vineyard was such as to prevent reinfestation, so the lack of a bordeaux spray did not interfere with results, and (4) the interval between the two sprayings was short.

OBSERVATIONS AND FIELD TESTS DURING 1912.

INSECT CONDITIONS IN VINEYARDS.

During this season the grape root-worm appeared in increasing numbers in many vineyards. However, we first began to find evidence of the destruction of root-worm larvæ in large numbers by both larvæ and adults of several species of beetles belonging to the family Carabidæ. Several vineyards which we had selected (owing to the large number of grape root-worm larvæ present) during the autumn of 1911, in which to conduct experiments during 1912, were found to have immense numbers of Carabid larvæ and adults in May and June, 1912, and the root-worm larvæ had practically disappeared. Carabid larvæ and adults were fed root-worm larvæ, and so the evidence is strong that the decrease in the number of grape root-worms was due largely to these predaceous enemies.

The grape leaf-hopper (*Typhlocyba comes* Say) was exceedingly abundant thruout the entire Chautauqua and Erie grape region during 1912, and as it threatened to do considerable damage much attention was given by the author to the control of this pest. For these two reasons the amount of field experimentation with the grape root-worm was considerably reduced.

EXPERIMENTS FOR THE CONTROL OF THE GRAPE ROOT-WORM.

During this season a number of vineyards were sprayed experimentally to control the grape leaf-hopper. In two of the plantings (Jillson and Dunham vineyards) there were portions which were also infested with the grape root-worm, therefore a combined spray was used. In the other vineyards, which will be mentioned, the experiments were aimed to control the root-worm.

TESTS IN THE VINEYARDS OF M. B. JILLSON AND J. R. DUNHAM.

The vineyard of Mr. Jillson is near Westfield, and that of Mr. Dunham is near Brocton. Both plantings were situated on slightly rolling Dunkirk loam, and both were sprayed primarily for the grape leaf-hopper. As stated above, certain portions were infested with the root-worm, and here a combined spray was used for the two pests. In each vineyard two plats were selected, the one being sprayed while the other was left as a check. The spraying mixture that was applied was bordeaux mixture (8-8-100), arsenate of lead, 6 lbs., "Black leaf 40" ½ pint, and water, 100 gallons. The adult, *F. viticida*, appeared in vineyards on this kind of soil about July 1, the majority emerging by July 6, and the spraying was done in both vineyards on July 15. This was the proper time for the control of the leaf-hopper, but we knew it to be rather late to attempt the control of the grape root-worm. However, the tests were made in order that we might determine the practicability of a single spray for both insects. The day was clear, but during the evening a thunderstorm occurred, and considerable rain fell.

The application was made with a Brown horsepower sprayer fitted with an Automatic Grape Leaf-hopper Attachment,[1] using six cyclone nozzles and maintaining a pressure of about 150 pounds per square inch. Between 140 and 150 gallons of liquid were applied per acre, much of the material being directed against the undersides of the foliage. However, the upper surfaces of the leaves were well covered with spray.

[1] This attachment is described in detail in Bulletin 344, N. Y. Agr. Expt. Sta. 1912.

The results of the spraying on the deposition of eggs by the grape root-worm in both vineyards are shown in Table VI, and it will be noted that the spraying had no effect on the number of eggs laid by the beetles. The cause of this failure to control was the lateness of the application, and the test strikingly illustrates the necessity of spraying at the proper time if one expects to control the root-worm. These results also show that, at least during certain seasons, a combined spray for the grape root-worm and the grape leaf-hopper is not practicable. These tests, however, have given us additional proof that a combination of nicotine sulphate, bordeaux mixture and arsenate of lead can be used with safety on grape foliage.

TESTS IN THE VINEYARD OF DR. C. C. ROOSA, SILVER CREEK.

This vineyard is situated near Silver Creek. The soil is Dunkirk clay, and the surface is nearly level. Heavy cropping, ravages by the grape root-worm just previous to the present owner's occupation, continued injury by the root-worm during 1911 and severe injury to the roots during the winter of 1911–12 had caused the death of a number of vines and the weakening of those remaining.

The adult beetles first appeared in this vineyard on July 5, and accordingly it was sprayed at the time we believed the maximum number of beetles had emerged, which was July 11. The day was clear, a light west wind blowing, the maximum temperature being 81 degrees F. Three parallel adjoining plats were selected, being numbered from east to west, the rows extending in a general north and south direction, thus placing the check plat on the east side. The materials used in each plat are shown in Table VI. During the night a light shower came from off Lake Erie which removed much of the poison from the leaves; however, there appeared to be sufficient material remaining to control the pest. A drenching rain on the 13th loosened the soil, and the beetles emerged in great numbers from July 14 to 23. The second spraying was applied on July 23. The sky was clear, a light west wind blowing, and the maximum temperature was 72 degrees F. Again, wholly unexpected by us, a light shower occurred during the night. It was noted that this shower had removed much of the spray from the leaves except on the plat sprayed with bordeaux mixture and arsenate of lead. The beetles fed a considerable time before disappearing, except on the bordeaux plat. Observations during this period revealed the fact

TABLE VI.— DATA SECURED FROM VINEYARDS SPRAYED EXPERIMENTALLY FOR THE CONTROL OF THE GRAPE ROOT-WORM, DURING 1912.

Plat.	Material used.	Dates of spraying.	Number of vines used for egg counts.	Average number of canes per vine.	Average number egg clusters per vine.	Number of eggs per vine.	Number of eggs per acre.	COMPARISONS.		
								Plats compared.	Difference in number of eggs per vine.	Difference divided by its probable error.
	Jillson Vineyard, Westfield.									
1	Bordeaux mixture (8-8-100), arsenate of lead, 6 lbs., B. L. 40, ½ pt.	July 15	10	3.1	25.6	420±78	254,100	1 & 2	47±149	0.3
2	Not sprayed	....	4	3.8	30.0	467±127	282,500	......	....	....
	Dunham Vineyard, Brocton.									
1	Bordeaux mixture (8-8-100), arsenate of lead, 6 lbs., B. L. 40, ½ pt.	July 15	15	5.5	19.3	367±40	222,000	1 & 2	—48±105	0.5
2	Not sprayed	....	5	4.4	19.4	319±97	193,000	......	....	....
	Roosa Vineyard, Silver Creek.									
1	Not sprayed	....	4	4.0	20.0	328±34	198,400	1 & 2 1 & 3	136±48 —147±51	2.8 2.9
2	Molasses, 1 gal., arsenate of lead, 6 lbs., water, 100 gals. Bordeaux mixture (8-8-100), arsenate of lead, 6 lbs	July 11 July 23	10	3.7	12.7	192±34	116,200	2 & 3	283±51	5.5
3	Molasses, 1 gal., arsenate of lead, 6 lbs., water, 100 gals	July 11 and 23	13	3.5	31.5	475±38	287,400	......	....	....

Station Vineyard, Fredonia: Section 6.

1	Bordeaux mixture (8-8-100), arsenate of lead, 6 lbs..	July 10 and 22	10	4.9	11.9	201±35	121,600	1 & 2	138±50	2.8
2	Molasses, 1 gal., arsenate of lead, 6 lbs., water, 100 gals. Bordeaux mixture (8-8-100), arsenate of lead, 6 lbs.......	July 10 July 22	15	4.3	18.0	339±35	205,100	......	....	....

Station Vineyard: Section 7.

1	Not sprayed................	....	20	2.8	18.3	453±59	274,100	1 & 2	173±66	2.6
2	Bordeaux mixture (8-8-100) arsenate of lead, 6 lbs..	July 10 July 22	20	3.8	17.0	280±30	169,400	......	....	....

that something was wrong with the molasses-arsenate of lead spray in this vineyard, and the egg counts confirmed these indications. The results are shown in Table VI.

The question of the lack of adhesiveness in the sweetened poison spray became an important problem, and laboratory experiments have confirmed these field observations that the addition of molasses destroys the adhesiveness of the arsenate of lead (see page 328). The better showing made by the bordeaux mixture in this experiment was due to the greater adhesiveness of the material, but the decrease in the number of eggs per vine on the plat sprayed with this mixture, while significant when compared with the check plat, is not sufficiently marked from a practical standpoint. Owing to the excessive rains, a shorter interval should have elapsed between the two applications.

TESTS IN THE STATION VINEYARDS AT FREDONIA.

Sections six and seven of the Station vineyards were used for these experiments. The rows extended north and south, and the plats were numbered from west to east. The materials used as well as the data of egg deposition are given in Table VI. The soil is Dunkirk silty clay loam, but the difference in vigor of vines in the two sections makes comparison between plats of different sections impossible. The first beetles were observed on July 5, altho the majority did not appear until about July 15 when they were present in enormous numbers. These sections are in the lea of a twenty foot plateau (Glacial Lake Warren beach), and there was a marked invasion of beetles from the vineyards on the higher land. The vines were vigorous, and the foliage dense, making it rather difficult to thoroly cover the leaves with spray.

The first application of spray material was made on July 10. The day was clear, with a light west wind. A rain occurred on the night of July 11, and we noted that much of the material had been washed from the foliage of the plat sprayed with molasses and arsenate of lead. We believed, however, that sufficient poison remained to kill the beetles that might feed. The second application was made on July 22. Both applications were made with a Victor "traction" sprayer.

It will be noted from Table VI that on none of the treated plats was the reduction in the number of eggs sufficient to prevent injury to the roots of the vines by the emerging grubs, altho the plats sprayed with two applications of bordeaux mixture and arsenate of lead gave reductions over both the check plat and the treatment with molasses and arsenate of lead. The failure to control the beetles in both sections was due to the excessive rains and too great an interval of time between the applications. The dense foliage and the immigration of beetles from unsprayed vineyards, due to the peculiar location of the section as described above, were also contributing factors.

DISCUSSION OF RESULTS OF EXPERIMENTS DURING 1912.

From the data collected (Table VI) it will be noted that the number of eggs per vine in all vineyards sprayed during this season was high, and the following conclusions seem warranted: (1) A combined spray for the grape leaf-hopper and the grape root-worm is not feasible during most seasons owing to the fact that the root-worm beetles will have laid too many eggs by the time a sufficient number of leaf-hoppers have hatched to make the spray effective for the latter insect. (2) The unsatisfactory results in the vineyards sprayed with molasses and arsenate of lead are due largely to the fact that molasses destroyed the adhesiveness of the arsenate of lead and rains, appearing shortly after the applications, washed the material from the foliage. In the plats where two applications of the sweetened poison were used the material applied at the second spraying was washed from the vines before the dispersion period of the beetles was past; therefore, migrating beetles were able to reinfest the vines, and feed with impunity. In the plats where the sweetened poison was used first, and where the second application consisted of bordeaux mixture and poison, the large number of eggs deposited shows that the interval of time between the two sprayings was too great. (3) The failure of two sprayings with bordeaux mixture and poison was due to several causes, such as local conditions favoring an abnormal immigration, dense foliage, excessive rains and the interval between sprayings being too long.

The advantage of using bordeaux mixture and arsenate of lead within a week after using the sweetened spray was not realized at the time these experiments were made. In fact we were of the opinion that injury to the foliage might occur if the applications were made while any of the molasses remained on the leaves. The reasons for this belief will now be explained.

After we found that the beetles were attracted by molasses in 1910, the question regarding the control of the powdery mildew immediately arose. In other words, could molasses be combined with bordeaux mixture and arsenate of lead? To answer this question we devised a series of laboratory tests, and found that if molasses be added to bordeaux mixture a reaction takes place between the sugar of the molasses and the bordeaux mixture whereby copper saccarate is formed, and at the same time a certain amount of copper is made soluble. We also found that the amount of soluble copper increases with the length of time the bordeaux and molasses are in contact, this being very marked after the materials were together several days. We therefore concluded that a small amount of molasses on the foliage might decompose bordeaux mixture, applied later, sufficiently to cause injury, and so planned to spray after there was no trace of the molasses remaining. The experiments during 1914 and 1915 have shown that we were too cautious, and that the two applications should not have an interval of more than ten days, and one week is better.

OBSERVATIONS AND FIELD TESTS DURING 1913.

OBSERVATIONS ON RELATIVE ABUNDANCE AND ENEMIES OF THE GRAPE ROOT-WORM.

The infestation by *F. viticida* during this season in the Chautauqua and Erie Grape Belt was very light. The activity of predaceous and parasitic enemies of the grape root-worm is believed to have been responsible for this reduction in numbers. As has been our custom in previous seasons, vineyards were selected in the summer of 1912 in which the adults and later the larvæ of *F. viticida* were numerous, our aim being to use these for experimentation during 1913. In several of these vineyards thousands of Carabid beetles developed, and destroyed practically all the larvæ of the grape root-worm. These circumstances necessitated the finding of other vineyards suitable for field tests after the first adults appeared, but, owing to the remarkable extent of this natural control, few vineyards were found that fulfilled our requirements.

EXPERIMENTS FOR THE CONTROL OF THE GRAPE ROOT-WORM.

TESTS IN THE VINEYARD OF DR. C. C. ROOSA, SILVER CREEK.

The number of beetles in this vineyard was sufficient to continue our experiments begun in 1912. Inasmuch as these vines had been seriously injured by the root-worm for several years, and as the bordeaux mixture and arsenate of lead gave the best results in 1912, the owner and the author decided to spray with the bordeaux mixture. However, it was decided to test the effect of the poison in the bordeaux mixture, since it began to appear that this mixture acts largely as a repellent.

Three parallel plats numbered from east to west were used in the experiment. The first was sprayed with bordeaux mixture without poison, the second with bordeaux mixture and arsenate of lead, while the third plat was not sprayed. The first beetles appeared in this vineyard on June 30 and the first application of spray was made on July 3. The day was clear with a maximum temperature of 86 degrees F., and there was a very light west wind. The second spraying was done on July 22, which was a fair day with little wind and with maximum temperature of 76 degrees F. A Victor "traction" sprayer was used for both applications and sufficient material was used to thoroly cover the foliage (Plate VII, fig. 1). As the vines were rather weak this required about 100 gallons per acre. The results are given in Table VII. The egg counts show practically no difference in the effectiveness of bordeaux mixture when used with arsenate of lead and without it, but both plats show barely significant differences over the unsprayed plat. A similar trial in 1914 indicates that the arsenate of lead has value when added to the bordeaux mixture, so it is possible that there may have been a systematic error in the infestation of this vineyard, which masked any beneficial effect of the arsenate.

TESTS IN THE VINEYARD OF U. P. MARKHAM, FREDONIA.

The experiments consisted of an untreated and two treated plats. The rows extend north and south, and the plats are numbered from west to east thus placing the check plat on the east side. The soil is Dunkirk gravel, and practically level. The materials used and the data gathered are shown in Table VII. The beetles appeared on the gravel soils on June 24, and by July 9, the date of the spraying, they were quite numerous, but very few eggs had been laid.[1] The day was partly cloudy, with a light westerly wind and with a maximum temperature of 78 degrees F. The application was made with a gasoline engine outfit which produced pressures varying from 100 to 150 pounds. The first rain occurred on July 12, but during the three days following the application most of the beetles present were killed on the plat sprayed with molasses. The failure to apply a protecting spray of bordeaux and arsenate of lead accounts for the high number of eggs deposited. The plat treated with bordeaux mixture and arsenate of lead shows considerable difference over the unsprayed plat, but the result is not without uncertainty owing to the high probable error of the difference between this and the check plat. The decreased number of eggs on the molasses-sprayed plat compared to the check plat is not significant, neither does the decrease in eggs on the bordeaux sprayed plat over the molasses plat approach anything like certainty.

TESTS IN THE VINEYARD OF HENRY BARNES, FREDONIA.

This vineyard is situated on level Dunkirk gravel loam soil. The cooperative tests were conducted on the following plan: the owner furnished the materials and the team, while the Station furnished the sprayer and the author directed the applications. We were able to secure comparative tests between the bordeaux mixture and arsenate of lead and the molasses and arsenate of lead mixture. Two plats, each nearly an acre in extent, were used, the plat sprayed with molasses and arsenate of lead being just west of the bordeaux plat. The vines were nearly uniform, and the infestation seemed to vary but slightly. The rows extended north and south.

The first beetles appeared during the last week of June, and they were present in rather large numbers during the first week of July. Owing to sprayer troubles the first application was not made until July 8. The day was partly cloudy with a light westerly wind and with a maximum temperature of 74 degrees F. The first rain occurred on July 12 or four days after spraying. The application

[1]The Spraying in the Markham and Barnes vineyards, as well as twenty acres of Station vineyard, was done with Station sprayers. We made the first application in the Station and Markham vineyards with a gasoline engine outfit, but owing to mechanical difficulties, high winds and rain the work was impeded. A traction sprayer was used for the second application in the Station vineyard but this was accidentally broken near the completion of the operation so additional sprays were not given the Markham and Barnes vineyards.

was made with a " traction " sprayer. About 110 gallons of liquid was applied per acre. Unfortunately the breaking of the sprayer prevented our making the second application at the proper time, and it had to be abandoned.

Table VII gives the data from this vineyard. Here the bordeaux mixture and arsenate of lead show a decided advantage over the molasses and arsenate of lead, but the number of eggs deposited on each plat is high, and even on the bordeaux plat was not reduced sufficiently to secure practical control of the pest. This test is an excellent example of the necessity of making a second application on both plats.

TESTS IN THE STATION VINEYARDS, FREDONIA.

Section 5 of the station vineyards is located on Dunkirk gravel soil which is slightly rolling. The first beetles appeared on this soil on June 24, and, as they were present in large numbers by July 1, the section was sprayed on this date. Molasses and arsenate of lead in usual proportions were used for the first application, and on July 8 a second application was made, using bordeaux mixture and arsenate of lead according to the ordinary formula. A gasoline engine sprayer was used for both applications. July 1 was clear with a very light wind and a maximum temperature of 85 degrees, but a light rain fell the following day, and this may have influenced the effectiveness of the spray. The section is divided into a number of plats treated during the previous four years with various fertilizers and cover crops which condition precluded the possibility of allowing a check plat in this section. An adjoining unsprayed vineyard was used as a check, since the infestation in the two vineyards where the egg counts were made appeared to be similar before the spraying, and the vines were similar in vigor.

The results of this experiment are given in Table VII. The difference between the two plats is indicative that this method of treatment will decrease the number of eggs deposited by the grape rootworm, but the ratio of the difference to the probable error shows that the difference is not without uncertainty.

DISCUSSION OF RESULTS OF FIELD TESTS DURING 1913.

The results in the Markham and Barnes vineyards illustrate the necessity of making a second application. In the Station vineyard spraying was done at what we believed to be the opportune time, and

TABLE VII.—DATA SECURED FROM VINEYARDS SPRAYED EXPERIMENTALLY FOR THE CONTROL OF THE GRAPE ROOT-WORM, DURING 1913

Plat.	Material used.	Dates of spraying.	Number of vines used for egg counts.	Average number of canes per vine.	Average number of egg clusters per vine.	Average number of eggs per vine.	Number of eggs per acre.	Comparisons. Plats compared.	Comparisons. Difference in number of eggs per vine.	Comparisons. Difference divided by its probable error.
	Roosa Vineyard, Silver Creek.									
1	Bordeaux mixture (8-8-100), no poison	July 3 and 22	5	2.4	2.8	56±18	33,900	1 & 2	11±20	0.6
2	Bordeaux mixture (8-8-100), arsenate of lead, 6 lbs	July 3 and 22	20	2.6	4.0	67±9	40,500	1 & 3	164±55	3.0
3	Not sprayed	....	5	3.4	11.0	220±52	133,100	2 & 3	153±53	2.9
	Barnes Vineyard, Fredonia.									
1	Bordeaux mixture (8-8-100), arsenate of lead, 6 lbs	July 8	20	3.6	8.2	117±14	70,800	1 & 2	153±51	3.0
2	Molasses, 1 gal., arsenate of lead, 6 lbs., water, 100 gals	July 8	10	3.3	14.6	270±49	163,350	......	....	....
	Markham Vineyard, Fredonia.									
1	Bordeaux mixture (8-8-100), arsenate of lead, 6 lbs	July 9	5	4.4	3.4	63±16	38,100	1 & 3	181±74	2.4
2	Molasses, 1 gal., arsenate of lead, 6 lbs., water, 100 gals	July 9	5	4.6	8.2	140±42	84,700	2 & 3	104±83	1.3
3	Not sprayed	....	5	4.2	15.6	244±72	147,600	1 & 2	77±45	1.7
	Station Vineyard, Fredonia.									
1	Not sprayed	....	25	3.6	4.5	81±8	49,000	1 & 2	29±12	2.4
2	Molasses, 1 gal., arsenate of lead, 6 lbs., water, 100 gals. Bordeaux mixture (8-8-100), arsenate of lead, 6 lbs	July 1; July 8	25	3.4	4.4	52±9	31,500	......	....	....

a low egg count was secured. However, the difference between the sprayed and unsprayed sections is only 2.4 times its probable error, and so lacks certainty as a single experiment. It is possible that the adjoining unsprayed vineyard used as a check did not have as severe an infestation as Section 5, and thus a systematic error may mask the results. On the other hand, the rain occurring so shortly after the first spraying may have introduced a disturbing factor. Knowing that large numbers of beetles were present before the spraying, the few eggs deposited are indicative that we secured the desired results. Excellent results were secured in the Roosa vineyard where two applications of bordeaux mixture and arsenate of lead were properly applied. The fact that this mixture without poison gave practically the same egg count as where the arsenate of lead was used must not be given too great weight, for a similar experiment during 1914 indicated that the poison is necessary.

OBSERVATIONS AND FIELD TESTS DURING 1914.

At first it appeared that the Carabid beetles had again seriously interfered with the number of root-worm beetles, and for a time it was difficult to find vineyards sufficiently infested to be worthy of experimentation. Gradually, after the first beetles appeared, vineyard after vineyard that was severely infested was brought to our attention. Eight vineyards were found that answered all requirements and the difficulty of getting them all sprayed at the proper time, had to be surmounted. Seven of the vineyards were sprayed at the proper time. Another vineyard received a rather late application of molasses and arsenate of lead, but owing to unfavorable weather the bordeaux mixture and arsenate of lead spray was applied entirely too late to control the grape root-worm.

TESTS IN THE VINEYARD OF E. L. DAY, DUNKIRK.

This vineyard was situated on soil mapped as Dunkirk very fine sandy loam, and the surface is level. The vines were of moderate vigor, and severely infested with the grape root-worm. The rows extended north and south. The first beetles appeared in this vineyard on June 28. A portion of the vineyard, comprising eight rows, was sprayed with molasses and arsenate of lead, the usual quantities being used. This application was made on July 1, the day being cloudy with a light south wind and a maximum temperature of 72 degrees F. The remainder of the vineyard on either side of this plat was sprayed with commercial bordeaux mixture and arsenate of lead. No rain occurred between the first and second sprayings. The second application was made on July 8, and consisted of commercial bordeaux mixture, 12 pounds, arsenate of lead, 6 pounds, and water, 100 gallons. The sprayings were accomplished with a " traction " sprayer.

As evidence of the effectiveness of the sweetened spray, we mention the fact that twenty-four hours after the first spraying eleven dead beetles were picked up from under one vine, while smaller numbers were gathered from under other vines. To test this material further eighty-eight beetles that were gathered from the foliage of these vines, were placed in a cage in the insectary, and fed unsprayed foliage. All the beetles died in two days' time, while the majority died in 24 hours. Careful counts were made of the egg clusters on the vines sprayed with the sweetened poison and, in order to remove the influence of any systematic errors that might be present, vines were selected on each side of Plat 1 for egg counts. The results are given in Table VIII.

It will be noted that the average number of eggs per vine is rather high when compared with several other vineyards. The same is true of the vines sprayed with the commercial bordeaux, but the difference in the number of eggs on the two plats is significant, and the plat treated with molasses and poison has the lower number of eggs. Observations in this vineyard just after spraying revealed the fact that the commercial bordeaux mixture did not cover the foliage nearly as well as home-made bordeaux mixture, and did not remain on the foliage as long. This difference in " body " is believed to have decreased the repellent power, and this would explain the fact that more eggs were laid on the vines even tho the sweetened spray had killed most of the beetles originally on the vines. The results on plat 1 were of practical importance because the actual number of eggs per acre was greatly reduced.

TESTS IN THE VINEYARD OF MRS. C. M. BENJAMIN, FREDONIA.

This vineyard is situated on Dunkirk gravel soil. The first rootworm adults appeared on June 20, and were present in moderate numbers when the vineyard was sprayed on June 30. The rows extend from east to west. The vineyard was divided into three plats: The one to the north was left as a check; the middle plat received an application of bordeaux mixture and arsenate of lead, and the plat to the south received an application of bordeaux mixture, arsenate of lead, and "Black leaf 40." The day was clear with a maximum temperature of 74 degrees F. and with a brisk southwest wind, but as the vineyard was protected by a woodland no trouble was experienced in applying the spray. Only one application was made, as this appeared to control the beetles.

From Table VIII we note that a decided decrease in the number of eggs per vine occurred in the sprayed plats, and that the differences of both plats over the check plat are marked. It is apparent that the use of nicotine in bordeaux mixture does not increase the effectiveness of the latter for the control of the grape root-worm since the number of eggs is very nearly the same in the two plats and the difference is only 0.2 of its probable error. The favorable results from a single spraying in this vineyard were due to the fact that the infestation was moderate, and the surroundings were such as to allow a small amount of infestation by migrating beetles. This result seems to bear out the contention that, in a moderately infested vineyard, a single timely spraying may occasionally hold the pest in check, provided the danger of reinfestation is not great.

TESTS IN THE VINEYARD OF HENRY BARNES, FREDONIA.

Section I of this vineyard is situated on practically level Dunkirk gravelly loam soil, while Section II was on slightly rolling Dunkirk gravel. The vines were vigorous and moderately infested with *F. viticida*. The rows in both sections extended north and south, and the plats were numbered from east to west. The first adults emerged in this vineyard on June 21 with the greater number emerging about July 1. The vines in Section I were sprayed on July 3. The day was clear with a light west wind and a maximum temperature of 72 degrees F. No rain appeared until July 12, or nine days later. Section II was sprayed on July 6. The day was clear with a light northwest wind and a maximum temperature of 82 degrees F. The comparisons sought were: Three brands of arsenate of lead (1) with each other and (2) with the check plat; (3) arsenate of lead and molasses with arsenate of lead and bordeaux mixture. Only a single spraying was given, as most of the beetles disappeared from the vines, and as migrating beetles did not disturb conditions it was not considered necessary to give the additional application.

It will be noted (Table VIII) that the number of eggs found on the sprayed plats of Section I was small, and that the differences between the sprayed plats and the unsprayed plat were all marked, and indicate that the sweetened poison was responsible for the decrease in eggs. Especially is this difference significant when the mean of the three plats compared is considered. It is practically certain, however, that the several brands of arsenate of lead acted similarly for the differences are only such as might be expected from normal variation. In Section II the number of eggs on both plats is low, but the difference between them is not significant.

TESTS IN THE VINEYARD OF F. G. SPODEN, FREDONIA.

This vineyard was situated on Dunkirk silty clay loam, and the vines were young and vigorous. The surface of Section I was comparatively level but Section II, while nearby, was on an eastern slope. The rows extended north and south, and the plats were numbered from west to east. The northern portion of this vineyard — the part used for comparisons — was found to be severely infested with grape root-worm the latter part of June. The first beetles emerged on June 25, and by July 1 they were present in large numbers. The vineyard was sprayed late on July 3, and early on July 4. July 4 was clear, calm with a maximum temperature of 78 degrees F. In these tests: (1) Several brands of arsenate of lead were compared with each other; (2) the sweetened sprays followed with bordeaux mixture and arsenate of lead were compared with two sprayings with bordeaux mixture and arsenate of lead; (3) bordeaux mixture alone was compared with bordeaux mixture with arsenate of lead. The infestation was uniform on the several plats of each section where the egg counts were made, but Section II had a lighter infestation than Section I. The first rain occurred on July 12, or eight days after the first application. The second spraying was made on July 14, the day being fair with a light south wind and with a maximum temperature of 80 degrees F.

After the first spraying on Plat 1, Section II, it was noted that the beetles remained, and fed extensively. As it began to appear that this area would be seriously injured, and since we were convinced that the omission of the poison was responsible, it was decided to add the arsenate of lead at the second application. Even with this second spraying the beetles laid many more eggs than in the adjacent plat. Three days after the first spraying it was noted that the beetles had almost disappeared from the molasses plats, but shortly afterwards more beetles were found on these vines. This is believed to have been due to the general dispersion and perhaps to the attractiveness of the molasses to the beetles. The migrants were avoiding the bordeaux-sprayed vines, and appeared to be moving to those sprayed with molasses; and the second spraying was made to check this movement.

A study of the data from this vineyard (Table VIII) will warrant the following conclusions: (1) All plats sprayed with molasses and arsenate of lead followed in due time with bordeaux mixture and arsenate of lead show small numbers of eggs per vine; (2) the mean difference of these plats over the plat sprayed with two applications of bordeaux mixture and arsenate of lead is significant; (3) the plats sprayed with the several brands of arsenate of lead gave uncertain differences, and so there is no reason to believe that important practical differences were present in the several forms of arsenate of lead, for the variation is very probably due to fluctuations in sampling, thus corroborating the results secured in the Barnes vineyard; (4) a single application with bordeaux mixture and arsenate of lead was far less efficient than two applications of the same material; (5) arsenate of lead in the bordeaux mixture is necessary for the control of the grape root-worm.

TESTS IN THE STATION VINEYARD, FREDONIA.

The entire vineyard, exclusive of Sections 2 (portion), 6 and 7, has each year received one or two sprayings of bordeaux mixture and arsenate of lead as necessity required. This we believe to have been necessary to keep the beetles within due bounds and to control the powdery mildew. While at first we were troubled with grape root-worm in Sections 2 and 5, no trouble was experienced in reducing the number of beetles, so no damage has been done by them. In sections 6 and 7 each year various sprays have been tried, and always a considerable number of vines have been left unsprayed to serve as checks. Here we have had numerous beetles each year. We also noted in Section 2 that, just as soon as we allowed the vines to remain unsprayed, the number of eggs laid was greatly increased, and that a season's thoro spraying caused them to disappear to a great extent. Section 7 has had portions that were not treated each year, and here the beetles have remained. As described later (page 325) it appears that the action of the wind upon migrating beetles coming from unsprayed vineyards to the west as well as the isolation of sections 6 and 7 previous to 1913 has had considerable influence on the number of eggs deposited.

The experiments in 1914 consisted of a test of one application of bordeaux mixture and arsenate of lead with an unsprayed plat between these sprayed. The results are given in Table VIII, and it will be noted that there is considerable difference in the number of eggs on the sprayed and check plats, altho better results would doubtless have been secured had a second application been given.

TESTS IN THE VINEYARD OF W. E. SKINNER, PORTLAND.

This vineyard was situated on level Dunkirk gravelly loam soil, and was found to be severely infested with grape root-worm on July 8. We presume that the first adults appeared about June 25. The vines were moderately vigorous, and the rows extended north and south. The owner had sprayed the entire vineyard with bordeaux mixture and arsenate of lead, except one acre which was sprayed with molasses and arsenate of lead, on July 9. The day was fair, with a light northwest wind and a maximum temperature of 90 degrees F. The spraying was thoro, a "traction" sprayer being used, and only a single application was made. The first rain appeared on July 12.

The results (Table VIII) with both mixtures are not very good so far as the control of the grape root-worm is concerned, but the difference is in favor of the sweetened poison, and is significant. The high egg count is further proof that the failure to control the beetles in 1912 and 1913 was due to the lack of a second repellent spray applied at the proper time after the first application.

TESTS IN THE VINEYARD OF N. G. AND J. T. MERRITT, SHERIDAN.

The vines of this vineyard were of moderate vigor, and the portion in which the experiments were conducted was severely infested with *F. viticida*, especially in the southern ends of the plats where the comparisons were made. The soil is Dunkirk very fine sandy loam and almost level. The first beetles appeared on June 28, and the majority had emerged by July 6. The rows extended north and south, and the plats were numbered from west to east. Tests were made with bordeaux mixture with both 6 pounds and 8 pounds of arsenate of lead; and with molasses with both quantities of arsenate of lead. This furnished comparisons of these plats with the check plat as well as comparisons between molasses and poison and bordeaux and poison. The first spraying was made on July 9, being applied by means of a gasoline engine sprayer. The day was fair, with a very light west wind (practically a calm) and a maximum temperature of 90 degrees F. Under such conditions it was possible to thoroly cover the foliage with spray. Within two days after the spraying it was found that practically all the beetles had disappeared from the molasses-arsenate of lead plats. In a few days there was a tendency for the vines to become re-infested, and therefore an application of bordeaux mixture and arsenate of lead was made on all plats on July 15. The first rain appeared July 23, eight days after the second spraying, but it was very light.

It will be noted in Table VIII that the number of eggs per vine on each sprayed plat decreases as we go from the west to the east. Since the plats sprayed with bordeaux mixture are to the west of the molasses plats, and also since plat 1 received less poison than plat 2 this condition might be expected. However, we note that plat 4 which received 6 pounds of arsenate of lead had less eggs than plat 3, which received 8 pounds of the same material, so we are of the opinion that a systematic error extends across the plats. If this is true the check plat had less eggs than would have been deposited on the other plats had they not been sprayed. Since the difference in the number of eggs on plats 1 and 2 is not significant we have combined them under the designation plat *a*, and plats 3 and 4 are combined and designated plat *b*. The check plat is lettered *c*. This arrangement makes fewer comparisons. Obviously no conclusion can be drawn from the difference between plats *a* and *b*, for this may be due entirely to a systematic error. The difference between plats *a* and *c* is in favor of plat *a*, but the difference is insignificant, due no doubt to the systematic error, but is included in the summary. The comparison between plats *b* and *c* shows a difference that perhaps is significant, because any systematic error that may have been present has tended to decrease this difference.

TESTS IN THE VINEYARD OF L. M. CARY, SHERIDAN.

In this vineyard the rows extend east and west, and the plats are numbered from north to south. Plat 1 was on rather level Dunkirk clay, but the soil changes rapidly to Volusia clay loam on plat 3, while plat 2 is intermediate in type, and these two latter plats are on more of a slope than plat 1.

We were not informed of the severe infestation in this vineyard until July 8, and an examination at this time revealed the insects in large numbers. We have no record of the appearance of the first beetles, but assume it to have been about June 28. Owing to the spraying operations in the Merritt vineyard and also because Mr. Cary did not purchase a sprayer until July 9, the molasses and arsenate of lead was not applied until July 10. The day was clear, but a rather strong breeze was blowing from the west which interfered with the proper application of the spray, altho the machine worked perfectly. The maximum temperature was 88 degrees F. Unfortunately, the following day very high winds set in, which, for almost a week, made it impossible to apply any spray. Thus the plat sprayed with molasses and arsenate of lead stood alone in the midst of four acres of unsprayed grapes; in other words, an excellent check was left on either side. Plats 1 and 2 were sprayed with bordeaux mixture June 17, but, unfortunately, by this time the beetles had laid most of their eggs. For this reason plat 1 also serves as a check, and furthermore shows that the second spray was applied too late to plat 2.

It will be seen in Table VIII that a rather large number of eggs were deposited on plat 2, just as was shown in our 1912 and 1913 experiments, where the second application was not made at the proper time. By comparing the number of eggs in plats 1 and 3 we note that the difference is 4.7 times its probable error, so it is very improbable that it is due to random sampling. Neither is it due to the late application of the bordeaux mixture and poison on plat 1, as this plat has a greater number of eggs than the check plat. Obviously we have a systematic error of sampling, and fortunately we can eliminate its effects by simply taking the average of plats 1 and 3. When this is done we find that plat 2 shows a large difference from the mean of plats 1 and 3. Since this difference is 13.5 times its probable error we have very great odds that the difference is due to the treatment given plat 2.

TABLE VIII.— DATA SECURED FROM VINEYARDS SPRAYED EXPERIMENTALLY FOR THE CONTROL OF THE GRAPE ROOT-WORM DURING 1914.

Plat.	Materials used.	Date of spraying.	Number of vines used for egg counts.	Average number of canes per vine.	Average number of egg clusters per vine.	Average number of eggs per vine.	Number of eggs per acre.	Comparisons. Plats compared.	Difference in number of eggs per vine.	Difference divided by its probable error.	Mean of similar comparisons in same vineyard.	Mean divided by its probable error.	Difference in number of eggs per acre.
	E. L. Day Vineyard, Dunkirk.												
1	Molasses, 1 gal; arsenate of lead, 6 lbs.; water, 100 gals.............. Commercial bordeaux mixture, 12 lbs.; arsenate of lead, 6 lbs.; water, 100 gals..........................	July 1 / " 8	10	3.1	5.6	85±15	51,400	1 and 2	125±28	4.5	....	..	75,700
2	Commercial bordeaux mixture, 12 lbs.; arsenate of lead, 6 lbs; water, 100 gals.	June 30 / July 8	20	3.0	9.4	210±23	127,100	......	....	....	....	..	.....
	C. M. Benjamin Vineyard, Fredonia.												
1	Not sprayed.....................	......	10	3.9	6.0	156±34	94,400	1 and 2	108±37	2.9	110±25	4.4	66,600
2	Bordeaux mixture (8–8–100); arsenate of lead, 6 lbs..................	June 30	10	4.0	2.1	48±14	29,000	1 and 3	112±35	3.2			
3	Bordeaux mixture (8–8–100); arsenate of lead, 6 lbs.; "Black Leaf 40," ½ pt..........................	" 30	10	4.0	2.8	44± 9	26,600	2 and 3	4±17	0.2	....	..	2,400
	Henry Barnes Vineyard, Fredonia. *Section I.*												
1	Brand A, arsenate of lead, 6 lbs.; molasses, 1 gal.; water, 100 gals...	July 3	10	3.1	2.0	27± 6	16,300	1 and 4	50±15	3.3	45± 9	5.0	27,200
2	Brand B, arsenate of lead, 6 lbs.; molasses, 1 gal.; water, 100 gals...	"	10	2.5	1.5	33± 9	20,000	2 and 4	44±17	2.6			
3	Brand C, arsenate of lead, 6 lbs.; molasses, 1 gal.; water, 100 gals...	"	10	3.2	2.3	36± 9	21,800	3 and 4	41±17	2.4			
4	Not sprayed.....................	......	10	4.1	4.3	77±14	46,600	......	....	....	....	..	.....

TABLE VIII.—(*Continued*).

Plat.	Materials Used.	Date of spraying.	Number of vines used for egg counts.	Average number of canes per vine.	Average number of egg clusters per vine.	Average number of eggs per vine.	Number of eggs per acre.	Comparisons: Plats compared.	Difference in number of eggs per vine.	Difference divided by its probable error.	Mean of similar comparisons in same vineyard.	Mean divided by its probable error.	Difference in number of eggs per acre.
	Henry Barnes Vineyard, Fredonia. *Section II.*												
1	Bordeaux mixture (8–8–100); arsenate of lead, 6 lbs.	July 6	10	4.1	3.5	56±12	33,900	1 and 2	15±14	1.1	....	..	9,100
2	Molasses, 2 gals.; arsenate of lead, 6 lbs.; water, 100 gals.	"	10	2.9	3.0	41± 8	24,800	......	....	....	....	..	.....
	F. G. Spoden Vineyard, Fredonia. *Section I.*												
1	Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	July 3	10	4.5	17.2	264±25	159,700	1 and 2	148±34	4.4	....	..	89,500
2	Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	July 3 " 14	10	3.3	7.3	116±23	70,200	2 and 3	85±24	3.5			
3	Brand A, arsenate of lead, 6 lbs.; molasses, 1 gal.; water, 100 gals. Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	" 4 " 14	10	5.2	3.0	31± 6	18,800	2 and 4	72±25	2.9	74±14	5.3	44,800
4	Brand B, arsenate of lead, 6 lbs.; molasses, 1 gal.; water, 100 gals. Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	" 4 " 14	10	5.3	4.4	44±11	26,600	2 and 5	66±25	2.6			
5	Brand C, arsenate of lead, 6 lbs.; molasses, 1 gal.; water, 100 gals. Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	" 4 " 14	10	4.8	3.3	50±10	30,300	3 and 4 3 and 5 4 and 5	13±12 19±12 6±15	1.7 1.6 0.4	....	.. .. ..	7,800 11,500 3,700
	Section II.												
1	Bordeaux mixture (8–8–100), no poison Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	July 4 " 14	10	4.6	7.0	122±21	73,800	1 and 2	84±22	3.8	....	..	50,800
2	Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	" 4 " 14	10	4.3	2.6	38± 7	23,000	......	....	....	....	..	.....

	Station Vineyard, Fredonia.												
1	Not sprayed	......	23	3.4	14.9	340 ±23	205,700	1 and 2	231 ±25	9.2	....	..	139,800
2	Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	July 8	20	2.2	5.7	109 ±10	65,900	......	....	....	....	..	.....
	W. E. Skinner Vineyard, Portland.												
1	Molasses, 1 gal.; arsenate of lead, 6 lbs.; water, 100 gals.	July 9	20	2.5	5.3	100 ± 8	60,500	1 and 2	101 ±18	5.6	....	..	61,100
2	Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	"	20	2.4	8.3	201 ±16	121,600	......	....	....	....	..	.....
	N. G. & J. T. Merritt Vineyard, Sheridan.												
a 1	Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	July 9, " 15	10	4.6	6.2	123 ±24	74,400	1 and 2	45 ±29	1.6	....	..	27,200
a 2	Bordeaux mixture (8–8–100), arsenate of lead, 8 lbs.	" 9, " 15	10	5.5	4.2	78 ±17	47,200	3 and 4	23 ±14	1.6	....	..	13,900
b 3	Molasses, 1 gal.; arsenate of lead, 8 lbs.; water, 100 gals. Bordeaux mixture (8–8–100); arsenate of lead, 6 lbs.	" 9, " 15	10	3.7	3.3	67 ±11	40,500	......	....	....	....	..	.....
b 4	Molasses, 1 gal.; arsenate of lead, 6 lbs.; water, 100 gals. Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs.	" 9, " 15	10	2.8	3.1	44 ± 9	26,600	......	....	....	....	..	.....
c	Not sprayed	......	10	4.0	8.0	154 ±33	93,200	a and b	45 ±16	2.8	....	..	27,200
a	Bordeaux mixture and arsenate of lead	......	20	....	5.2	101 ±15	61,100	a and c	53 ±36	1.5	....	..	32,100
b	Molasses and arsenate of lead	......	20	....	3.2	56 ± 7	33,900	b and c	98 ±34	2.9	....	..	59,300
	L. M. Cary Vineyard, Sheridan.												
1	Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs. (application too late)	July 17	10	4.1	12.9	290 ±18	175,500	1 and 3	104 ±22	4.7	....	..	63,000
2	Molasses, 1 gal.; arsenate of lead, 6 lbs.; water, 100 gals. Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs. (application too late)	" 10, " 17	10	3.7	4.8	90 ±17	54,500	Average (1–3) and 2	148 ±11	13.5	....	..	89,500
3	Not sprayed	......	10	3.4	9.3	186 ±12	112,500		....	....	....	..	.....
Av. (1—3).	See text	......	20	3.8	11.1	238 ±14	144,000	......	....	....	....	..	.....

A summary of the results of the experiments made during 1914 will be considered after the experiments conducted during 1915 have been discussed.

OBSERVATIONS AND FIELD TESTS DURING 1915.

TESTS IN THE VINEYARD OF FRED DENSON, SHERIDAN.

Altho several vineyards were found that were severely infested with the grape root-worm, only one suitable for field tests was available: that of Fred Denson, near Sheridan. This vineyard had been severely infested during 1914 but no treatment had been given, so that the injury was marked and an immense number of beetles appeared in 1915. The soil is Dunkirk clay and the section for the most part sloped gradually to the north, but the northern end was rather abrupt. The rows extended north and south.

The first adults appeared on July 9, but the emergence was slow, and so the majority of beetles did not appear until about one week later. Observations in this vineyard indicated that a systematic error of infestation extended across the section from east to west, therefore the placing of the plats was such that correction could be made for such an error if it appeared in the data; viz, the plats were repeated on either side of the central plat. Furthermore it was desired that the check plat should be least affected by the influence of the sprayed plats, and was also planned to correct for systematic error. This was accomplished by placing the check plat at the ends of the sprayed plats and making it of sufficient size to extend across the section (Fig. 7).

The first application of spray was made on July 20 and 21, followed by the second spray on July 31. A Brown horse-power sprayer was used. The application of the first spray was delayed several days by rain and threatening weather, but by the afternoon of July 20 it appeared that fair weather could be expected for several days, and the spraying was started. However, a trace of rain fell in the evening, which was not sufficient to affect the sprayed vines. The maximum temperature was 82 degrees F. and a very light west wind was blowing. July 21 was partly cloudy, with a maximum temperature of 85 degrees F. and a very light north wind. No rain fell for four days, but from July 26 to 30 the precipitation was 1.29 inches, and this removed the material on the plats sprayed with molasses and arsenate of lead. July 31 was cloudy, with a maximum temperature of 89 degrees and a light northwest wind. On the following day the precipitation was .71 inches, and considerable rain fell for nearly a week. This, however, did not affect the vines sprayed with bordeaux mixture and arsenate of lead sufficiently to influence egg laying by the beetles. The applications given the various plats, and the results of the treatments are shown in Table IX.

It will be noted that no systematic error extended across the plats, as those treated similarly gave nearly the same number of eggs per vine. Furthermore the data obtained in three portions of the check plat were practically the same. In order to make comparisons

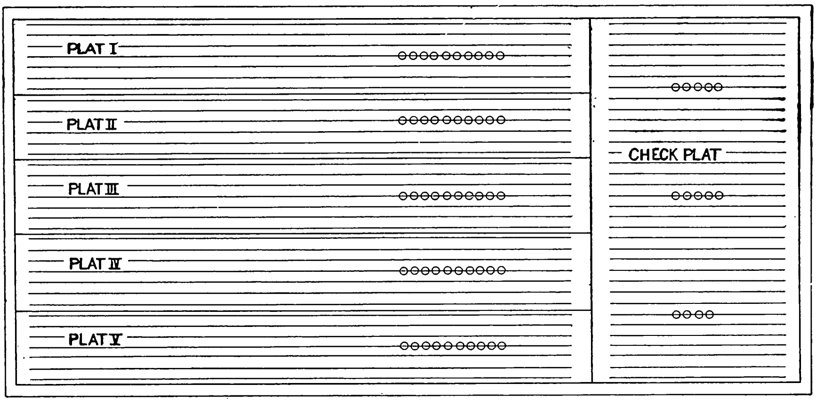


Fig. 7.— Map of Vineyard of Fred Denson, Sheridan, Showing Location of Plats.

between the materials used the plats treated alike are averaged and designated plats *a* and *b*.

The following points are emphasized by the data:

1. All treated plats had a much smaller number of eggs per vine than the check plat, and the differences are highly significant.

2. The plats sprayed with molasses and arsenate of lead followed with bordeaux mixture and arsenate of lead gave lower egg counts than the plat sprayed twice with bordeaux mixture and arsenate of lead. The means of these plats, however, when compared with plat 3 did not give significant differences.

TABLE IX.— DATA SECURED IN VINEYARD OF FRED DENSON, SPRAYED FOR THE CONTROL OF GRAPE ROOT-WORM. SHERIDAN, 1915.

Plat.	Materials Used.	Dates of sprayings.	Number of vines used for egg counts.	Average number of canes per vine.	Average number of egg clusters per vine.	Average number of eggs per vine.	Number of eggs per acre.	Comparisons. Plats compared.	Comparisons. Difference in number of eggs per vine.	Comparisons. Difference divided by its probable error.	Comparisons. Difference in number of eggs per acre.
1	Molasses, 2 gals.; arsenate of lead, 6 lbs.; water, 100 gals.............. Bordeaux mixture (8–8–100); arsenate of lead, 6 lbs....................	July 20 " 31	10	3.2	2.6	45± 9.6	27,200	1 and 4	1.5±11.6	0.1	900
2	Molasses, 1 gal.; arsenate of lead, 6 lbs.; water, 100 gals.............. Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs....................	July 20 July 31	10	4.9	3.8	82.5±16.5	49,900	2 and 5 3 and 6	12.5±22.0 315.0±44.3	0.6 7.1	7,550 190,600
3	Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs....................	July 21 July 31	10	3.3	6.1	101±24.4	61,100	a and 6 b and 6	371.7±37.5 339.7±38.6	9.9 8.8	224,900 205,500
4	Molasses, 2 gals.; arsenate of lead, 6 lbs.; water, 100 gals.............. Bordeaux mixture (8–8–100), arsenate of lead, 6 lbs....................	July 21 July 31	10	2.6	2.8	43.5± 6.5	26,300	a and b a and 3	32.0±12.4 56.7±25.1	2.6 2.3	19,400 34,300
5	Molasses, 1 gal.; arsenate of lead, 6 lbs.; water, 100 gals.............. Bordeaux mixture (8–8–100); arsenate of lead, 6 lbs....................	July 21 July 31	10	4.3	4.3	70.0±14.6	42,350	b and 3	24.7±26.8	0.9	14,900
6	Check..................................	......	14	4.8	18.4	416.0±37.0	251,700	......	....	......	....
a	Average of plats 1 and 4............	......	20	2.9	2.7	44.3± 5.8	26,800				
b	Average of plats 2 and 5............	......	20	4.6	4.1	76.3±11.0	46,200	......	....	......	....

3. The use of two gallons of molasses in the spray reduced the number of eggs to a greater extent than one gallon, but here again the difference is less than three times its probable error which causes some uncertainty to be attached to the results.

4. The favorable control of the grape root-worm with sweetened poison in this vineyard was due largely to the fact that the weather was carefully observed, and the applications made at a time when fair weather was expected for several days, and also that a proper interval of time had elapsed when the spraying with bordeaux mixture and arsenate of lead was made. It may be added that all the applications were made very thoroly.

DISCUSSION OF RESULTS OF EXPERIMENTS DURING 1914 AND 1915.

From the data in Tables VIII and IX the following features are apparent:

Two sprayings with bordeaux mixture and arsenate of lead applied at the proper time gave a marked decrease in the number of eggs as compared with the check plat (Merritt and Denson vineyards).

A single application of bordeaux mixture and arsenate of lead at the proper time caused a decreased number of eggs to be deposited (Benjamin and Station vineyards). However too much emphasis must not be placed on a single application as the results will depend largely on the environment, especially freedom from re-infestation. In the Spoden vineyard a single spray allowed many more eggs to be deposited than on the adjoining plat which received two applications of the same material. In this vineyard bordeaux mixture without poison gave poor results, and also in the Cary vineyard the same mixture with arsenate of lead applied too late, was a failure so far as the control of the root-worm was concerned.

A single spraying with molasses and arsenate of lead gave a decrease in number of eggs over the number found on the check plats (Barnes and Cary vineyards). This practice is not to be recommended, as in previous seasons a single application gave poor control.

Molasses and arsenate of lead followed in a week or ten days by bordeaux mixture and arsenate of lead gave a marked decrease in eggs over the check plat (Merritt and Denson vineyards).

Molasses and arsenate of lead followed in a week or ten days by bordeaux mixture and arsenate of lead in comparison with two applications of the latter mixture decreased the number of eggs in every instance (vineyards of Day, Spoden, Merritt and Denson).

In the Barnes vineyard single applications of the two mixtures gave results in favor of the sweetened poison, but it should be stated that in previous years the reverse was true.

It must be remembered that the favorable results secured from single sprays in 1914 were due to the favorable climatic conditions (lack of rain) which existed for some time after the sprays were applied and that in 1912 and 1913 when more rain occurred during the spraying season the use of a single spray of molasses and arsenate of lead was a failure in every instance.

An application of two gallons of molasses per 100 gallons of mixture gave better control than one gallon (Denson vineyard) but the results are not without uncertainty.

Tests and comparisons of the leading brands of arsenate of lead indicated that, so far as the control of the grape root-worm is involved, no difference exists between the several brands.

DECREASE IN NUMBER OF GRAPE ROOT-WORMS DURING THE PERIOD 1912 TO 1918.

There has been considerable fluctuation in the numbers of *F. viticida*, at various times, since 1900, but usually there were present each year sufficient beetles to cause considerable damage thruout the Chautauqua grape region. Certain years the excessive numbers caused much damage. Since 1912 in the Chautauqua county vineyards there has been a steady decline in the number of adult beetles each summer with a consequent lessening in the number of eggs laid, thus permitting fewer larvæ to feed on the roots. At the present writing there are few vineyards infested sufficiently to demand remedial measures. While all the factors causing these fluctuations are not known, it is believed that so far as the present decline is concerned, several species of ground beetles (Family, Carabidæ) have exerted an important influence. The adults as well as the larvæ (at least of the larger species) of these carnivorous insects eat the grape root-worm. We have observed several severely infested vineyards in which the root-worms later were practically annihilated by the ground beetles. The decrease in numbers of *Fidia* have been so marked as to prevent the continuation of field experiments for their control during the period of 1916 to 1918, inclusive.

MISCELLANEOUS EXPERIMENTS RELATED TO GRAPE ROOT-WORM CONTROL.

EXPERIMENT TO TEST THE EFFECT OF WIND ON THE FLIGHT OF *Fidia viticida.*

The relation of the direction of the wind to the dispersion of the adults of *Fidia viticida* has a practical bearing on the results of treatment, the placing of check plats and on the question of infestation of new vineyards. It has been generally believed that the beetles fly with the wind, and in order to test this point more fully the following experiment was carried out.

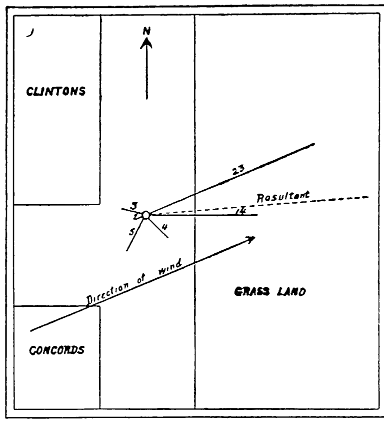


Fig. 8.— Diagram Showing Relation of Apparatus to Environment and Directions Taken by the Beetles.

The length of each line represents the number of beetles going in the direction indicated. Figures are number of beetles observed.

Fifty beetles were captured and placed in a wide mouthed bottle; within fifteen minutes the bottle was set in a saucer of water so as to prevent the beetles from crawling away, and the bottle opened. This apparatus was first placed on the platform of a wagon scale which was on the leeward side and distant about thirty feet from Concord vines. The scales were on the top of an escarpment exposed to the light southwest wind and the land sloped abruptly at least to sixteen feet below the level of the scales. This was at 4 P. M., but the wind appeared to be too strong, and the beetles refused to fly.

On the following day the same outfit was taken to low land, and placed on the ground in the position shown in the diagram (Fig. 8). The nearest vines to the leeward were at least one-eighth of a mile distant, the intervening land being in grass. A row of Clinton grapes was only six feet distant but to the windward, while at nearly a right angle to the direction of the wind and twelve feet distant were Concords. The day was clear, temperature was 75 degrees F. and the time from 10 to 11 A. M. The wind varied in velocity; at times there was a calm for a minute or two, and at no time was the wind strong, being generally from the west-southwest. Twenty-three beetles flew directly with the wind, fourteen flew to the east, four flew at right angles to the wind (i. e., south-southeast) when its velocity was very low. During periods of calm one beetle flew directly opposite to the prevailing wind, three flew to the Clinton grapes and five to the Concords.

The experiment was made on July 19, 1913, during the period of dispersion. From this experiment we conclude: (1) That the general tendency of the beetles is to fly with the wind; (2) that they do not appear to migrate to any extent when the wind is brisk; (3) that Concord vines are considerably more attractive to the grape root-worm than Clintons. This is also corroborated by the fact that the author has never found a Clinton vineyard severely infested by this species. Altho the beetles flew with the wind, and altho there were no vines in sight in this direction, many of them alighting on grass stalks, this does not determine whether they will leave grape vines and fly with the wind without vines being in sight towards which they might fly. The observations of the author would indicate that this does not usually take place, unless there is an abundance of beetles in a vineyard. The more usual tendency in isolated vineyards is for the beetles to remain in a restricted area. This accounts for the fact that such vineyards may be severely infested for a series of years, and the author believes that in such isolated vineyards it is much more difficult to repel the insects from the vines by means of bordeaux mixture and poison than is usually found in infested areas adjoining other vineyards. In such vineyards the author has found that the bordeaux mixture gave poor results in controlling the pest, whereas in vineyards not isolated the same material applied under similar conditions gave excellent results. It is believed that the more usual manner is for the adults, singly — not in swarms — to fly short distances from vine to vine in the direction of the prevailing wind.

Several attempts to repeat this experiment at other seasons, resulted in failures because of the refusal of the beetles to fly. There is the possibility that the dispersion period had not been reached, and so the beetles were disinclined to move about to any great extent.

TESTS WITH ARSENITE OF ZINC.

Arsenite of zinc was one of the new insecticides during 1912, and since it was claimed to possess certain advantages over arsenate of lead tests were made to determine its effect both on Concord grape foliage and on the grape root-worm.

On June 22, 1912, ten vines were sprayed, using arsenite of zinc at the rate of six pounds in 100 gallons of water; and on June 24 ten additional vines were sprayed, using the formula: arsenite of zinc, 6 pounds, molasses, 2 gallons, and water, 100 gallons. The weather was hot and dry until July 11, when there followed a series of rainy and cloudy days until July 14. No injury was apparent on any of the sprayed vines until July 16, but from that date the "burning" became more marked, and by July 26 the vines on both plats dropped all their foliage.

Inasmuch as the preliminary tests with this insecticide showed no injury to the foliage by July 8, on that date we sprayed nearly one acre of Concord vines with the following mixture: arsenite of zinc, 3 pounds, molasses, 2 gallons, and water, 100 gallons. Our object in this test was to determine the effectiveness of this poison in decreasing the number of eggs laid by *F. viticida*. Many dead beetles were found under the vines the following day. However, on July 16 we began to see evidences of injury to the fruit and foliage, and in ten days every vine had had practically all its foliage destroyed and the fruit that was not injured by the spray had shrivelled because of the loss of foliage. The nature of the injury is shown in Plate IX, Fig. 1, and Plate X. The vines were not killed, but it required four seasons of careful handling to bring them to their original vigor and productiveness.

In a nearby vineyard on July 13, during a lull in the rainy period, we applied to Concord grapes 100 gallons of bordeaux mixture (8–8–100) to which was added 2 pounds of arsenite of zinc. Here no injury developed. Further experiments during the same season proved that the excess of lime in the bordeaux mixture counteracted the injurious principle in the arsenite of zinc. We are inclined to the opinion that the lime combined with the arsenic that became soluble during the wet period, and thus protected the vines. The relation of the weather to the injury described is clearly shown. Hot, dry weather permitted the material to produce no effect, while the rains and cloudy weather made conditions favorable for injury to the foliage. Inasmuch as no advantage was indicated for arsenite of zinc over arsenate of lead, and since it has the disadvantage of lack of adhesiveness and uncertainty of safety to grape foliage, no further tests with this material have been made.

THE EFFECT OF MOLASSES ON THE ADHESIVENESS OF ARSENATE OF LEAD.

During the winter of 1912–13 about 500 tests were made with different brands of arsenate of lead and other insecticides, to determine their adhesive properties either alone or with other materials. The tests were made on glass plates, and the washing was accomplished by means of a rose sprinkler in the laboratory. The details of these experiments have been published and the reader is referred to the original article [1] for the description of the apparatus and the methods employed. However, for the purpose of interpreting the data of field tests, the table of characteristic data and the conclusions deduced are herewith reproduced.

From Table X we note (1) that the percentage of material remaining on the plates after sprinkling differs considerably with the different brands of leads; (2) no dry arsenate of lead proved as adhesive as the better adhering paste arsenates of lead; (3) several of the brands of paste arsenate of lead had poorer adhesive qualities than the brands of dry arsenate of lead; (4) in every instance, save one, the addition of molasses to an arsenate of lead lessened its adhesive properties, and this decrease in sticking power was greater in some brands than in others; (5) molasses greatly decreased the adhesiveness of a commercial preparation of bordeaux mixture and arsenate of lead; and (6) cane sugar used in practically the same amount as contained in molasses caused marked lack of adhesiveness in arsenate of lead; therefore we believe that the sugar contained in the molasses is largely responsible for the decreased power of adhesion in the experiments previously reported in this study.

SUMMARY OF CONTROL EXPERIMENTS FROM 1910 TO 1915.

The aims of the field tests described in this bulletin were two: the investigation of the value of bordeaux mixture and arsenate of lead in controlling the grape root-worm; and, the development of

[1] Hartzell, F. Z. The influence of molasses on the adhesiveness of arsenate of lead. *Jour. Econ. Ent.* 11: 62–66. 1918.

TABLE X.— DATA OF ADHESIVE TESTS.

Material applied to plates.	Average amount of material on plates after drying 24 hours and before sprinkling.	Average amount of material on plates after sprinkling and later drying for 24 hours.	Percent of material remaining on plates.	Number of plates used.
	Grams.	Grams.		
Brand A, a paste arsenate of lead without molasses	.0587	.0017	2.9	5
Brand A with molasses	.2632	.0012	*2.0	5
Brand B, a paste arsenate of lead without molasses	.0424	.0024	5.7	5
Brand B with molasses	.1452	.0002	*.5	5
Brand C, a paste arsenate of lead without molasses	.0580	.0509	87.8	5
Brand C with molasses	.1611	.0158	*27.2	5
Brand D, a paste arsenate of lead without molasses	.0353	.0140	39.6	3
Brand D with molasses	.1426	.0046	*13.0	3
Brand E, a dry arsenate of lead without molasses	.0479	.0039	8.1	2
Brand E with molasses	.1814	.0047	*9.8	2
Brand F, a dry arsenate of lead without molasses	.0707	.0079	11.2	2
Brand F with molasses	.2070	.0045	*6.4	2
Brand G, a paste arsenate of lead without sugar	.0546	.0089	16.3	3
Brand G with cane sugar	.1564	.0016	*2.9	2
Brand H, a commercial preparation of Bordeaux and lead without molasses	.0501	.0438	87.4	5
Brand H with molasses	.1840	.0016	*3.2	5

*In the tests in which molasses was added we have assumed that the same amount of insecticide was added that was found on the plate of the same brand without molasses and have calculated the percentage retained using this amount as the base.

a method of using sweetened poison so as to make a more efficient treatment for combating the adults than is bordeaux mixture and poison alone. In attempting to achieve the latter result, owing to the fact that the lack of adhesiveness of the molasses and arsenate of lead spray was not known, reverses were suffered during several seasons. Finally it has been demonstrated that the sweetened spray should be applied when a large number of adults are present and at a time when there are good reasons for expecting fair weather for several days following the spraying, the object being to kill as many of the beetles as possible; then, in about one week follow the treatment with a thoro spraying with bordeaux mixture and arsenate of lead to repel all invading beetles as well as to prevent oviposition by the females remaining in the vineyard.

In all the field tests, two sprayings with bordeaux mixture and arsenate of lead applied thoroly and at the proper time have given effective control. In a few instances, when the infestation was not too intense and also where the danger of re-infestation was not great, a single application of this material has produced a marked reduction in the number of eggs.

The causes of failure to control with bordeaux mixture and arsenate of lead were three: (1) making the applications too late; (2) too long an interval of time between the first and second applications; and (3) lack of thoroness. This last condition has been largely due to efforts to spray when the wind was too strong, poor spraying apparatus or to vines trained so as to allow a clumping of the foliage.

The use of bordeaux mixture without poison was variable in its effects. In a test during 1913 the lack of poison did not permit the deposition of more eggs than where the arsenate of lead was used, but in a similar test in 1914 the lack of poison allowed many more eggs to be deposited than were found on the adjoining bordeaux and lead plat.

A combined spray for the grape leaf-hopper and the grape root-worm was not possible, at least during certain seasons, owing to the fact that the periods for effective control of these two insects do not coincide.

The use of nicotine sulphate with bordeaux mixture and arsenate of lead did not injure Concord grape foliage in any instance.

Twenty pounds of glucose and arsenate of lead with 100 gallons of water did not control the root-worm as effectively as bordeaux mixture and lead. Furthermore, owing to the lack of odor it was not as attractive to the beetles as one gallon of molasses in the same amount of water, and, as it destroys the adhesiveness of the poison to the same extent as molasses, field tests with glucose were discontinued.

The molasses and arsenate of lead spray applied at a time when rains did not occur for several days, followed in a week or ten days with bordeaux mixture and arsenate of lead proved more efficient in combating the grape root-worm than two applications of the latter mixture. Occasionally the omission of the bordeaux mixture and poison after the spraying with molasses and lead was effective, but the practice is very apt to result in failure as happened in the field tests during 1912 and 1913.

The addition of molasses destroys the adhesiveness of the arsenate of lead and the failure to appreciate this fact resulted in lack of control of the root-worm in several vineyards during 1912 and 1913. Another cause of failure was the allowing of too great an interval between the application of the molasses spray and the bordeaux mixture and poison.

Two gallons of molasses to each 100 gallons of spray material decreased the number of eggs per vine considerably more than one gallon both in 1911 and 1915. While the individual differences show some uncertainty the fact that similar results were secured both seasons indicates that considerable confidence can be placed in the data.

Arsenite of zinc when used alone or with molasses seriously injured grape foliage.

RECOMMENDATIONS.

Control of the grape root-worm.— If the beetles are moderately numerous, spray within a week of the appearance of the first adults, using bordeaux mixture (8–8–100) and 6 pounds of arsenate of lead. Repeat the application in about ten days. If, however, the beetles are present in excessive numbers, spray, as soon as the beetles appear in abundance on the vines, with molasses, 2 gallons, arsenate of lead, 6 pounds and water, 100 gallons. The application should be made when the weather conditions are such that no rain is to be expected for three or four days. Spray a second time one week later using bordeaux mixture (8–8–100) and arsenate of lead, 6 pounds All applications should be thoroly made. Inasmuch as the beetles are more active during warm days, better results have been obtained by applying the molasses mixture on such days providing rains were avoided.

Climatic conditions will determine the interval of time between applications. During hot weather the interval should be shorter than during cool periods. Seasons having numerous showers the latter part of June or early July and vineyards whose environment is such as to permit of a continuous re-infestation may make necessary three treatments when the grape root-worm is abundant. Serious re-infestation may be expected where the sprayed vines are to the leeward — judged by the direction of the prevailing wind — of a seriously infested vineyard because the beetles fly with the wind.

The cumulative effect of bordeaux mixture and arsenate of lead upon the number of beetles is marked. Altho this material may not give as decided results as the sweetened spray when used for a single season on a vineyard severely infested with the grape root-worm, nevertheless the use of this material over a period of years in the same vineyard produces an appreciable decrease in the numbers of these beetles.

Materials.— A cheap stock molasses, owing to its more pronounced odor, is to be preferred to the more refined grades.

The better brands or grades of paste arsenate of lead are recommended for the poison in the spraying of grapes because of their adhesiveness and safety to foliage.

The home-made bordeaux mixture was found to be the cheapest and most practical form of this spray to apply. Concentrated prepared bordeaux mixture was found to be less adhesive, more expensive, and did not assist in the control of the beetles as well as the home-made product. The use of substitutes for either bordeaux mixture or arsenate of lead has usually resulted in severe injury to the foliage, and is not recommended except experimentally, and then on only a few vines. Many vineyardists have suffered severe losses from the use of untried preparations. Molasses should not be added to bordeaux mixture as injury to foliage may occur and in addition the latter mixture destroys the attractiveness of the molasses for the beetles.

Use all formulas as recommended. The addition of other substances or the changing of the proportions of the several constituents of a formula may produce injury. A mixture that is safe for another crop may not be safe for the grape. Even different species of grapes vary in their susceptibility to injury from certain preparations. The mixtures recommended above were found to be safe on every variety of grape upon which they were tried.