e
& Insects

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 86.

L. O. HOWARD, Entomologist and Chief of Bureau.

PLANT-BUGS INJURIOUS TO COTTON BOLLS.

BY

A. W. MORRILL, Ph. D.,

Entomologist of the Arizona Horticultural Commission and of the Arizona Agricultural Experiment Station.

Issued June 14, 1910.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

SOME OF THE MORE IMPORTANT PLANT-BUGS WHICH ATTACK COTTON BOLLS.

Fig. 1.—The conchuela (*Pentatoma ligata*). Fig. 2.—The brown cotton-bug (*Euschistus servus*). Fig. 3.—The green soldier-bug (*Nezara hilaris*). Fig. 4.—*Thyanta custator*. Fig. 5.—*Acanthocephala femorata*. Fig. 6.—The leaf-footed plant-bug (*Leptoglossus phyllopus*). Fig. 7.—The bordered plant-bug (*Largus succinctus*). Fig. 8.—The cotton stainer (*Dysdercus suturellus*). Fig. 9.—*Oncopeltus fasciatus*, showing egg of Tachinid parasite attached to upper side of head between the eyes. All enlarged one-third. (Original.)

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 86.

L. O. HOWARD, Entomologist and Chief of Bureau.

PLANT-BUGS INJURIOUS TO COTTON BOLLS.

BY

A. W. MORRILL, Ph. D.,

Entomologist of the Arizona Horticultural Commission and of the Arizona Agricultural Experiment Station.

Issued June 14, 1910.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, *Entomologist and Chief of Bureau.*
C. L. MARLATT, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. CLIFTON, *Executive Assistant.*
W. F. TASTET, *Chief Clerk.*

F. H. CHITTENDEN, *in charge of truck crop and stored product insect investigations.*
A. D. HOPKINS, *in charge of forest insect investigations.*
W. D. HUNTER, *in charge of southern field crop insect investigations.*
F. M. WEBSTER, *in charge of cereal and forage insect investigations.*
A. L. QUAINTANCE, *in charge of deciduous fruit insect investigations.*
E. F. PHILLIPS, *in charge of bee culture.*
D. M. ROGERS, *in charge of preventing spread of moths, field work.*
ROLLA P. CURRIE, *in charge of editorial work.*
MABEL COLCORD, *librarian.*

SOUTHERN FIELD CROP INSECT INVESTIGATIONS.

W. D. HUNTER, *in charge.*

W. D. PIERCE, R. A. CUSHMAN, C. E. HOOD, E. S. TUCKER, *engaged in cotton boll weevil investigations.*
F. C. BISHOPP, J. D. MITCHELL, H. P. WOOD, *engaged in cattle tick life history investigations.*
A. C. MORGAN, G. A. RUNNER, S. E. CRUMB, *engaged in tobacco insect investigations.*
D. L. VAN DINE, *engaged in sugar cane and rice insect investigations.*
F. C. PRATT, *engaged in cactus insect investigations.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., December 13, 1909.

Sir: I have the honor to transmit herewith for publication a manuscript entitled "Plant-bugs Injurious to Cotton Bolls," by Dr. A. W. Morrill, entomologist of the Arizona Horticultural Commission and of the Arizona Agricultural Experiment Station, Phoenix, Ariz. The work upon which this manuscript is largely based was conducted by Doctor Morrill and this report prepared and submitted by him while he was a special field agent of this Bureau. It grew out of an investigation of the so-called "conchuela" of northern Mexico, a plant-bug which has proved to be especially destructive to cotton bolls. The same insect pest was studied further in western Texas, and other species were investigated both there and in other sections of the United States.

Although the injury to the cotton crop effected by plant-bugs is of course secondary to that caused by the boll weevil, yet it is by no means inconsiderable and renders necessary a knowledge of the life histories of these injurious bugs and of the best methods for their control. I would therefore recommend the publication of this manuscript as Bulletin No. 86 of the Bureau of Entomology.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Damage by the boll weevil has brought into prominence many other insects which attack the cotton plant, the work of which has been largely overlooked. Among the most important of these minor insects are various species of plant-bugs. Many of these have been known as enemies of the cotton plant for some years, but they have received only slight attention from economic entomologists. When their damage is added to the injury done by the cotton boll weevil, still further reducing the crop, they become of such importance that full knowledge of their habits and life history is demanded. The studies upon which this bulletin is based were conducted to add to our knowledge of the biology of an important group of insect pests and of the most practical and efficient methods by which they may be controlled.

The plant-bugs with which this bulletin deals, in addition to destroying many cotton bolls and squares, cause more or less staining of the fiber, thus reducing the quality. A large portion of the so-called "spotted cotton," which everywhere suffers a considerable reduction in price below unspotted cotton, is due to the work of plant-bugs. The damage is not confined to any restricted areas, though different species of bugs occur in different parts of the cotton belt. Therefore the damage that is done by these insect pests every year is by no means inconsiderable.

The work accomplished by Doctor Morrill and reported on in this bulletin grew out of an investigation of the Mexican conchuela (*Pentatoma ligata* Say) in northern Mexico. An opportunity was there afforded for a rather careful study of the life history and habits of a representative of the large family of plant-bugs. This was followed by investigations of the same species in western Texas and of other species in other localities. As a result Doctor Morrill's work gives rather complete knowledge of insects the work of which will assume new importance as the area of boll-weevil infestation continues to increase in the United States.

For valuable notes and data on various subjects concerning the conchuela, and especially on its seasonal history, for hearty cooperation in experimental work, and for the facilities which aided in conducting field observations, much credit is due Mr. J. P. Conduit and Mr. J. A. Vaughan, of the Tlahualilo Agricultural Company, Tlahualilo, Durango, Mexico. Mr. B. F. Butler of the same company, manager of the Hacienda San Fernando, Lerdo, Durango, Mexico, furnished valuable information concerning the comparative grading of the cotton staple at infested and uninfested sections of the Laguna district. All of the investigations reported in this paper were conducted by Doctor Morrill, except where special credit has been given in the text. Of the original text figures, numbers 2, 3, 4, 5, 6, 10, 11, 15, 16, 17, and 18 were drawn by Mr. J. F. Strauss, of this Bureau, while the remainder are the work of the author.

W. D. Hunter,
In Charge of Southern Field Crop Insect Investigations.

CONTENTS.

	Page.
Historical review of published writings on plant-bugs injurious to cotton bolls	11
General considerations	13
Nature of injury by plant-bugs	13
Amount of damage to cotton by plant-bugs	20
Plant-bugs as disseminators of plant diseases	23
The conchuela (*Pentatoma ligata* Say)	23
History	23
Distribution	24
Food plants	25
Description	25
Life history	29
Methods of study	29
Adults	29
Period between maturity of adults and beginning of egg laying	29
Reproduction	30
Proportion of sexes	32
Longevity	32
Relation of temperature to activity of adults	35
Eggs	35
Period of incubation	35
Proportion hatching in the laboratory	37
Effect of low temperature on vitality	38
Hatching	38
Nymphs	39
Duration of nymphal stages	39
Length of life without food	40
Molting	41
Habits	41
Nymphs	41
Adults	43
Fertilization	43
Egg laying	43
Feeding	44
Gregariousness	47
Flight	48
Seasonal history	48
Increase and decrease in numbers during the season	48
Hibernation	53
Destructiveness	55
Individual capabilities	55
Reduction in yield of infested cotton fields	57
Effect of plant-bug attack on quality and market value of lint	61

The conchuela—Continued. Page.
Natural control 62
Weather influences 62
Parasites attacking eggs 62
Parasites attacking adults and nymphs 64
Predatory enemies 64
Artificial control 67
Preventive measures 67
Field measures 68
Hand-picking 68
Other methods of collecting bugs from cotton plants 72
Contact insecticides 72
Trap crops and attraction to lights 72
The grain bug (*Pentatoma sayi* Stål) 73
Pentatomid bugs of the genus Euschistus 74
Pentatomid bugs of the genus Nezara 78
Pentatomid bugs of the genus Thyanta 84
Other Pentatomids frequenting or attacking cotton 87
Insects of the squash-bug family (Coreidæ) injurious to cotton 88
Insects of the leaf-bug family (Capsidæ) injurious to cotton 92
Insects of the chinch bug family (Lygæidæ) injurious to cotton 93
Insects of the cotton stainer family (Pyrrhocoridæ) injurious to cotton 94
Methods of control for general application 98
Farm practice and cultural methods 98
Direct methods of combating plant-bugs in cotton fields 99
Index 101

ILLUSTRATIONS.

PLATES.

Page.

PLATE I. Some of the more important plant-bugs which attack cotton bolls. Fig. 1.—The conchuela (*Pentatoma ligata*). Fig. 2.—The brown cotton-bug (*Euschistus servus*). Fig. 3.—The green soldier-bug (*Nezara hilaris*). Fig. 4.—*Thyanta custator*. Fig. 5.—*Acanthocephala femorata*. Fig. 6.—The leaf-footed plant-bug (*Leptoglossus phyllopus*). Fig. 7.—The bordered plant-bug (*Largus succinctus*). Fig. 8.—The cotton stainer (*Dysdercus suturellus*). Fig. 9.—*Oncopeltus fasciatus*, showing egg of Tachinid parasite attached to upper side of head between the eyes.......... Frontispiece.

II. Effects of plant-bug attack on cotton bolls. Fig. 1.—Boll with section of carpel removed to show plant-bug injury. Fig. 2.—Portion of full-grown cotton boll showing lock of cotton ruined by destruction of seed at apex by *Thyanta custator*. Fig. 3.—Lint partly removed from seeds to show discoloration by cotton stainer (*Dysdercus suturellus*). Fig. 4.—Decay of seeds in immature cotton boll as a result of feeding by plant-bugs; no external evidence of injury. Fig. 5.—Exterior of cotton boll injured by *Calocoris rapidus*. Fig. 6.—Cross section of immature cotton seed damaged by Pentatomid bugs. Fig. 7.—Inside of carpel of cotton boll showing feeding punctures by plant-bugs. Fig. 8.—Cotton boll showing external spots referred to on page 16.......... 16

III. Effects of plant-bug attack on cotton bolls; egg and puparium of Tachinid parasite. Fig. 1.—Locks of a cotton boll shriveled by the conchuela. Figs. 2–5.—Small Sea Island cotton bolls destroyed by the cotton stainer. Fig. 6.—Nearly mature Sea Island cotton boll opened to show damage by cotton stainer. Fig. 7.—Same, with seeds and lint removed to show feeding punctures and proliferation due to feeding by cotton stainer. Fig. 8.—Cotton boll showing two locks damaged by four and six feeding punctures, respectively, by the green soldier-bug (*Nezara hilaris*). Fig. 9.—Head and thorax of the conchuela, showing egg of Tachinid parasite, *Gymnosoma fuliginosa*, attached to side of prothorax at left. Fig. 10.—Puparium of Tachinid parasite, *Gymnosoma fuliginosa*.. 18

IV. A cotton plant, showing the bolls injured by the conchuela.......... 18

V. Fig. 1.—Egg-batch of conchuela, showing hatched and unhatched eggs. Fig. 2.—Egg-batch of conchuela from which 32 Proctotrypid parasites (*Telenomus ashmeadi*) have emerged.......... 26

TEXT FIGURES.

FIG. 1. The conchuela (*Pentatoma ligata*): Adult, egg-mass, eggs.......... 26

2. The conchuela: Nymph, first instar.......... 27

3. The conchuela: Nymph, second instar.......... 27

4. The conchuela: Nymph, third instar.......... 28

	Page.
FIG. 5. The conchuela: Nymph, fourth instar	28
6. The conchuela: Nymph, fifth instar	29
7. Diagram of a portion of the Tlahualilo Cotton Estates	50
8. *Telenomus ashmeadi*, an important parasite of the conchuela (*Pentatoma ligata*)	63
9. Plan for the construction of a collecting can for use in hand-picking cotton plant-bugs	69
10. The grain bug (*Pentatoma sayi*): Nymph, first instar	72
11. The grain bug: Nymph, fifth instar	73
12. The brown cotton-bug (*Euschistus servus*): Nymph, first instar	74
13. The brown cotton-bug: Nymph, fifth instar	75
14. The green soldier-bug (*Nezara hilaris*): Nymph, first instar	78
15. The green soldier-bug: Nymph, fifth instar; light and dark types	79
16. *Nezara viridula:* Nymph, fifth instar; light and dark types	83
17. *Thyanta custator:* Nymph, first instar	84
18. *Thyanta custator:* Nymph, fifth instar; light and dark types	85
19. The leaf-footed plant-bug (*Leptoglossus phyllopus*): Adult	88
20. The northern leaf-footed plant-bug (*Leptoglossus oppositus*): Eggs and adult	90
21. The northern leaf-footed plant-bug: Nymphs	90
22. *Trichopoda pennipes*, a Tachinid parasite of Coreid plant-bugs	92
23. The cotton leaf-bug (*Calocoris rapidus*): Nymphs and adult	93
24. The bordered plant-bug (*Largus succinctus*): Nymph, first instar	94
25. The bordered plant-bug: Nymph, fifth instar	95

PLANT-BUGS INJURIOUS TO COTTON-BOLLS.

HISTORICAL REVIEW OF PUBLISHED WRITINGS ON PLANT-BUGS INJURIOUS TO COTTON BOLLS.

For reasons hereinafter explained, comparatively little has been written concerning insects of the suborder Heteroptera (better known as plant-bugs) in relation to their damage to cotton. The earliest records of this kind are found in the writings of Townend Glover. In the U. S. Agricultural Report for 1854,[a] in a short article on insects infesting the cotton plant, Glover writes: "Several insects (Pentatoma and Anisoscelis) were very abundant in the cotton fields, both on the bolls and leaves, which have been accused of piercing the young bolls for the sake of the juice, but as none were observed in the act it can not be stated definitely whether they actually do harm or not, before their habits have received further investigation." In the report published for the following year (1855)[b] the same writer gives a brief account of many insects which frequent the cotton plant, and refers to the rotting of bolls as possibly due to the feeding of plant-bugs, mentioning especially two Pentatomids, one apparently *Nezara hilaris* Say, and the other apparently of the genus *Euschistus*, as also a Coreid, which, judging from the description and drawing, is *Leptoglossus phyllopus* L. The cotton leaf-bug (*Calocoris rapidus* Say), which in 1903 and 1904 proved to be of considerable importance as a cotton pest in certain sections of Texas, was here first recorded in this connection and nearly two pages in this report were devoted to the well-known "red bug" or cotton stainer (*Dysdercus suturellus* H. Schf.), an account being given of its occurrence and depredations on cotton in Florida. The report for the year 1858[c] contains additional notes on this latter pest. No writings concerning Heteropterous insects attacking cotton bolls, published between the date of this last-mentioned report and that for the year 1875, are known to the writer. In Glover's report for 1875[d] the cotton

[a] Agricultural Report for 1854, p. 61.

[b] Agricultural Report for 1855, pp. 86–87, 93–95, 103–105.

[c] Agricultural Report for 1858, pp. 271–273.

[d] Report of Commissioner of Agriculture for 1875, p. 124.

stainer is again referred to. The same author in 1878[a] figures and mentions certain Heteroptera found on cotton, including *Nezara pennsylvanica* De Geer, *Euschistus punctipes* Say, and *Leptoglossus phyllopus* L. Professor Comstock, in his report for 1879,[b] reviews what was then known about the cotton stainer and gives an account of its first appearance as an orange pest, stating that the principal injury to this fruit was done where cotton was planted in close proximity to the orange groves. In Professor Comstock's Report on Cotton Insects,[c] published in 1879, the green soldier-bug (*Nezara hilaris*) is credited with being more or less beneficial in cotton fields, owing to its reported destruction of cotton worms. The report of Mr. E. A. Schwarz of the destruction of cotton in the Bahamas by *Dysdercus suturellus* as observed by him in 1879[d] is of special interest on account of his description of the injury caused by this insect, and will be referred to again in discussing the nature of the injury caused by Heteropterous pests. In 1889 Riley and Howard[e] gave the most complete account of the cotton stainer that has been published. Insect Life, in 1890,[f] contains a brief note to the effect that a correspondent of the Division of Entomology had sent in specimens of the green soldier-bug (*Nezara hilaris*), reporting that they were damaging cotton in Florida. Mr. F. W. Mally, in 1893,[g] in his report on the bollworm of cotton briefly described injury to cotton by *Calocoris rapidus* and *Largus cinctus* H. Schf. In a paper entitled "Notes on cotton insects found in Mississippi," published in 1895,[h] the late Dr. Wm. H. Ashmead gave brief notes on a number of Heteroptera which he had collected on cotton, including several actually observed feeding on the boll. A report of damage to cotton in Peru by one of the cotton stainers (*Dysdercus ruficollis*) was noted by Dr. L. O. Howard in 1900,[i] in a Miscellaneous Results bulletin of this office, and a similar report of damage by the St. Andrews cotton stainer in Cuba was noted by Mr. W. D. Hunter,[j] in a bulletin of the same series published in 1902. Extensive damage to cotton in Mexico in 1903 by the Pentatomid bug known as the conchuela (*Pentatoma ligata* Say) led the following year to a preliminary investigation of this pest, which was reported by the author in a previous bulletin of this

---

[a] Manuscript Notes from My Journal, Pl. XVI.
[b] Report of Commissioner of Agriculture for 1879, pp. 203–204.
[c] Report on Cotton Insects, p. 167.
[d] Report on Cotton Insects, pp. 348–349.
[e] Insect Life, Vol. I, pp. 234–241.
[f] Insect Life, Vol. III, p. 403.
[g] Bul. 29, Div. Ent., U. S. Dept. Agr., p. 31.
[h] Insect Life, Vol. VII, pp. 320–321.
[i] Bul. 22, Div. Ent., U. S. Dept. Agr., p. 100.
[j] Bul. 38, Div. Ent., U. S. Dept. Agr., p. 106.

Bureau.[a] Prof. E. D. Sanderson during the same year conducted observations on miscellaneous cotton insects in Texas, including several of the Heteroptera. The results of his work on this subject have been incorporated in a Farmers' Bulletin of the Department of Agriculture[b] and in a regular bulletin of this Bureau.[c] Plant-bugs attacking cotton in the Bismarck Archipelago and in German East Africa have been considered by Dr. Th. Kuhlgatz in a publication of the Berlin Zoological Museum in 1905.[d] This report contains but few field notes outside of records of food plants. A valuable report on cotton stainers in the West Indies was published by Mr. H. A. Ballou in 1906.[e]

GENERAL CONSIDERATIONS.

NATURE OF INJURY BY PLANT-BUGS.

In beginning the investigation of plant-bugs destructive to the cotton boll one of the first steps found to be necessary was a study of the nature of the injury itself so that it might be identified positively or at least with reasonable certainty. As a result it has been more and more impressed upon the author that to the lack of an accurate knowledge of this subject is due the almost complete ignoring of these insects as cotton pests. In general the connection between the insects and the damage which results from their attacks is very obscure to the casual observer, and consequently seldom suspected. Even to an entomologist the damaged boll when dry gives by itself no direct evidence of the cause of its condition without reference to a field demonstration of the relation between the insects and the stained or shriveled locks.

PUBLISHED DESCRIPTIONS OF THE EFFECT OF PLANT-BUG ATTACK ON COTTON BOLLS.

In Glover's brief publication on this subject in the U. S. Agricultural Report for the year 1855 is to be found the earliest mention of plant-bugs—Pentatomids and Coreids—as possible producers of "rot" in cotton bolls and also of the nature of injury by the cotton stainer. This discussion, of the damage to cotton caused by the Coreidæ, is the most complete that has been published, and in fact all later references to the subject are based directly or indirectly upon this except the report of Mr. Schwarz's observations in the Bahamas and the recent report by Mr. Ballou. Heretofore it seems to have been the popular belief in Florida that the principal damage to the

[a] Bul. 54, Bur. Ent., U. S. Dept. Agr., pp. 18–34.

[b] Farmers' Bul. 223, U. S. Dept. Agr., pp. 20–21.

[c] Bul. 57, Bur. Ent., U. S. Dept. Agr., pp. 44–49.

[d] Mittheilungen aus dem Zoologischen Museum in Berlin, III Band, 1 heft, pp. 31–114.

[e] West Indian Bulletin, Vol. VII, No. 1, pp. 64–85.

cotton was through the staining of lint in the open bolls by the excrement of these insects. In this connection it seems well to refer to the common belief among the natives of that part of Mexico where the conchuela has been so destructive, that the damage to the cotton is effected by the voiding of excrement upon the lint and unopened bolls. The author can state positively that such a belief is unfounded in this instance, and that he is, moreover, disposed to look carefully into the source of all such similar suppositions before accepting them as entirely credible. Glover quotes at length a communication from a Sea Island cotton grower in Florida who shows himself to be a careful observer, capable of distinguishing between fact and theory. This correspondent states: "The pod or boll is perforated by the bug. Whether the staining matter is imparted to the fiber of the cotton during the perforation directly or by a slow process diffusing itself with the sap abounding at the time in the pod is not yet ascertained. I am of the latter opinion, *from the fact that almost the entire product of the boll is discolored when it opens*, which does not seem at all to cause a premature development."[a] As opposed to this source of the discoloration Glover merely states: "It has been stated by other planters that the fæces of the insect produce the reddish or greenish stain." Three years later the same author states[b] concerning the injury by the cotton stainer: "It drains the sap from the bolls by its puncture, causing them to become diminutive or abortive, but the principal injury it does is by sucking the juice of the seed and boll and then voiding an excrementitious liquid, which stains the cotton fiber yellow or reddish, and very much depreciates its value in the market, the stains being indelible." This description of the injury, as well as the descriptions presented in the later writings of Glover and others on the cotton stainer in Florida, seems to be based on the first account of the insect damage from which the above quotations were made. In 1879 Mr. E. A. Schwarz,[c] in a report on insects injuring cotton in the Bahamas, refers to the cotton stainer of the Bahamas, later identified as belonging to the same species which occurs in this country. He states regarding its injury: "It punctures the green bolls, thus preventing them from opening; the bolls wilt and finally dry up, the half-formed cotton and dried-up seeds giving food to a number of other insects; more often the cotton-bug crowds in the half or not quite half open bolls, sucking the seeds, thus preventing the cotton from blowing, or at least renders the cotton yellow and unfit for use." As these observations extended over a period of less than ten days, they do not disprove the statements of Glover's

[a] Italics are mine.—A. W. M.

[b] Agricultural Report, 1858.

[c] Report upon Cotton Insects, pp. 347–349.

correspondent that the discoloration appears as soon as the boll opens.

Following the foregoing accounts the next reference to the nature of plant-bug damage, so far as known to the writer, is a brief description of damage to cotton in Egypt by a Lygæid, *Oxycarenus hyalinipennis* Costa, published in 1890.[a] This description, which is credited to Dr. E. Sickenberger, states that these insects "suck the sap from the base of the young pods and from the blossoms and thus prevent their development; they attack also the seeds when they are tender, which results in a diminution of the germinative strength and consequently a diminution in the product of the plant." A staining of the lint is also mentioned but the exact method by which this injury is brought about is unexplained.

The cotton leaf-bug (*Calocoris rapidus* Say) and the bordered plant-bug (*Largus succinctus* L.) are reported by Mr. F. W. Mally[b] to damage cotton bolls, leaving a small, round, black dot at the point of the puncture. He says: "The injury nearly always has the effect of causing the boll to '*flare*' and drop, or if not, then the tuft of cotton in that section of the boll becomes stained." The first accounts of damage to cotton bolls, with Heteropterous insects determined as the cause by definite experimental work, were published in 1905, Prof. E. D. Sanderson describing the injury caused by *Calocoris rapidus*, and the present writer the injury by the conchuela, *Pentatoma ligata* Say. Concerning the former Professor Sanderson[c] says: "It punctured the squares and young bolls, either causing them to drop or making the bolls shrivel or decay where punctured. The punctures in the boll are indicated by small round black spots resembling diseased places, which gradually become larger and sunken." The fullest consideration heretofore published of the nature of the injury caused by the cotton stainers is found in the recent paper by Mr. H. A. Ballou, previously referred to. This author reports no personal observations concerning the staining of cotton lint by the excrement of the bugs but mentions the probability of injury through the feeding of the insects on immature bolls and, later, on the seed at time of the opening of the bolls.

EXTERNAL EVIDENCE OF PLANT-BUG INJURY.

As the leaf-bug (*Calocoris rapidus*) is sometimes present in considerable numbers in cotton fields where no external evidence of injury such as described by Professor Sanderson can be found, it seems likely that the sunken spots on the outside of the boll, resembling some diseased condition, are not a necessary accompaniment of

---

[a] Insect Life, Vol. III, p. 68, 1890.

[b] Bul. 29, o. s., Div. Ent., U. S. Dept. Agr., p. 31, 1893.

[c] Farmers' Bulletin 223, p. 20, 1905.

this insect-damage (Pl. II, fig. 5). However, the fact that they have been produced in some cases differentiates the injury by this Capsid from that of all Pentatomids, Coreids, and Pyrrhocorids which has come under the writer's observation. Investigations during the past two years in many sections of Texas and in northern Mexico with representatives of these three last-mentioned families of Heteroptera have failed to show a direct connection between spots of any kind on the outside of the carpels of the injured bolls and the insect's punctures. In nearly all cotton fields bolls can be found which are marked with reddish or brownish spots (Pl. II, fig. 8), more frequently seen on the parts of the boll not covered by bracts, and never showing on the inside of the carpels. It is apparently an evidence of a physiolog-cal disorder of little or no consequence, but in some cases these spots have appeared to bear a relationship to the condition of the developing lock. To determine if any such relationship existed in the case of green bolls damaged by plant-bugs, 100 bolls were examined, with the following results:

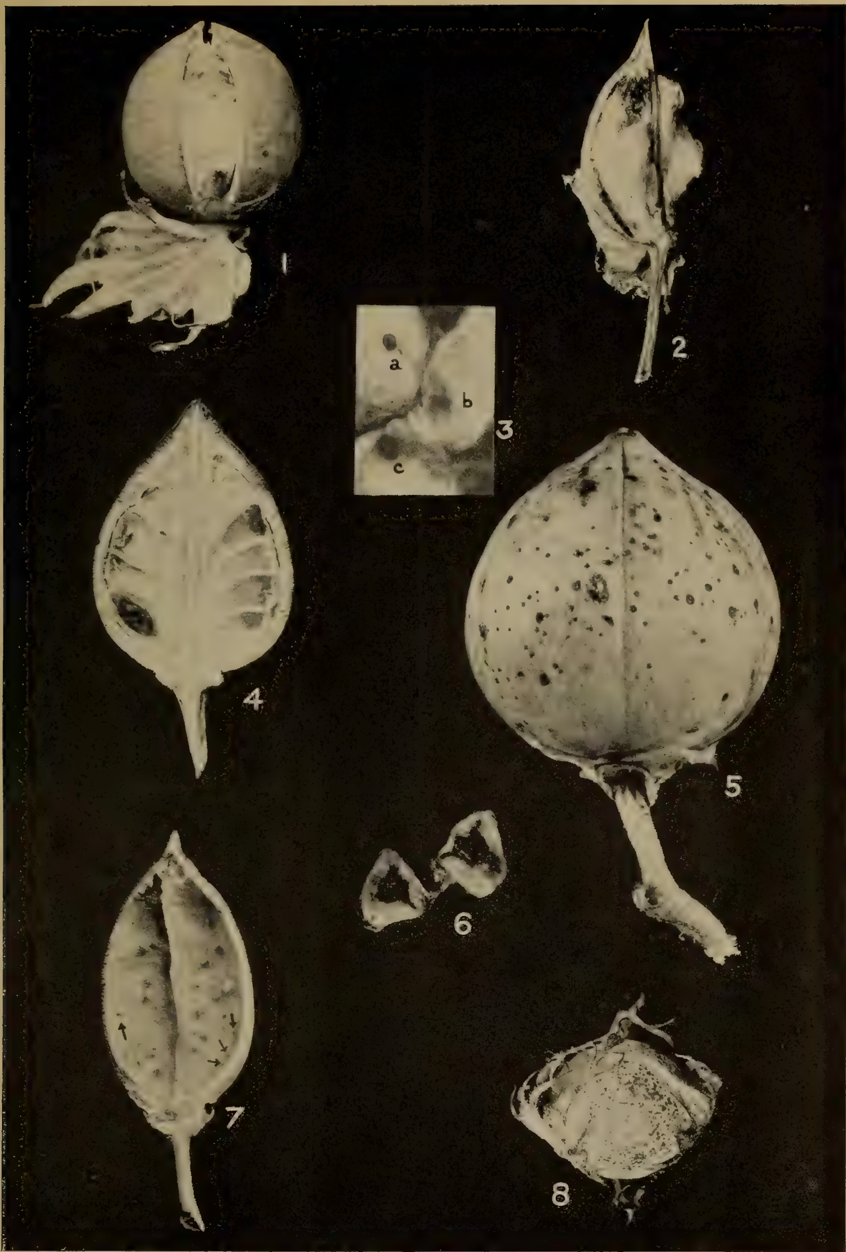
Average number of spots in 25 bolls with slightly stained locks	2.24
Average number of spots in 75 bolls with badly stained locks	3
Percentage of badly stained bolls without spots	10
Percentage of slightly stained bolls without spots	46

A second lot of green bolls picked from plants on July 11, 1905, was examined and the results are here presented in tabular form.

TABLE I.—*Relation of external spots to plant-bug injury of cotton bolls.*

Number of external spots.	Number of bolls.	Number of bolls damaged.	Number of bolls uninjured.
More than one	17	17	0
One	11	9	2
None	10	7	3
Total	38	33	5

The punctures may be through the spot, but this is entirely accidental. One boll of the above lot showing over 60 conchuela punctures was found to have but three small external spots, while the carpel of the lock most severely damaged was entirely free from discoloration. Among those examined which showed but one external spot, several were as badly damaged as any of the entire number. From the foregoing observations we may conclude that the spots here referred to with which every cotton grower is familiar do not bear a direct relation to punctures by plant-bugs, for the spots may be present on bolls which show no punctures, which in all cases are detectable when present as hereafter described, and may be absent on badly damaged bolls. They are shown, however, to have a secondary



EFFECTS OF PLANT-BUG ATTACK ON COTTON BOLLS.

Fig. 1.—Boll with section of carpel removed to show plant-bug injury. Fig. 2.—Portion of full-grown cotton boll, showing lock of cotton ruined by destruction of seed at apex by *Thyanta custator*. Fig. 3.—Lint partly removed from seeds to show discoloration by cotton stainer (*Dysdercus suturellus*); *a*, Seed and attached lint from uninjured boll; *b–c*, same from boll damaged by cotton stainer, showing lint stained deepest close to seed. Fig. 4.—Decay of seeds in immature cotton boll as a result of feeding by plant-bugs; no external evidence of injury. Fig. 5.—Exterior of cotton boll injured by *Calocoris rapidus*. Fig. 6.—Cross section of immature cotton seed damaged by Pentatomid bugs. Fig. 7.—Inside of carpel of cotton boll, showing feeding punctures by plant-bugs. (Arrows point to punctures without proliferation.) Fig. 8.—Cotton boll showing external spots referred to on page 16. (Original.)

relationship in that they occur with greater frequency on bolls injured by plant-bugs than on those entirely free from injury from this source.

Although no external discoloration in the form of spotting of the bolls is known to result directly from the attacks of the representatives of the Heteropterous families thus far studied, and included in this discussion, there is frequently present more or less reliable external evidence of damage. Bolls when severely attacked by plant-bugs may flare, turn yellowish, become flaccid, and finally fall to the ground. This has been observed to take place in bolls as large as 1⅛ inches in diameter, although it more often occurs in bolls which have attained less than one-half of the normal mature size than in larger bolls. Occasionally a deformity results from the destruction of one lock when the boll is quite small, but this frequently occurs when there is no evidence to connect the deformity with plant-bugs. In addition to these physical changes in the boll, it has been observed with several of the plant-bugs that damaged bolls may be detected in many cases by the yellowish stain produced on the bracts and carpels by the liquid excrement.

INTERNAL APPEARANCE OF BOLLS DAMAGED BY PLANT-BUGS.

Description.—Plant-bug injury to cotton bolls can be positively determined only by means of an internal examination. This subject was treated in the author's report[a] of preliminary investigation of the conchuela in northern Mexico, but additional observations allow of a more complete consideration at this time. While these observations are for the most part based on the conchuela, it has been found that the same effects result from the attacks of the other representatives of the Pentatomidæ, as well as the representatives of Coreidæ and Pyrrhocoridæ upon which studies have been made. The most essential factor in determining injury to cotton bolls by these plant-bugs is the appearance of the inner side of the carpels (Pl. II, fig. 7), where the point of entrance of the insect's setæ is marked by a minute dark spot surrounded by a watery or blisterlike, bright-green area, contrasting distinctly with the light, dull-greenish background. In many cases, particularly in bolls three-quarters grown or more, these blisterlike areas increase to a diameter of 4 or 5 millimeters, but in other cases, more especially in small, rapidly growing bolls, a physiological reaction in the form of a proliferation of plant tissue takes place. This proliferation (Pl. III, figs. 6–8) is of the same nature as that which results from the puncturing of the carpels of the bolls by boll weevils, described by Hunter and Hinds in a previous bulletin of

[a] Bul. 54, Bur. Ent., U. S. Dept. Agr., pp. 29–30, 1905.

this Bureau.[a] That this abnormal growth may be caused by the punctures of Heteropterous insects was first pointed out by the author in his report of preliminary investigations of the conchuela.[b] Since then, in the course of more extended investigations of this and other Heteropterous cotton pests, incidental observations on this point have been made by the writer, a summary of which will be found in a publication by Dr. W. E. Hinds dealing with the relation of the proliferation to the cotton boll weevil.[c] When caused by the boll weevil, this growth can be easily distinguished from that caused by Heteropterous insects by the distinct open puncture which extends through from the outside of the carpel. The entire inner side of the carpels of bolls damaged by plant-bugs is frequently found on examination to present a rough or papulous surface due to the fact that the punctures are so close to one another that the proliferous growths merge together. At Tlahualilo, Durango, Mex., on July 17, 1905, an examination of 100 injured bolls revealing over 4,000 punctures by plant-bugs (practically all by *Pentatoma ligata*) developed the fact that 34 per cent of the punctures had resulted in proliferation. On November 1, 1905, an examination of 25 bolls at Dallas, Tex., from a field where three species of Pentatomidæ (*Nezara hilaris*, *Euschistus servus*, and *Thyanta custator*) occurred in considerable numbers, gave the following results in regard to proliferation, using the lock as the unit:

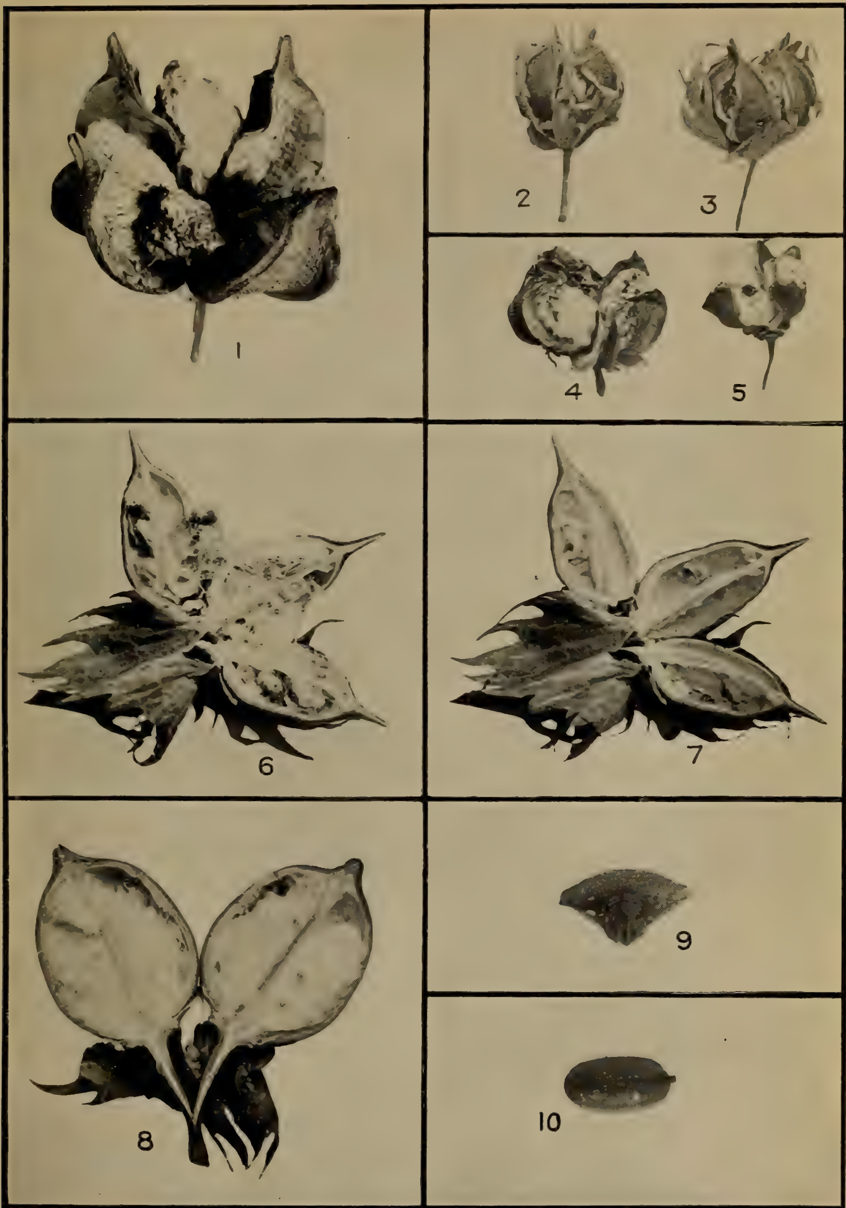
TABLE II.—*Proliferation on inside of carpels of locks fed upon by Pentatomids.*

Size of bolls (diameter).	Locks.					
	Number.	Number showing prolifera-tion.	Per cent showing prolifera-tion.	Destroyed by plant-bugs.	Slightly injured.	Unin-jured.
Inches.						
$\frac{1}{2}$–$\frac{7}{8}$	60	42	70	39	3	0
1 –$1\frac{1}{4}$	40	11	27	8	3	[a]2
Total.....	100	53	....	47	6	2

[a] Inside carpels showing three and four punctures, respectively—no apparent injury.

The objective point of the attack by insects investigated is the seed, which they are able to reach with little difficulty by means of the threadlike organs of their mouth-parts, except in large, nearly mature bolls which are protected by the resistance offered by the lint. Except in the larger sized bolls, therefore, a blisterlike spot or prolif-

[a] Bul. 51, Bur. Ent., U. S. Dept. Agr., 1905.
[b] Bul. 54, Bur. Ent., U. S. Dept. Agr., p. 29, 1905.
[c] Bul. 59, Bur. Ent., U. S. Dept. Agr., p. 29, 1906.



EFFECTS OF PLANT-BUG ATTACK ON COTTON BOLLS; EGG AND PUPARIUM OF TACHINID PARASITE.

Fig. 1.—Locks of a cotton boll shriveled by the conchuela. Figs. 2-5.—Small Sea Island cotton bolls destroyed by the cotton stainer. Fig. 6.—Nearly mature Sea Island cotton boll opened to show damage by cotton stainer. Fig. 7.—Same with seeds and lint removed to show feeding punctures and proliferation due to feeding by cotton stainer. Fig. 8.—Cotton boll showing two locks damaged by four and six feeding punctures, respectively, by the green soldier-bug (*Nezara hilaris*). Fig. 9.—Head and thorax of the conchuela, showing egg of Tachinid parasite, *Gymnosoma fuliginosa*, attached to side of prothorax at left. Fig. 10.—Puparium of Tachinid parasite, *Gymnosoma fuliginosa*. (Original.)

A COTTON PLANT SHOWING THE BOLLS INJURED BY THE CONCHUELA.

The cotton plant shown bears 76 bolls, all but 10 of which have been destroyed by this insect. (Original.)

eration on the inner side of the carpel, such as has been described, indicates an injury to the seed or discoloration of the lint directly opposite. When a seed of a rapidly growing boll is fed upon at first the stimulation, probably partly mechanical and partly due to salivary fluids of the bug, causes an increase in the flow of sap to the injured seed, causing a characteristic watery appearance. The seed afterwards gradually becomes discolored (Pl. II, figs. 4, 6) and proliferous tissue is extruded from it in some cases. Punctures near the tip of the lock are most effective in destructiveness; in one case (Pl. III, fig. 8) 4, 6, 16, and 10 punctures per lock, respectively, were found to have produced proliferation from the seed nearest the tip of the boll in each lock and would have prevented the opening out of the cotton if it had been allowed to mature. This is equivalent to complete destruction of the boll. The lint surrounding the point where the insect's mouth-parts enter turns yellowish, and, if the injury is severe, finally becomes a dirty brown and decays (Pl. II, figs. 1, 2; Pl. III, figs. 1–8), which probably is the condition Glover referred to as "the rot."

As the great majority of the punctures are made on the outer half of the bolls, it is there that staining is most frequently found.

In general bolls damaged by plant-bugs when open (Pl. III, figs. 1–5; Pl. IV) are characterized by shriveled locks and only partial spreading of the carpels. The entire lock may become a brownish shriveled mass or the shriveling may be confined to the outer tip. Again, locks may be perfect except for a small stained patch of lint, which, however, might offset the value of the unstained product. Seeds in nearly mature bolls may be destroyed without the surrounding lint becoming badly stained. Consequently where Heteropterous cotton pests are abundant, there is a reduction in the percentage of seed capable of germinating. This phase of the subject of plant-bug damage has received no especial attention.

Proof that described injury is due to plant-bugs.—The evidence that plant-bugs cause injury such as described above amounts to positive proof. Sufficient evidence was given by the author in a previous report and, although much more might be added, it is unnecessary to more than summarize the facts there presented:

1. In a field where the number of conchuelas averaged about 15 per acre and the number of other plant-bugs was a negligible quantity, a specimen of the species named (*Pentatoma ligata* Say) was known to have fed on a single boll for over 36 hours. After several days, during which no bugs were found on this plant, the 15 bolls found on this plant were cut open and examined, with the result that only the one upon which the insect was known to have fed showed the injury described.

2. In the same field two plants upon which 4 and 3 adult conchuelas, respectively, were found, neighboring plants in all directions, being free from the pest at the time, were found to be injured to the extent of 7 bolls out of 15 examined, and 18 bolls out of 20 examined, respectively, while as a check the bolls on the next adjacent plant in the row to each of the foregoing were examined and but 3 injured bolls were found out of a total of over 30.

3. The injury to the bolls which has been described as due to plant-bugs was invariably found in sections of a cotton plantation comprising 27,000 acres, where the conchuela was also found; but in a section where no plant-bugs could be found, although careful search was made for them, no injury of this kind was observed.

4. Cage tests, consisting in the confinement of several adult conchuelas on two plants in a field where no plant-bugs of any kind could be found and where an examination of many bolls indicated entire absence of the supposed plant-bug injury, resulted in 20 bolls of a total of 34 on the caged plants showing the injury a few days later when an examination was made.

AMOUNT OF DAMAGE TO COTTON BY PLANT-BUGS.

It is very probable that each year since cotton has been grown in this country certain localities have suffered from injuries by plant-bugs to the cotton bolls. The cotton stainer (*Dysdercus suturellus*) for many years has been the most serious enemy with which the growers of Sea Island cotton in Florida have had to contend, and the same pest Mr. Schwarz in 1879 (l. c.) declared to be the most formidable enemy of cotton culture in the Bahamas, making questionable the possibility of continued cotton growing on those islands. Professor Sanderson's reference to the damage by the leaf-bug (*Calocoris rapidus*) shows this insect to be capable of considerable destruction to cotton bolls, although no estimate of the amount destroyed has been made.

In the Laguna District of Mexico—the leading cotton-growing section of that Republic—the conchuela accompanied by related pests of less frequent occurrence has been more or less destructive to cotton during the past few years. A specimen of the insect named was sent to this Bureau in August, 1902, from Mexico, by Dr. A. Dugés with the note that it was injurious to cotton at San Pedro de la Colonia, Coahuila, Mexico. In 1903 the same pest attracted considerable attention on account of its unusual abundance in the cotton fields of the Laguna District, particularly those near Tlahualilo, a settlement located in the State of Durango about 50 miles from San Pedro de la Colonia. After investigation by the author it was conservatively estimated that the damage to the crop for the season 1903–4 was between 10 and 15 per cent. This loss on the one plantation according to this estimate was between 1,200 and 1,500 bales. A study was made of the losses occasioned by these pests in 1905 on the above-mentioned plantation, and the results in detail are considered under the subject of "Destructiveness" of the conchuela. Briefly, this damage on the entire plantation approximated between 5 and 10 per cent, and for one section of 120 acres where the bugs had been most abundant, the destruction as estimated December 4–6, 1905, amounted to 30 per cent of all bolls, including unopened bolls, and 41 per cent of all bolls open at that time.

In this country damage by plant-bugs, with the exception of that by the cotton stainer, has never attracted so much attention as has that by the conchuela in Mexico. Nevertheless, after the characteristics of plant-bug injury have been brought to one's attention, a person is generally impressed with the frequency with which it is met in the cotton fields. The appearance of the conchuela as an enemy of miscellaneous crops in western Texas, near Barstow, in 1905 led to an investigation, in connection with which estimates were made of the damage of the insect to cotton in that locality. As has been stated in a paper dealing with this outbreak, it was estimated that about 10 per cent of the cotton was destroyed near Barstow in 1905. In one field on August 11, 30 per cent of the bolls had been ruined, but the disappearance of the majority of the insects and the continuance of the fruiting of the plants resulted in the percentage of injury being ultimately reduced by one-half.

Plant-bugs occur in cotton fields in the northern half of the State of Texas in much greater abundance than in the southern half, and in 1905, special attention having been given for the first time to the occurrence of plant-bug injuries, it was evident that the aggregate losses from this cause must have been large. It is impossible to approximate the total loss chargeable to the work of plant-bugs in 1905, but it is almost certain that for northern Texas an estimate of 4 or 5 per cent of all bolls is not too high. As a matter of fact the writer's personal examinations in many cotton fields in the section of Texas referred to indicated that this estimate is much too low. Plant-bugs (Pentatomids) were especially abundant near one corner of a 60-acre cotton field at Dallas, Tex., used for experimental purposes by this Bureau. On September 9, 1905, 43 green cotton bolls were picked at random in the section of the field referred to, and of these 29, or 68 per cent, were damaged by the bugs, about 50 per cent being ruined and the others showing badly stained lint. On November 4, 25 bolls were picked at random in a section of the field where these insects had been abundant, and the results of the examination are summarized in the following table:

TABLE III.—*Injury by plant-bugs to cotton bolls.*

BOLLS.

Diameter.	Number.	Uninjured.	Slightly injured.
Inches.			
$\frac{1}{2}$–$\frac{7}{8}$	15	[a] 1	0
1–$1\frac{1}{4}$	10	1	[b] 2
Total	25	2	2

LOCKS.

Number.	Destroyed by bugs.	Slightly injured by bugs.	Destroyed by weevils.	Uninjured.
60	45	8	1	6
40	15	11	2	12
100	60	19	3	18

FEEDING PUNCTURES.

Total.	Number in destroyed locks.	Number in slightly injured locks.	Number in uninjured locks.	Average per destroyed lock.	Average per slightly injured lock.	Average per uninjured lock.	Average per destroyed boll.
366	346	20	0	7.7	2.5	0	26
300	186	82	32	12.4	7.0	2.6	30
666	532	102	32	8.9	5.3	1.8	28

Destroyed bolls.		Slightly injured bolls.		Destroyed locks.		Slightly injured locks.		Uninjured locks.
Maximum number of punctures.	Minimum number of punctures.	Maximum number of punctures.	Minimum number of punctures.	Maximum number of punctures.	Minimum number of punctures.	Maximum number of punctures.	Minimum number of punctures.	Maximum number of punctures.
69	7	....	....	20	1	5	1	....
81	15	55	16	22	4	16	1	10

[a] Two locks destroyed by boll weevil larvæ.
[b] Including one boll with 55 feeding punctures by bugs, lint only slightly stained at time of examination.

The data given in Table III will serve as a guide to the relation between plant-bug punctures and the damage which results, as well as an example of a condition which may be occasionally met with in cotton fields of northern Texas where large numbers of plant-bugs are concentrated in small areas. Fortunately such occurrences are not common and are generally restricted to small areas where the surroundings are favorable for the breeding of the bugs in large numbers.

Due credit has not hitherto been given plant-bugs for their part in diminishing the yield of cotton and lowering the quality of the lint. This failure to connect the injury with the cause, as has been pointed out, is largely due to a lack of understanding of the nature of the injury, as well as to the fact that plant-bugs have always been found in cotton fields and except in rare instances no good criterion for judging the amount of loss has been afforded. Field agents of this Bureau, engaged in investigating cotton insects, frequently have met cotton growers in northern Texas who ascribed the shriveled condition of the locks of bolls damaged by these bugs to dry weather. In Florida some cotton growers have explained damage of this same kind as due to the prevalence of wet weather.

Summarily it may be stated that locally plant-bugs frequently cause large losses and throughout large sections of the cotton States cause small but appreciable losses which it is important should be determined in a less cursory manner than heretofore.

PLANT-BUGS AS DISSEMINATORS OF PLANT DISEASES.

Various plant-bugs have been suspected of transmitting fungous and bacterial diseases of plants, but as yet there appears to have been no careful investigation of this matter. That the transmission of the spores of cotton boll anthracnose (*Colletotrichum gossypii* Southworth) by plant-bugs from one boll to another is possible requires no demonstration. An investigator would rather be concerned with the extent to which these cotton-frequenting insects are responsible for the spread of the disease. It is highly probable that the bacillus of the cotton boll "rot" (*Bacillus gossypinus* Stedman) may be disseminated to a greater or less extent by means of plant-bugs whose mouth setæ would furnish a means of direct entrance of the organism to the interior of the boll. The entire subject is one which offers a field for interesting and valuable research, but for the present no estimate can be made of the damage to cotton indirectly caused by plant-bugs through dissemination of pathogenic fungi and bacteria.

THE CONCHUELA.

(*Pentatoma ligata* Say.)

(Pl. I, fig. 1.)

HISTORY.

The conchuela [a] was described in 1831, but first became known as an insect of economic importance when, in August, 1902, specimens were received from a correspondent of the Bureau of Entomology,

[a] This is the common name used for this insect by the natives of the Laguna District of Mexico. It is a Spanish word meaning "little shell" and is based on a fancied resemblance to a shell.

with the note that the species was injuring cotton in the Laguna District of Mexico at San Pedro de la Colonia, State of Coahuila. In March, 1904, the author was directed by the Entomologist to investigate a reported partial destruction of the cotton crop by an unknown pest in the Laguna District of Mexico. The specific report emanated from a large plantation of between 25,000 and 30,000 acres of cultivated land located in the northern portion of the Laguna District, the headquarters being at Tlahualilo, State of Durango. At the season of the year when the first visit was made, although the cotton stalks were still standing in the fields, it was impossible to establish positively the relationship between the conchuela and the large number of ruined bolls present everywhere on the plantation. The second visit to Tlahualilo from August 30 to September 8, 1904, resulted in this point being definitely determined as well as in the procuring of considerable information concerning the insect and its work. The details of these preliminary investigations were reported on in a previous bulletin of this Bureau.[a]

The investigations were continued in 1905 at Tlahualilo, where the author of this report spent the month of July and a week in the early part of December.

The conchuela has recently become known as a pest in western Texas, where, in 1904 and 1905, near Barstow, it occasioned considerable loss to seed crops of alfalfa, and in the latter season proved, in addition, its destructiveness to miscellaneous crops, including peaches, grapes, peas, and other garden products. The report of the investigation of this unexpected outbreak has been published under a separate title.[b]

DISTRIBUTION.

The distribution of *Pentatoma ligata* is a wide one, the species occurring rarely in the eastern half of the United States, and with much more frequency in the arid and semiarid regions of the Western States and Mexico. It is probably of considerable significance that hitherto localities where this species has been found to occur in large numbers have been situated in the Lower Sonoran faunal region of the Lower Austral zone. In Texas miscellaneous collections for three years by members of the Bureau of Entomology engaged in cotton boll weevil investigations have not included a single specimen of *Pentatoma ligata* taken east of the semiarid region or approximately the ninety-eighth degree of longitude. A single specimen in the collection at the office of the Texas state entomologist bears the label Beeville, Tex., which is situated between the ninety-seventh and the ninety-eighth degrees of longitude and is the easternmost

[a] Bul. 54, Bur. Ent., U. S. Dept. Agr., pp. 18–34, 1905.

[b] Bul. 64, Pt. I, Bur. Ent., U. S. Dept. Agr., 1907.

locality in Texas from which the writer has seen a specimen of the species. West of the ninety-eighth degree of longitude specimens have been collected at the following points and elevations in the State of Texas: San Diego, 300 feet; Abilene, 1,700 feet; Barstow, 2,500 feet; Llano, 1,000 feet; San Angelo, 1,800 feet; San Antonio, 675 feet; Clarendon, 2,700 feet. The known Mexican localities where the species has been collected, with their elevations, are: San Pedro de la Colonia, Coahuila, 3,600 feet; Tlahualilo, Durango, 3,700 feet.

FOOD PLANTS.

Like most other plant-feeding Pentatomids whose habits are known, the conchuela has a wide range of food plants and shows a decided preference for fruits and seeds. In Texas and Mexico its principal food in uncultivated regions is the bean of the mesquite (*Prosopis* sp.) and the berry of a common wild solanum (*Solanum elæagnifolium*), known among the natives of Mexico as "trompillo." Of these two the former seems to be preferred according to observations in northern Mexico where the two food plants grow together on the arid plateaus. Records of other wild food plants of the species, with the observer and locality, are as follows: Spanish bayonet or bear grass (*Yucca* sp.), Barstow, Tex., J. C. Crawford; wild currant (*Ribes* sp.), San Antonio, Tex., W. E. Hinds and J. C. Crawford; sage, Clarendon, Tex., W. D. Pierce. Records of cultivated food plants, with the observer and locality, are as follows: Cotton, alfalfa, grapes, corn, chilli pepper, and tomato, Tlahualilo, Durango, Mexico, A. W. Morrill; peaches, Barstow, Tex., J. C. Crawford; cotton, grapes, Milo maize, sorghum, alfalfa, peas, tomato, Barstow, Tex., Crawford and Morrill. The fact that in 1905, at Barstow, Tex., the conchuela attacked several of these crops in sufficient numbers to cause considerable damage has been referred to under the subject of the history of the species. The range of food plants which has been recorded points to the likelihood that this insect may use as a food plant almost any of our cultivated grains, fruits, and vegetables which circumstances may place in the way.

DESCRIPTION.

ADULTS.

(Pl. I, fig. 1; text fig. 1.)

This species belongs to the subgenus Chlorochra Stål, and in common with certain other members of this group exhibits a wide variation in color. The general color is usually dull olivaceous, frequently either grayish, pinkish, purplish, or greenish, and occasionally black or brown. The punctures are black or dark gray. The species is most strikingly characterized by its general dark color, with the lateral margins of the thorax above and below, the basal third to two-thirds of the costal margins of the wing corium, and the tip of the scutellum varying in color in different specimens from pale yellow to bright crimson. In a series of 63 specimens collected at random the range in length was found to be from 12 to 16.5 mm. While in this species there was one of either sex measuring 16.5 mm., the females in general are slightly larger than the males. Among 10 specimens of each sex collected at random in a cotton field, the average length was 15.1 mm. in the case of the females and 14.1 mm. in the case of the males, the former ranging from 14 to 16.5 mm., the latter from 13 to 14.5 mm.

FIG. 1.—The conchuela (*Pentatoma ligata*): *a*, Adult bug; *b*, egg-mass on leaves; *c*, egg just before emergence of nymph; *d*, egg at an earlier stage of development; *e*, egg from side showing exit hole at the top; *f*, egg closed. *a*, *b*, enlarged; *c-f*, greatly enlarged. (Author's illustration.)

EGGS.

(Text fig. 1; Pl. V, fig. 1.)

The writer has described the egg of this species in a previous report. From the examination of 25 eggs deposited by various females the dimensions may be stated as follows: The greatest diameter of individual eggs varies from 0.95 to 1.22 mm., rarely exceeds 1.1 mm., and averages about 0.98 mm.; the height varies from 1.2 to 1.45 mm. and averages about 1.28 mm. The egg is irregularly ovoid in form. When first deposited it is pale green but the chorion soon turns white except for certain areas which are translucent and grayish in color, turning to dark gray or brown as the embryo develops.

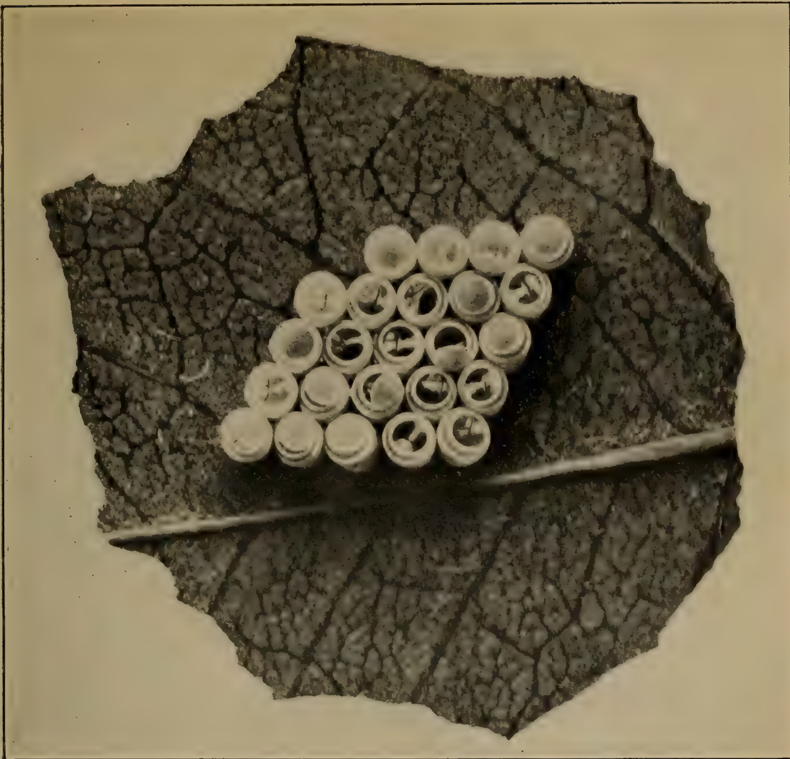


FIG. 1.—EGG BATCH OF CONCHUELA (PENTATOMA LIGATA), SHOWING HATCHED AND UNHATCHED EGGS. ENLARGED 6⅔ DIAMETERS. (AUTHOR'S ILLUSTRATION.)

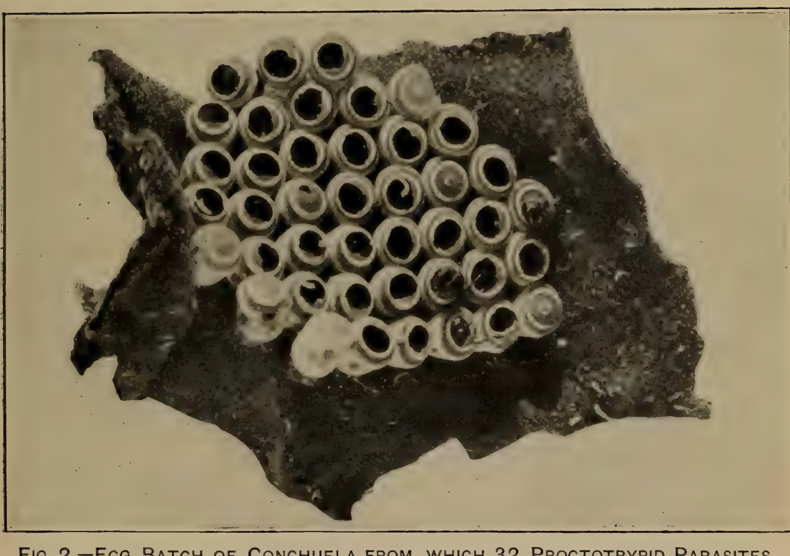


FIG. 2.—EGG BATCH OF CONCHUELA FROM WHICH 32 PROCTOTRYPID PARASITES (TELENOMUS ASHMEADI) HAVE EMERGED ENLARGED 6⅔ DIAMETERS. (AUTHOR'S ILLUSTRATION.)

This illustration shows three parasites, including male and female, ready to emerge; also an egg destroyed, probably by an ant.

NYMPHS.

(Figs. 2–6.)

First instar.—In the first instar the head and thorax are deep brown. The abdomen is deep slate-gray with a middorsal series of shiny black spots, whitish at the marginal incisures between which just inside the margin of each segment is a spot of deep brown. Specimens in this stage vary in length from 1 to 1.75 mm. and in width from 1 to 1.5 mm. according to individual variation and age.

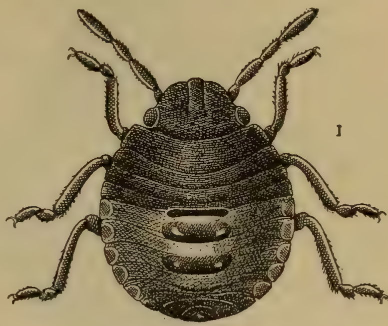


FIG. 2.—The conchuela: Nymph, first instar. Enlarged 21 diameters. (Original.)

Second instar.—The head and thorax of the nymphs in the second instar are shiny black, the thorax being margined with yellowish or orange-red. The abdomen above is dark violaceous, the venter paler. There is a series of black spots on the dorsum of the abdomen as in the first instar and a ventral series of black spots is sometimes present along middle one to each of the last four segments. The abdominal segments above and below have a yellowish or orange-red border, which narrows posteriorly. The length of second-instar nymphs varies from 1.6 to 2.5 mm., and the width from 1.3 to 2 mm.

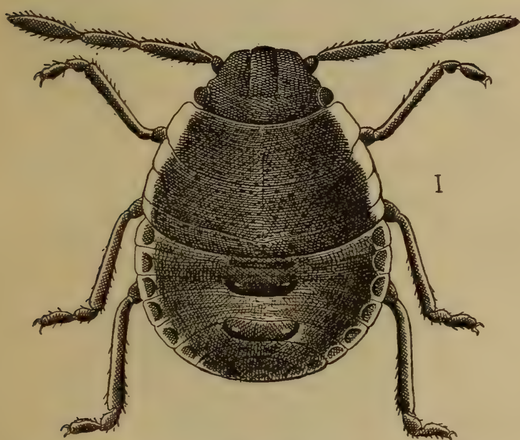


FIG. 3.—The conchuela: Nymph, second instar. Enlarged 21 diameters. (Original.)

Third instar.—The nymphs in the third instar are much like those of the second but are subject to greater variation in color. There is more or less olivaceous along the middle of the venter of the thorax. The abdomen usually has a pale violaceous ground color and dark violaceous spotting. The ventral series of spots is usually distinct, consisting of one spot on each of the segments from the fourth to the eighth, the anterior spot being the smallest. Frequently inside the reddish border on each segment from the second to the ninth is a more or less thickened crescentic black mark. Corresponding markings are sometimes present on the venter. The lines of the segments are usually dark in color. The length in this instar varies from 3.5 to 4 mm., and the width from 3 to 3.5 mm.

Fourth instar.—The fourth instar is characterized by the first external evidence of the developing wing-pads. The ventral side of the head, and sometimes the two basal segments of the beak, are more or less olivaceous. The black crescentic markings inside the margin of the abdominal segments are more distinct than before. Otherwise the color corresponds very nearly with that of the third instar. The length of the fourth-instar nymph varies from 4.8 to 6.5 mm., and the width from 3.7 to 5 mm.

FIG. 4.—The conchuela: Nymph, third instar. Enlarged 13 diameters. (Original.)

Fifth instar.—In the last or fifth nymphal instar the head and thorax are rarely uniformly black as in the two preceding instars but are more or less olivaceous, with black punctures. The venter of the thorax has usually an olivaceous but sometimes a pale purplish or rosaceous ground color, with black punctures and markings. The basal segments of the legs are more or less olivaceous. The abdomen is colored as in the previous instars except that the ventral series of spots along the mesal line is either absent or only faintly indicated. The length of the nymphs in the fifth stage varies from 9 to 11 mm., and the width from 6 to 8 mm.

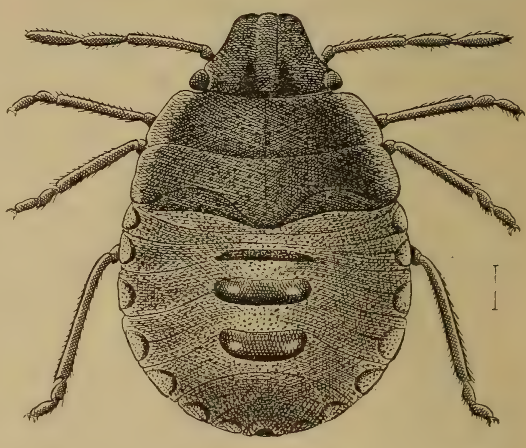


FIG. 5.—The conchuela: Nymph, fourth instar. Enlarged 10 diameters. (Original.)

LIFE HISTORY.

Methods of Study.

Studies in the life history of this and other species of plant-bugs were conducted in an improvised laboratory at Tlahualilo, Durango, Mexico, during July, 1905, and at the boll weevil laboratory at Dallas, Tex., after August 5, 1905. The insects were confined in lantern chimneys covered at the top with cheese cloth held in place by rubber bands, the number of adults to a cage ranging from one to five. The adults were provided daily with freshly picked green cotton bolls until about October 1, after which fresh bolls were supplied every two days as long as any were available. Nymphs were fed upon fresh green cotton leaves or twigs, cotton bolls cut or broken in two, and immature cotton seed from which the lint was first removed. Records were made at least once each day, noting deaths, eggs deposited, time of examination, etc. During the writer's occasional absences from the laboratory on field work these records were made by Mr. W. W. Yothers and Mr. A. C. Morgan.

FIG. 6.—The conchuela: Nymph, fifth instar. Enlarged 6 diameters. (Original.)

Adults.

PERIOD BETWEEN MATURITY OF ADULTS AND BEGINNING OF EGG-LAYING.

The data at hand on the length of time elapsing from the maturity of the adults to the beginning of oviposition are not sufficiently extensive to permit the drawing of conclusions. Apparently the specimens upon which the data are based were influenced by the laboratory conditions, for the period varied in length from 23 to 95 days and averaged 45 days in the case of the five specimens which were reared to maturity in the laboratory during July and August and which deposited one or more batches of eggs. Three females in addition to the foregoing lived 6, 34, and 125 days, respectively, but deposited no eggs.

REPRODUCTION.

Monthly and daily rate of oviposition and relation to temperature.—Including all the female specimens of *Pentatoma ligata* upon which observations were made, the average daily rate of egg production was 1.45. Omitting the month of November, during which no eggs were deposited, the rate was 1.8 per day, while up to October 1 the rate was 2.4 per day. The more important data on egg deposition are summarized in the following table:

TABLE IV.—*Rate of egg deposition of the conchuela.*

Lot.	When collected.	Where collected.	Number of females.	Total number of eggs deposited.	Average number of eggs deposited per insect per day.					
					July.	Aug.	Sept.	Oct.	Nov.	Total.
	1905.									
A	July 6–10	Tlahualilo, Mexico.	21	2,755	2.74	3.05	0.51	0	0	1.92
B	Aug. 11–12	Barstow, Tex	8	592	......	4.6	.57	0	0	2.5
C	Sept. 12	do	14	1,271	......	......	6.27	1.56	0	5.4
D	Oct. 13	do	[a] 10	0	......	......	......	0	0	0

[a] These insects were soft, indicating that they were newly matured.

A study of the effect of temperature on egg production in the species here considered leads to the conclusion that the effective temperature as concerns egg-laying in the faunal region where these records were made, i. e., Lower Austral, is a little less than 75° F. The effect of temperature changes upon egg production is well illustrated by the data given in the following table relating to insects of lot A referred to in Table IV:

TABLE V.—*Relation of temperature to egg-laying in the conchuela.*

Period.	Average daily mean temperature.	Number of eggs per day deposited by 20 females.
1905.	°*F.*	
July 11–15	82.6	67
July 16–20	75.3	11
July 21–25	78.1	61
July 26–30	80.8	66

Egg-laying capacity.—A summary of the laboratory records regarding egg-laying capacity is presented in the following table:

TABLE VI.—*Egg-laying capacity of specimens of the conchuela collected in cotton fields.*

Lot.	When collected.	Number of females.	Average number of eggs deposited per female.	Maximum number of eggs deposited per female.
	1905.			
A	July 6	21	131	321
B	Aug. 12	8	74	(a)
C	Sept. 12	14	91	b 122
D	Oct. 13	10	0	0

a No individual records kept for this lot.
b This record is for the only female specimen isolated from others of same sex.

The above records are based on females collected in the field, lot A at Tlahualilo, Mexico, and the remaining lots from Barstow, Tex. In all cases it may be presumed that the specimens had deposited eggs before the records began. From the fact that few nymphs were present, while the number of adults was rapidly increasing in the field where lot A was collected, it is probable that the migrating insects consisted of males and females which had recently reached maturity in the surrounding mesquite and arrived at the cotton field as a consequence of their search for a better food supply. The status of these insects in the mesquite as hereafter described adds further evidence to the support of this supposition. If we consider, accordingly, that the individuals of lot A had averaged to begin egg-laying one week before the above records begin, the daily rate being the same as for the remainder of the month, the average number of eggs deposited by each female of the lot would be 150 and the maximum number 340.

Duration of fertility.—Four lots of insects were used in testing the duration of fertility in isolated females. The results are summarized as follows:

TABLE VII.—*Duration of fertility in females of the conchuela isolated from males.*

Lot number.	Number of females.	When isolated.	Deposition of first infertile egg.		Deposition of last fertile egg.	
			Date.	Number of days after isolation.	Date.	Number of days after isolation.
		1905.	1905.		1905.	
1	5	July 10	Aug. 11	32	Aug. 26	47
2	1	July 10	Aug. 7	28	Sept. 14	66
3	5	July 10	Sept. 10	60	Sept. 10	60
4	2	July 11	Aug. 16	36	Aug. 23	44
Average				39		54

Two points of importance are brought out by the data given in Table VII. First, it is evident that the duration of fertility after isolation does not cover the normal egg-laying period of the female. Second, the end of the period of fertility in the female is not well marked and a considerable period may elapse between the deposition of the first infertile egg and of the last fertile egg.

PROPORTION OF SEXES.

While observations on a small scale indicated a preponderance of the number of females over the number of males, the final and most conclusive observation as well as the totals show that the two sexes occur in about equal abundance. The difference in favor of the female sex shown in the totals is less than 2 per cent over an equal division, a difference which might occur in any arbitrarily chosen series from a large number of specimens including exactly one-half of each sex.

TABLE VIII.—*Proportion of sexes of the conchuela.*

When collected.	Where collected.	Number of males.	Number of females.	Total.
September, 1904	Tlahualilo, Durango, Mexico.	7	12	19
July 11, 1905	do	17	25	42
July 12, 1905	do	247	253	500
Total		271	290	561

LONGEVITY.

Adults collected in the field.—Provided that an abundance of food is available, the length of life of the adults when protected from their natural enemies is dependent upon the season of the year in which the insects reach maturity. The following tabulations summarize the data concerning this point in the life history of the conchuela derived from the laboratory records.

TABLE IX.—*Summary of records of longevity of adults of the conchuela collected in cotton fields.*

Number of specimens. ♀	Number of specimens. ♂	Where collected.	When collected.	Maximum longevity. (Days.) ♀	Maximum longevity. (Days.) ♂	Average longevity. (Days.) ♀	Average longevity. (Days.) ♂
			1905.				
21	6	Tlahualilo, Durango, Mexico	July 6-10	142	79	71	37
8		Barstow, Tex	Aug. 12	83		29	
14	2	do	Sept. 12	29	[a] 9	17	9
5	0	Clarendon, Tex	Sept. 19	[b] 91+		53	
9	11	Barstow, Tex	Oct. 13	[b] 67+	[c] 67+	[b] 67+	53+

[a] Apparently parasitized by Tachinid fly but no parasite emerged from body of supposed host.
[b] In hibernation test December 1; all alive December 19; all dead March 8, 1906.
[c] Alive January 17, 1906, in hibernation cage; dead March 8, making 98+, but to keep on same basis as other specimens the record was included only up to December 19, 1905.

In order to show in a more graphic manner the vitality of the females collected at various times during the year, the data concerning that sex are arranged in the form presented below:

TABLE X.—*Longevity of adult females of the conchuela collected in field.*

When collected.	Where collected.	Number of specimens.	Number alive in sucessive months.[a]					
			July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.								
July 6–10	Tlahualilo, Durango, Mexico	21	21	20	13	7	4	0
August 11–12	Barstow, Tex	[b] 8		8	4	1	1	0
September 12	do	[c] 14			14	6	0	0
September 19	Clarendon, Tex	5			5	5	2	0
October 13	Barstow, Tex	10				10	10	[d] 10

[a] Record on the first day of each month following that during which collection was made.
[b] Not including 6 which died in less than five days after trip from Barstow to Dallas, Tex.
[c] Not including 2 which died in less than five days after trip from Barstow to Dallas, Tex.
[d] Hibernating alive December 19.

All of the above records on the duration of adult life are incomplete, as it was not definitely known in any case how long the insect had been in the adult stage when collected. Conditions at Tlahualilo indicate that the specimens collected at that point had been in the adult stage, on the average, about ten or twelve days. There were no means of judging on this point in the case of the specimens collected during August and September, but those collected on October 13 were still soft and specimens which died in transit contained no recognizable eggs; hence with little doubt this lot of specimens had matured within the week preceding their collection.

Adults reared to maturity in the laboratory.—As will be explained under the subject of the molting of nymphs, imperfect or crippled adults are frequently produced in the laboratory. From the ten apparently normal adults which reached maturity in confinement the most complete records on longevity were obtained.

TABLE XI.—*Summary of records of longevity of adults of the conchuela which reached maturity in laboratory.*

Number of specimens.		Where collected.	When mature.	Maximum longevity. (Days.)		Average longevity. (Days.)	
♀	♂		1905.	♀	♂	♀	♂
1	1	Tlahualilo, Durango, Mexico	July 21	[a] 49+	[a] 49+		
2		do	July 29 and August 4	[b] 143+		86+	
2		Barstow, Tex	August 7 and 14	[b] 127+		76+	
2	2	do	August 15 and 16	[b] 126+	69	71+	53

[a] Specimens lost. [b] Used in hibernation test December 1, 1905; alive December 19, 1905.

From the data given in the foregoing tables we are able to estimate approximately the length of adult life of the conchuela under laboratory conditions. Fortunately the natural enemies of the insect and probably also its greater activity in the field materially lessen the average duration of adult life below that which was found to obtain in the laboratory. A cage test in a cotton field failed to give positive evidence regarding normal longevity of the adults on account of the fact that the amount by which the insects' lives were shortened through their attempt to escape can not be estimated. Seventeen specimens which became adult between July 25 and July 31 were confined in a wire cage placed over a cotton plant bearing a dozen bolls and many blooms and squares. The cage rested on cheese cloth in order to facilitate the finding of dead bugs. On August 27 Mr. John Conduit, of Tlahualilo, noted that 10 live adults could be seen and no dead ones. On September 2 Mr. Robert Vaughan, of Tlahualilo, noted that there were 5 dead specimens, and on October 15 another dead specimen was observed. Live adults were noted as follows: September 10, 2; September 20, 1; October 9, 1; October 12, 2; October 15, 1; October 18, 1; October 20, 0; October 24, 0; October 31, 0. The number of adults noted on each date simply includes those which could be seen from outside the cage. It is not impossible that some of the insects found an opportunity to escape, as of the 17 insects only 7 can be definitely accounted for. The results show that 5 died in from 32 to 37 days, 1 in between 45 and 50 days, and 1 in between 78 and 83 days after reaching the adult stage. The sex of the specimens used in this cage test was not recorded.

Length of life when deprived of food.—Without food the life of adult conchuelas is very short in summer temperatures. On July 21, 28 adults—12 females and 16 males—taken on cotton plants at 11.30 a. m. were placed, at 12.30 p. m., without food, in a wire cage whose dimensions were 2 by 1 by 1 foot. The insects were very restless and flew almost continuously during daylight from one side to the other in the cage. In 33 hours from the time they were last fed only 7 of the 28 were alive and in 48 hours all were dead. In a second experiment 17 adults—8 females and 9 males—taken on cotton plants July 22 at 5 p. m. were placed, at 6 p. m., in a lantern globe loosely filled with soft, crumpled paper to prevent the insects from exhausting themselves by attempting to fly. Twenty-six hours after being deprived of food 9 of the 17 were dead and 41 hours after being deprived of food the last surviving specimen was noted as dying. The daily mean temperature at Tlahualilo at the time of the foregoing tests in the starvation of the conchuelas was between 75° and 80° F. On September 20, two specimens of this species were collected in western Texas and confined in separate pill boxes without food. These two specimens lived 5 and 6 days, respectively. The length of life without food is clearly dependent upon temperature conditions, as will be further discussed under the subject of hibernation.

RELATION OF TEMPERATURE TO ACTIVITY OF ADULTS.

Observations were made in October on some surviving specimens of the lots included in Table IX for the purpose of obtaining information on the effect of temperature on the feeding of these insects. The number of observations is too small to determine this point in more than a general way, and we are justified only in concluding that the degree of temperature at which feeding ceases is between 52° and 60° F.

TABLE XII.—*Observations on relation of temperature to feeding of the conchuela.*

Date of observation.	Hour.	Temperature.	Number of adults feeding.	Number of adults not feeding.	Remarks.
1905.		°*F.*			
October 11	8 p. m.	55–60	8	8	Specimens in laboratory.
October 19	7.15 p. m.	66	7	12	Do.
October 20	8.30 a. m.	49	0	14	Specimens out of doors.
Do	8.15 p. m.	52	0	19	Specimens in laboratory.
October 21	8.30 a. m.	51	0	[a] 19	Do.

[a] Including one with setæ inserted in boll, but motionless and evidently not feeding. Plant-bugs in the laboratory have even been observed to die in this position.

For comparison, observations were also made with a miscellaneous lot of Pentatomids, including specimens of *Pentatoma sayi*, *Euschistus servus*, *Nezara hilaris*, and *Thyanta custator.* These are summarized as follows:

TABLE XIII.—*Observations on relation of temperature to feeding of miscellaneous Pentatomids.*

Date of observation.	Hour.	Temperature.	Number of adults feeding.	Number of adults not feeding.
1905.		°*F.*		
October 11	8 p. m.	55–60	5	5
October 19	7.15 p. m.	66	4	3
October 20	8.15 p. m.	52	0	7

EGGS.

PERIOD OF INCUBATION.

As is the case with all insect eggs, the developmental or incubation period of the eggs of the conchuela is influenced to a marked degree by slight variations in temperature. From the entire lot of egg-batches deposited in the laboratory, numbering over 160, 26 have been selected for a study of the relation of temperature to incubation period, owing to the comparative completeness of the records. The number of intervening calendar days has been taken as the basis and the additional periods approximated by a plan which has been followed throughout and which is believed to have produced very nearly correct averages. To the number of intervening calendar days has been added the known additional hours and one-half the hours between observations during which egg-laying or hatching might have occurred. In many cases the exact time of the egg-deposition or of hatching was noted, consequently lessening the chances for error. For example, a female was observed in the act of depositing an egg-batch at 4 p. m., July 16. This batch had hatched when the record was taken at 3 p. m. on July 23. The number of intervening calendar days in this case was six. The known additional period is 8 hours, 4 p. m., July 16, to 12 midnight. The period preceding the time the eggs were first noted as having hatched, during which no observations were made, was 23 hours, one-half of which is added to the known period of 8 hours, making practically five-sixths of a day. This added to the intervening calendar days gives $6\frac{5}{6}$ days as the approximate incubation period.

TABLE XIV.—*Relation of temperature to period of incubation of eggs of the conchuela.*

Place.	Period.	Number of egg batches.	Number of eggs.	Range.			Average.		
				Intervening calendar days.	Approximate incubation period.	Average daily mean temperature for intervening days.	Daily mean temperature.	Approximate incubation period.	
	1905.				*Days.*	*°F.*	*°F.*	*Days.*	*Hours.*
Tlahualilo, Durango, Mexico.	July 14–23	3	99	6 to 6	$7\frac{1}{6}$ to $6\frac{2}{3}$	75.4 to 76.1	75.8	6	19
Do	July 22–30	5	234	5 to 4	$6\frac{1}{12}$ to $5\frac{1}{6}$	79.1 to 79.5	79.4	5	9
Dallas, Tex.	Aug. 6–Sept. 15	11	350	3 to 2	$4\frac{1}{6}$ to $3\frac{1}{6}$	80.1 to 86	82.8	3	15
Do	Sept. 16–Oct. 5	7	313	6 to 4	7 to 5	73.7 to 75	74.3	5	23
Summary with averages	July 14–Oct. 5	26	996	2 to 6	$3\frac{1}{6}$ to $7\frac{1}{6}$	73.7 to 86	78	5	8

From the last three columns of the above table can be computed the average effect of 1° of temperature on the duration of the incubation period within the limits noted.

TABLE XV.—*Effect of 1° of temperature on incubation period of eggs of the conchuela.*

Place.	Range, average daily mean temperature.	Number of degrees represented by range.	Increase or decrease in incubation period corresponding to 1° of temperature.
Tlahualilo, Durango, Mexico	75.8 to 79.4	3.6	0.39 days or 9 hrs. 30 min.
Dallas, Tex.	74.3 to 82.8	8.3	.27 days or 6 hrs. 30 min.

The average of the Tlahualilo and Dallas records shows that between the limits of 74.3° and 82.8° the average increase or decrease in the incubation period corresponding to a single degree of temperature is estimated at 7 hours and 55 minutes. It is a notable coincidence that in the case of the eggs of the spined soldier-bug (*Podisus maculiventris* Say) the author found in Massachusetts that with an average daily mean temperature ranging between 62° and 72°, 1° of temperature corresponded with approximately 7 hours and 40 minutes.[a]

An instance of a much more prolonged incubation period was not included in the foregoing table but was reserved for separate discussion, as it is evidently a case of intermittently arrested development, due to low temperatures. The egg batch in question numbered 28 eggs and was deposited on October 17; 13 hatched on November 3. The average daily mean temperature[b] during the 16 days of incubation was 65.7° F. The average daily maximum for this period was 72.3° F. and the average daily minimum was 59° F. To the author it seems plain that the 16-day period can only be explained by the supposition that development of the eggs was arrested from time to time by the low temperatures. Here again a comparison with the records obtained from the eggs of the other species of the Pentatomid mentioned in the preceding paragraph is instructive as showing the adaptation of the physiological processes of the two species to climatic conditions. The eggs of the spined soldier-bug at Amherst, Mass., with practically the same average daily mean temperature (65.5° F.) hatched in 8½ days, or after a period one-half as long as in the case of the eggs of the conchuela.

PROPORTION HATCHING IN THE LABORATORY.

In many cases no note was made as to whether or not eggs hatched, but the records of nearly a thousand eggs will suffice to give fairly accurate knowledge on the subject. The eggs selected were deposited during July and August by conchuelas collected in the cotton fields at Tlahualilo and abnormal conditions were eliminated, as will be explained. The total number of eggs was 942, and of these 68, or 7.2 per cent, failed to hatch. Eggs of the conchuela deposited in the field seldom fail to hatch if not destroyed by parasites or predaceous enemies. The number of unparasitized egg-batches collected in the field is too small to permit the drawing of conclusions concerning the proportion that hatch, and for information on this point laboratory data must be used. If, however, we omit records of eggs from infertile females and of certain abnormal eggs, mechanically prevented from hatching, there is no reason to expect any appreciable difference in the proportion of eggs hatching under laboratory conditions and those hatching under normal field conditions. Infertile eggs have never been collected in the field nor has any egg-laying

[a] Bul. 60, Bur. Ent., U. S. Dept. Agr., p. 158, 1906.

[b] Records based on a recording thermometer in the room with the eggs.

female brought from the field into the laboratory proved unfertilized; hence this factor should be eliminated from the laboratory records in order to make them comparable with actual field conditions.

As an illustration of the mechanical prevention of hatching referred to, a conchuela in one instance deposited eggs in two layers, the nymphs in the lower layer of eggs, numbering 20, being of course unable to escape from the shells. This manner of depositing the eggs was evidently due either to interference by other specimens in the cage or to a lack of sufficient leaf-area, both of which conditions are abnormal. Occasionally eggs are deposited, both in the laboratory and in the field, wrong side up with relation to other eggs of the batch. This also usually results in mechanical prevention of hatching and accounts for the failure to hatch of somewhat less than 1 per cent of the 942 eggs referred to above. Other eggs may fail to hatch owing to the exit hole at the top being abnormally small, as the author has observed to occur in two instances with eggs of the harlequin cabbage bug (*Murgantia histrionica* Hahn). The extent of this abnormal condition may not be noticeable, yet sufficient to prevent emergence of the nymph. Still other eggs may be abnormal in the respect that the lid which must be raised to permit the escape of the nymph is too solidly attached to the neck of the egg in proportion to the strength of the insect.

EFFECT OF LOW TEMPERATURE ON VITALITY.

An experiment was made to determine the extent to which development of eggs might be retarded or otherwise affected by low temperature. In this experiment 12 egg-batches comprising 288 eggs were used, all of which were deposited between August 27 and September 16 by 8 different females. Each batch of eggs was placed in an ice box within 24 hours after being deposited and kept there until November 2, with the temperature almost invariable and averaging 49° F. Upon examination it was found that the eggs had been entirely destroyed, being shriveled so that there could be no doubt of their condition. It would seem, therefore, that such long-continued low temperatures are fatal to the conchuela in the egg-stage.

HATCHING.

As the eggshell is nontransparent, the developing nymph is invisible up to the time of hatching. The stout spine on the egg-burster is directed at the suture between the lid and the neck of the egg at a point opposite the hinge. By pressure from below a split is made along the suture and the pale pinkish head of the nymph surmounted by the egg-burster appears beneath the partially opened lid. The integument of the insect being soft, the emergence is by slow, scarcely perceptible peristaltic movements, the egg-burster slipping over the head and along the venter as the emergence progresses. The position of the nymph in the egg is with the dorsum toward the hinge of the lid. The antennæ and legs are closely appressed to the body and extended directly backward. Movement of the antennæ and legs begins as soon as they are free from the egg and emergence is not completed until the legs are sufficiently strong to enable the insect to cling to the egg-batch. Individual nymphs have been observed to emerge in from 12 to 15 minutes after the lid is first raised. Emergence of nymphs from a batch of eggs usually extends over a period of less than 1½ hours, but activities in this line as in others are largely under the influence of temperature. A record on October 10 shows a difference of 2 hours and 15 minutes between the appearance of the first nymphs and last nymphs to emerge from a batch of 13 eggs.

NYMPHS.

DURATION OF NYMPHAL STAGES.

Under normal summer temperatures.—In spite of the most careful attention one can reasonably give, the death rate of Pentatomid nymphs under observation in the laboratory is very high. In no case were nymphs of the conchuela reared to maturity in the laboratory, but the duration of the various stages was determined by more than 35 individual records. The prevailing temperature conditions seem to control the duration of the nymphal stages of these and other Pentatomids, while a lack of food supply seems to result only in either a stunted growth or death from starvation. During the months of July and August, 1905, at Tlahualilo, Durango, Mexico, and Dallas, Tex., respectively, the data summarized in the following table were obtained, being based on from 5 to 35 specimens in each instar.

TABLE XVI.—*Observations on duration of nymphal stages of the conchuela.*

Stage.	Average duration.	Minimum duration.	Maximum duration.
	Days.	*Days.*	*Days.*
First instar	4.5	4	5
Second instar	6	5	7
Third instar	8	6	10
Fourth instar	8	5	12
Fifth instar	12	7	17
All nymphal instars	38.5	27	51

It is very unlikely that the maximum duration of each stage given above would ever be equaled by a single specimen passing through the successive stages, even in the laboratory during the summer months. It is, moreover, probable that under out-of-door temperature conditions the average duration of all nymphal instars taken together is a few days less than the average obtained by the laboratory observations.

This would seem to be the natural result of the insects being frequently exposed to direct sunlight. The average daily mean temperature during July at Tlahualilo was 81.5° F., and during August at Dallas was 82.8° F., the daily mean for the 2 months averaging 82.1° F. There is considerable variation independent of temperature. This is shown by specimens reared from the same egg-batch and kept in the same cage, having in every respect equally favorable opportunities for development. The range in duration of the stages becomes greater with each succeeding instar, which fact is well brought out by Table XVI.

Cold as a factor in retarding development.—At an average daily mean temperature of 69.4° F., the minimum length of the second instar among three specimens of the conchuela was 19 days, the period being from September 26 to October 15. In Table XVI is included a record of 7 days as the duration of this instar in one specimen. This represented the minimum length of the second instar among more than 10 specimens of the same brood. The period extended from July 20 to July 27, the average daily mean temperature being 77.9° F. A comparison of these two records plainly shows the effect of temperature on the duration of nymphal stages. Still greater retardation was exhibited by a lot of 31 fifth-instar nymphs of the conchuela, although the records are not as exact as those given, owing to the fact that the specimens were collected in the field and the entire length of the stage is consequently unknown. The specimens referred to were collected at Barstow, Tex., on October 13, and taken to the laboratory at Dallas, where they were confined in a wire breeding-cage out of doors, and supplied with fresh cotton bolls up to about the middle of November. From among these nymphs adults appeared on the following dates: October 17, 2; October 18, 1; October 19, 2; October 26, 3; November 3, 1. Nymphs were recorded as dead on the following dates: October 10, 5; October 14, 2; October 16, 1; October 26, 1. On December 19, 2 nymphs were still alive, although feeble and barely able to crawl, owing to lack of food. The average mean temperature at Dallas from October 15 to December 19 was 53.7° F., the October average being 62.9° F., November, 57.1° F., and up to December 19, 41° F.

LENGTH OF LIFE WITHOUT FOOD.

Like the adults, the nymphs of the conchuela, when deprived of food during the summer months, are short-lived. Nymphs in the first instar have been recorded as surviving as long as 5 days without food, which period is the longest ever noted under natural temperature conditions in any instance during the months of July, August, and September. On August 11, 46 nymphs hatched from a batch of eggs and all but 3 of these were dead from starvation on August 14, none surviving after the fourth day. There seems to be little or no difference in the ability of nymphs in later instars to withstand starvation, so far as observed in all cases with summer temperatures, death taking place in from 2 to 4 days. Data in connection with the retarding influence of cold, given in the preceding paragraph, illustrate the effect of low temperature on the length of life without food of nymphs in the fifth instar. In an ice box with an average temperature of 48.6° F., the life of a nymph of the first instar has been prolonged to nearly 40 days without food. In the brood of 24 nymphs to which this specimen belonged, all were alive on the seventeenth day after being placed in the ice box; 18 alive on the twenty-third day; 10 alive on the twenty-ninth day; and only 1 alive on the thirty-seventh day. A third-instar nymph, robust, and apparently well fed previously, lived only 8 days in the ice box without food, the temperature as before averaging 48.6° F.

MOLTING.

As the time for molting approaches, a nymph becomes less active, ceases to feed, and shows a tendency to seclude itself where it will be less liable to interference by other individuals of the brood. A twig or other suitable object is tightly clasped, and the insect by pressure, exerted perhaps by means of air drawn into the trachea, splits the integument of the dorsum along the mesal line of the thorax, and in a line on each side of the head extending from the inner margin of the eye backward to the prothorax. The insect becomes freed from its old skin usually in the course of twenty or thirty minutes, although in one observation a conchuela in molting its fifth-instar skin required slightly over an hour. The insect as it emerges is pale pink and very soft, but gradually attains its normal color during the course of an hour. Adults remain soft to the touch for several days after molting. The molted skin which originally covered the abdomen shrivels, and, as is also the case with the integument which covered the thorax and head, only the black markings remain.

HABITS.

NYMPHS.

FEEDING AND GREGARIOUSNESS.

For several hours after hatching, the young nymphs of the conchuela remain closely clustered either on or near by the egg-batch. If there are any unhatched eggs in the batch, the nymphs after a few hours' quiescence begin to feed on them, although it is probable that if such eggs contain nymphs they are dead or unable to hatch. Frequently enough food is contained in unhatched eggs of a batch to enable several nymphs to molt for the first time. For the most part the nymphs are dependent on the juices of plants for food although eggs of their own and other species of insects are fed upon with relish wherever accident places them in their way. Except for this habit of feeding on insect eggs, the writer has never observed nymphs of the conchuela to attack living insects. In one instance, however, a nymph in the fifth instar exhibited a decided preference for animal food over vegetable. This nymph was in a cage in the laboratory with specimens of other species of Pentatomids, including a nymph in the fifth instar of *Podisus lineatus* H. Schf. This last-mentioned specimen died, but was not removed from the cage, and 24 hours later the nymph of the conchuela was observed feeding on the dead insect. As there was a fresh cotton boll in the cage, feeding on the dead insect was clearly a matter of preference.

The habits of nymphs on the cotton plant are much like those of the adults, except that the nymphs are less conspicuous, frequently being entirely hidden by the bracts of the bolls. They have a well-marked gregarious tendency, especially in the first three stages, during which all the surviving nymphs of a brood are usually found on the same boll. In a field at Tlahualilo, nymphs of the fifth instar occurred in unusual abundance in a field of cotton averaging 5 or 6 bolls over 1 inch in diameter per plant. The nymphs reached the plants by crawling, and at the time of examination while less than one-fourth of the total number of bolls were infested, as a rule, each infested boll had several nymphs clustered upon it. As many as 17 fifth-instar nymphs were counted on a single boll, while frequently from 5 to 15 nymphs were found on a single boll, with the plant otherwise free from the pest.

DISTANCE CAPABLE OF TRAVELING FOR FOOD.

The distance which nymphs of the conchuela are capable of traveling for food proved to be a matter of considerable importance at Tlahualilo in 1905, owing to an invasion by nymphs of vineyards, gardens, and cotton fields adjoining an alfalfa field where the insects were breeding in enormous numbers. The cutting of the alfalfa removed the food supply of the insects, thereby causing a migration in search of food.[a] The adults distributed themselves by flight, but the migration of the nymphs was limited by their capabilities for crawling. Few of the nymphs in the first 3 instars got beyond

[a] Migrations of this kind have not been previously unknown among the Pentatomidæ. Prof. D. A. Saunders in reporting an unusual outbreak of Uhler's green plant-bug (*Pentatoma uhleri*?) in South Dakota says regarding this point: "By the middle of June the bugs, being now about half-grown and their wings beginning to appear, began to migrate in great droves 'on foot' toward the cultivated fields. Mr. Senn estimates that they would make about one-half mile in a little less than a day across cultivated fields * * *." (Bul. 57, S. Dak. Exp. Sta., p. 39, Feb., 1898.)

the limits of the alfalfa field. The fourth-instar nymphs were found in abundance on fence posts, tree trunks, cotton plants, and weeds within 10 yards of the alfalfa field where they originated, and were scarce from 10 to 20 yards from this field. Nymphs in the fifth instar invaded a cotton field up to about 30 yards, in numbers estimated to average between ten and fifteen per plant; from 30 to 40 yards, between five and ten per plant; and from 40 to 60 yards, between two and five per plant. Few, if any, attained a distance of more than 60 yards from the point of origin. In these estimates due allowance has been made for the nymphs which occurred in the field before the beginning of the migration. These records do not show the maximum distance which the nymphs are capable of crawling, for the new food supply immediately adjoined the field of original infestation. It is certain, however, that this distance is over 60 yards.

ADULTS.

FERTILIZATION.

Laboratory observations show that males of the conchuela are polygamous and females polyandric. During copulation in the cotton fields, both insects are usually engaged in feeding on a boll or other part of the plant. No attempt has been made to ascertain how long a pair of the insects remain in coitu, but in 2 instances a note was made of more than one-half hour or more than 2 hours, respectively. With other species of Pentatomid bugs, pairs have been observed in coition for a period of several hours at a time.

EGG LAYING.

Place of deposition.—Eggs are deposited in batches or clusters wherever the female happens to be feeding or resting. On cotton they have been found on both upper and lower surfaces of the leaf, though more commonly on the latter, also on bracts of bolls and on stems. In a cotton field at Llano, Tex., in September, 1905, a female conchuela was observed depositing a batch of eggs on lint in an open boll. On grape, 11 batches of eggs collected on July 12 were deposited as follows: 8 on underside of the leaves, 1 on the upper surface of the leaf, and 2 on the tendrils. Of 9 egg-batches collected on July 17, 4 were on the underside and 3 on the upper surface of alfalfa leaves and 5 on the underside of a solanaceous weed, the "trompillo" of the natives of Mexico. At Barstow, Tex., eggs of the conchuela with eggs of another Pentatomid which will be referred to later—*Pentatoma sayi* Stål—were frequently found on the seed-clusters of alfalfa, a favorite feeding place. In captivity the females of the conchuela, as well as other cotton-feeding Pentatomids, deposit eggs usually on the cotton bolls supplied for food, but occasionally on paper at the bottom of the cage and on the cheese-cloth cover at the top.

Number of eggs per batch.—The conchuela, in common with other members of the family Pentatomidæ, deposits eggs with considerable regularity in parallel rows, each egg except those in the outside rows being in contact with 6 others. The frequency with which eggs are deposited in multiples of 14 is strongly marked. A total number of 172 egg-batches of this species was deposited in the laboratory during these investigations. The total number of eggs in these batches was 4,900, or 28.4 eggs per batch. The number of eggs most frequently noted in single batches was 28, and the number ranking next in frequency was 42. The maximum number of eggs deposited in a single batch was 79.

Rate of deposition of individual eggs.—The intervals between the deposition of individual eggs in a batch, with midsummer temperature, varies from one minute to one and three-quarters minutes according to records made in the case of 2 females under observation while depositing eggs. The first of these specimens deposited 13 eggs in twenty minutes, 4 of which were deposited with one-and-one-half-minute intervals. The second specimen deposited 15 eggs in as many minutes.

FEEDING.

Part of plants preferred.—The conchuela shows a marked preference for the juices of the seeds and fruits of its food plants. In a report of preliminary investigations of this insect the writer recorded an observation regarding this preference. As no specific observation on this point has been made, it may be repeated that of 57 adults feeding on cotton plants, 43 were on bolls, 4 on leaves, and 10 on stems. The proportion feeding on bolls in this observation is less than ordinarily, as is incidentally shown by data given in another paragraph relating to proportion of time adults spent in feeding. The immature seed are the objective point of the insect's attack, as has been stated in describing the nature of the plant-bug injury. Rapidly growing bolls of medium size are preferred to large, nearly mature bolls, the lint of which offers serious resistance to the entrance of the threadlike mouth setæ. In connection with this preference bolls on the lower branches of the cotton plant are less subject to attack than are those growing on branches higher up.

Conspicuous position when feeding.—The conchuela is by far the most conspicuous of the Pentatomids destructive to cotton bolls which are discussed in this bulletin. This is as much so on account of its selection of a feeding place as on account of its size and striking color. This characteristic is an important factor under some conditions in the control of the pest in cotton fields, as will be explained in discussing remedial measures. The author's outline of field work necessitated the examination of many thousand cotton plants for the purpose of counting the insects which were found on them. From this experience it is certain that in the cotton fields in clear summer weather fully 90 per cent of the conchuelas are visible to the observer from a standing posture and without moving any part of the plant. It was a rare occurrence, when making records of the kind indicated, that any additional specimens of these insects were found by using the hands to open up the plant. Only a few instances have been observed where the adult conchuela has been entirely or almost entirely hidden by the bracts of the cotton boll on which it was feeding. When feeding on a boll these insects generally occupy a position on the upper half. When resting, during bright sunlight, they are commonly observed in a conspicuous position on the cotton boll or on the upper surface of the leaves. The resting in the sun is usually observed during the forenoon.

Proportion of time adults spend in feeding.—In the determination of the amount of damage an individual conchuela is capable of inflicting in a cotton field it is important to know what part of its time it is engaged in feeding on cotton bolls. Observations were conducted both in the laboratory and in the field, and the results are summarized in the following tables:

TABLE XVII.—*Feeding records on the conchuela in the field, Tlahualilo, Durango, Mexico, July 22, 1905.*

Hours of observation.	Number of observations.	Number of conchuelas feeding on bolls.	Number of conchuelas crawling or resting on plants.	Per cent feeding on bolls.
9 a. m. to 12 m	251	142	109	56
1 p. m. to 5.30 p. m	66	51	15	77
Summary for day	317	193	124	66

TABLE XVIII.—*Laboratory feeding records on the conchuela, Lot A,*[a] *Series I, Tlahualilo, Durango, Mexico, July 20–22, 1905.*

Hours of observation.	Number of observations.	Number of conchuelas feeding on bolls.	Number of conchuelas not feeding.	Per cent feeding.
6.30 a. m. to 8.30 a. m	69	50	19	72.4
9 a. m. to 12 m	46	46	25	45.6
1 p. m. to 5 p. m	115	57	58	49.5
5.30 p. m. to 7 p. m	69	48	21	69.8
8 p. m. to 10 p. m	69	62	7	89.8

TABLE XIX.—*Laboratory feeding records on the conchuela, Lot A, Series II, Dallas, Tex., September 4–8, 1905.*

Hours of observation.	Number of observations.	Number of conchuelas feeding on bolls.	Number of conchuelas not feeding.	Per cent feeding.
6 a. m. to 12 m	47	8	37	17
1 p. m. to 6 p. m	24	9	15	37.5
7 p. m. to 10 p. m	24	15	9	62.5

[a] Collected in cotton fields in Tlahualilo between July 6 and 10.

TABLE XX.—*Summary of laboratory feeding records on the conchuela, Lot A.*

Place.	Time.	Per cent feeding in daylight.	Per cent feeding at night.	Per cent feeding, day and night.
Tlahualilo, Durango, Mexico	July 20-22, 1905	59.4	89.8	74.6
Dallas, Tex	Sept. 4-8, 1905	27.2	62.5	44.8

A comparison of Tables XVII and XVIII shows a close correspondence between the laboratory and field observations on the amount of time the adults spend in feeding during daylight. The fact that in the field the conchuela feeds almost constantly after sunset has already been recorded.[a] We may safely assume that the adults feed for fully as large a percentage of the nighttime in the field as in the laboratory. Considering, therefore, that 90 per cent of the night (Table XVIII), and 66 per cent of the day, is spent in feeding, the percentage of the calendar day spent in feeding at the times and places of these observations was approximately 78.

Table XX shows a difference between the same lot of insects which is probably attributable to the difference in age of the specimens. Difference in temperature could have had no appreciable effect as it was slight, the average daily mean at Tlahualilo on the days of the observations being 76° F. and at Dallas 79° F.

Method of attack.—For locating the position for piercing the carpel of a cotton boll the conchuela makes use of its antennæ and tip of the rostrum. As in other Heteroptera, the rostrum is used only as a guide for the threadlike setæ and is never forced into the object upon which the insect may feed. As the setæ sink into the boll the rostrum bends at the joint between the first and second segments, being directed backward. The setæ at the same time are freed from the rostral groove of the basal two segments, and as these two segments fold together, this allows a greater depth of penetration. Next, the apical or fourth segment is bent or folded back leaving the setæ in the rostral groove only at the angle between the third and fourth segments. In this position the rostrum forms a letter "Z," the upper angle representing the joint between the second and third and the lower angle the joint between the third and fourth segments. Feeding may be continued with the rostrum in this position or the rostrum may be freed entirely from the setæ and directed straight back along the middle of the venter in the usual position it occupies when the insect is resting or crawling. The insect may therefore use practically the entire length of the setæ to penetrate through the carpel and the developing lint to the cotton seed. This length is about one-fourth of an inch. When feeding, the bug alternately

[a] Bul. 54, Bur. Ent., U. S. Dept. Agr., p. 26, 1905.

raises and lowers its head. After withdrawing the setæ from the boll, a downward stroke of one of the fore tibiæ places them in the rostral groove, each tibia for this object being provided with a short spine located on its inner side slightly beyond the middle.

Miscellaneous observations on feeding habits.—Twenty-six observations gave 20 minutes as the average time the adults fed through one puncture in a cotton boll. The maximum length of time in these observations was 1 hour and 30 minutes. In his report of preliminary investigations [a] on the conchuela the author presented his observations on the length of time adults remain on a single boll and on a single plant as follows: "One adult under observation in the field visited 4 bolls, 2 on each of 2 plants in 2 days, and remained for over 36 hours on the last of the 4 bolls. Another adult bug remained on the same boll for $2\frac{3}{4}$ days. Three remained on the same boll for over 30 hours and 3 others were found on the same plant 30 hours after they were first recorded. In none of these cases was it known how long the insects had been on these plants previous to their first being noted."

Abnormal predaceous and cannibalistic habits.—Starving adult conchuelas confined with live caterpillars of the bollworm (*Heliothis obsoleta* Fab.) and the cotton boll cutworm (*Prodenia ornithogalli* Guen.) failed to exhibit any indication of carnivorous habits. Dead or dying insects, however, are not always refused and are sometimes fed upon by adults as well as by nymphs in preference to cotton bolls. (See feeding habits of nymphs, pp. 41–42.) On a few occasions where 2 or more adults have been confined together in breeding cages, dead or dying specimens have been fed upon by the survivors of the lot. All evidence at hand goes to show that in the field the adult conchuelas are entirely phytophagous.

GREGARIOUSNESS.

The gregarious habit exhibited by the conchuela, like its habit of occupying a conspicuous position on the plant, is of considerable importance in its control. The author has previously noted [b] this striking feature, basing the records on observations made at a season of the year when these insects were comparatively scarce. Between August 31 and September 6, 1904, in a selected section of the cotton fields at Tlahualilo, 34 adults were collected on 16 plants, although the insects were so few that but 5 or 6 plants out of 100 were found to be infested. In July, 1905, 2 other species of Pentatomids (*Pentatoma sayi* Stål and *Thyanta perditor* Fab.) were found associated with the conchuela and occurring in moderate abundance on the

---

[a] Bul. 54, Bur. Ent., U. S. Dept. Agr., p. 26, 1905. [b] Loc. cit., pp. 26–27.

cotton plants. Field observations showed that whatever the nature of the attraction which is the basis of the occurrence, it is operative between the different species of Pentatomids as well as between individuals of the same species.

As a result of this gregarious tendency it was found that of 467 cotton plants examined on July 15, 1905, in one of the most heavily infested sections of the plantation at Tlahualilo, the infested plants, or those plants upon which there was at least 1 bug, numbered 91 and averaged about 2 bugs per plant. There were therefore about five times as many of the insects upon the infested plants as upon the average of the plants examined. A further concentration of these bugs was observed on the individual bolls. Of 100 bolls upon which one or more of the bugs was feeding 52 were found to have from 2 to 5 bugs each and 48 only 1 bug each. In all, there were 175 bugs feeding on the 100 bolls.

FLIGHT.

In September, 1904, conchuelas in the field showed themselves capable of only short flights, about 25 feet being the maximum distance attained by any one effort observed. In July of the following year observations showed these insects to be strong fliers. Gentle winds have little effect on the flight of the insects, as they seem to fly as often against as with the wind. Many of the insects have been observed to fly as far as the eye could follow. In one instance when lost to view the specimen was about 50 feet above the ground and gradually rising higher; in another case a specimen disappeared from view without rising higher than 15 or 20 feet.

The numbers of the insects in any given locality are subject to rapid changes owing to their flying propensities, but extensive migrations are always traceable to the need for a fresh food supply.

SEASONAL HISTORY.

INCREASE AND DECREASE IN NUMBERS DURING THE SEASON.

Previous to the season of 1903, as far as can be learned, the conchuelas attracted no particular attention as cotton pests in the Laguna district of Mexico. For the information here presented concerning the seasonal history of these insects in 1903 and 1904 the author is indebted to Mr. John Conduit, resident manager of the Tlahualilo cotton plantations, who, owing to the immense tract of cotton grown under his supervision, gives particular attention to cotton pests, and in addition to personal examinations in the fields directs the "bosses" of the various parts of the estate to send in to the office specimens of insects taken on the cotton plants, with information concerning their abundance. The bosses in their turn make examinations and send dozens of laborers into the various subdivisions of the estate to search for any particular insect concerning which information may be desired at headquarters. This system made it possible to obtain accurate information concerning the abundance of the Pentatomid bugs here considered.

In 1903 the conchuelas were abundant only during the month of July and reached a maximum in numbers about July 20. Their first appearance was in the outlying districts, next to the mesquite, but they soon spread all over the cotton plantation, although they were more abundant in certain parts than in others. The insects disappeared early in August and did not reappear in noticeable abundance during the season, although the cotton plants remained green until October 17, when the first frost was recorded.

Although a close watch for the insect was maintained during the late spring and early summer of 1904, the first specimen was not taken in the field until July 6. During the following seven days a rapid increase in its numbers was noted, and on July 17 it was observed that a marked decrease had occurred. Nowhere on the plantation were the insects as abundant as in July of the previous year, nor were they so generally distributed.

On August 31 a personal examination in the cotton fields by the author showed the insects to be very scarce, although in certain sections of the plantation the open cotton bolls with stained and ruined lint gave unmistakable evidence of their greater abundance a few weeks earlier in the season.

In July, 1905, a detailed numerical study was made, which verifies Mr. Conduit's general observations for the two previous seasons. While the subject of natural enemies is discussed under a separate heading, it is necessary to mention here that the abundance of the conchuela during the season is principally dependent upon the efficiency of its parasitic and predaceous enemies. Egg-laying by the average individual is distributed over such a long period of time that it can hardly be said that the conchuelas naturally appear in broods. However, practically the same effect may be produced locally to a greater or less extent by the action of natural enemies. During the first two weeks of July adults and nymphs in all stages were found in abundance on mesquite in the uncultivated lands surrounding the Tlahualilo Cotton Plantation. The gradual ripening and drying of the beans was evidently causing a migration of the adults in search of food, many finding their way into the cotton fields. Egg-parasitism was acting as a practically complete check on further multiplication in the mesquite. In their search for food the first migrants from the mesquite settled in large numbers in sections of the plantation upon which *zoca* or seppa (stubble) cotton was growing, and later the migrants showed a preference for the planted cotton when the bolls became more numerous and large enough to be attractive to them.

The most thorough study of the changes in the numerical status of the conchuelas during July, 1905, was made in a *tabla* comprising about 120 acres and known as "Ceceda A 14" (fig. 7). The cotton in this *tabla* was *zoca* or seppa, and during the first half of July repre-

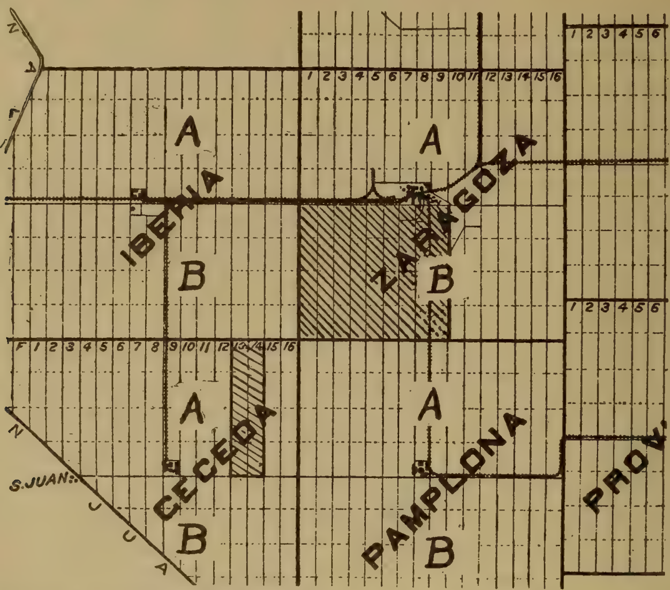


FIG. 7.—Diagram of a portion of the Tlahualilo Cotton Estates. The shaded *tablas* are the principal ones referred to in the text. (Original.)

sented conditions more attractive to the insects than did any equal area of *planta* (planted) cotton. Five examinations were made during July near the west end of this *tabla*, beginning with a row about 15 or 20 yards from the end and examining across the *tabla*, changing to next row east, every 10 plants. The results of this examination are summarized in the following table:

TABLE XXI.—*Variation in abundance of Pentatomids during July, 1905, at Tlahualilo, Durango, Mexico.*

When examined.	Number of plants per row.	Number of infested plants in 100.	Adults per 100 plants.			Total adult Pentatomids per 100 plants.	Number of nymphs *P. ligata* per 100 plants.[a]
			P. ligata.	*P. sayi.*	*Thyanta* sp.		
1905.							
July 11	100	19	52	0	0	52	0
15	99	30	52	3	2	57	1^{3} 1^{4}
21	98	31	59	4	0	63	2^{4}
27	103	12	33	0	0	33	0
29	96	7	17	0	0	17	1^{2} 1^{5}
Total	493	99	213	7	2	222	6
Average	98.6	19.8	42.6	1.4	.4	44.2	1.2

[a] Small figures indicate the instars.

Bugs were picked from the plants on this *tabla* between the examinations of July 11 and 15 and again between the examinations of July 27 and 29, the first pickings averaging about 7 per row and the second averaging between 5 and 10. The removal of these may be taken into consideration, although affecting the general results but little. The data obtained by these examinations show that conchuelas, or in a broader sense the Pentatomids, reached their maximum numbers in this field about July 20, and during the following week there was a decrease of nearly 50 per cent. Considering the picking just previous to the last examination, a continuance of the natural decrease in numbers is evident.

Following the same general plan, four additional examinations were made on July 15 for the purpose of showing the numerical status of the bugs on that date throughout the *tabla*. The length of the *tabla* being about one and one-quarter miles, five examinations were made, one at each end and three between, at places estimated to divide the *tabla* into fourths. Table XXII shows the data obtained by these examinations.

TABLE XXII.—*Numerical status of Pentatomid bugs in field of 120 acres, July 15, 1905.*

Examination No.	Number of plants in row.	Number of plants infested by adults per 100.	Number of adults *P. ligata* per 100 plants.	Number of nymphs *P. ligata* on 100 plants.[a]	Number of adults *P. sayi* per 100 plants.	Number of adults *Thyanta* sp. per 100 plants.	Total adult Pentatomids per 100 plants.
1	99	30	52	1^{3} 3^{4}	3	2	57
2	82	26	57	1^{2} 1^{5}	8	2	67
3	103	17	33	9^{2} 1^{4}	0	1	34
4	127	5.5	7.8	0	0	1	8.8
5	56	12.5	21.4	0	0	1	22.4
Total	467	91	171	16	11	7	189
Average	93.4	18.2	34.2	3.4	2.2	1.4	37.8

[a] Small figures indicate the instars.

As there were nearly 1,660 rows in the above *tabla*, it may be estimated from the data given that there were on July 15 approximately 60,000 conchuelas in the entire area of 120 acres.

Another series of observations made in *planta* cotton in Zaragoza B, *tablas* 1–9, also shows a diminution of the pest during the last 10 days of July. A single row was examined on each *tabla* about 200 yards from the east end, the rows running north and south.

TABLE XXIII.—*Abundance of Pentatomids, Zaragoza B, July 25, 1905.*

Tabla.	Number of plants in row.	Percentage of plants infested.	Number of adults *P. ligata* per row.	Number of adults *P. sayi* and *Thyanta* sp. per row.	Number of adult Pentatomids per 100 plants.	Number of nymphs *P. ligata* per row.[a]	Egg-batches *P. ligata.*
1	310	6.4	30	[b]2	10.3	11^{2}	1
2	227	1.3	4	0	1.8	1^{2}	2
3	247	1.6	4	[c]2	2.4	0	1
4	232	2.1	11	[c]2	5.6	0	0
5	254	3.1	10	[c]1	4.3	0	0
6	270	3.3	16	0	5.9	0	0
7	314	6.0	43	0	13.7	0	0
8	213	6.1	21	[b]2	9.6	0	0
9	209	3.8	25	0	11.9	0	0
Total	2,276	....	164	9	65.5	12^{2}	4
Average	255	3.7	18.2	1	7.3	1.33	.44

[a] Small figures indicate the instars. [b] *Thyanta* sp. [c] *Pentatoma sayi.*

TABLE XXIV.—*Abundance of Pentatomids, Zaragoza B, August 1, 1905.*

Tabla.	Number of plants in row.	Percentage of plants infested.	Number of adults of *P. ligata* per row.	Number of adults (Table XXIII) *P. sayi* and *Thyanta* per row.	Number of adult Pentatomids per 100 plants.	Number of nymphs *P. ligata* per row.[a]	
1	301	3.0	13	0	4.3	1^{2}	0
2	236	2.1	6	0	2.5	1^{5}	0
3	265	1.1	3	0	1.1	1^{3}	0
4	308	1.0	3	0	1.0	1^{3} 1^{4}	0
5	303	3.9	10	2	4.0	2^{1} 1^{4}	0
6	275	1.1	3	0	1.1	0	0
7	371	.5	2	0	.5	0	0
8	232	4.3	18	0	7.7	25^{2}	1
9	170	1.1	3	0	1.8	0	0
Total	2,461	....	61	2	24.0	33	1
Average	273.4	2.0	6.8	0.2	2.7	3.6	0.1

[a] Small figures indicate the instars.

The observations in Zaragoza B were made partly as a check on those made in Ceceda A, *tabla* 14. In the latter block a large percentage of the bolls had already been ruined and probably rendered less attractive as food for the bugs. There seemed to be a possibility that the decrease in numbers during the last 10 days of July was due to migration of the adults to other fields. In Zaragoza B, *tablas* 1–9, the cotton was in such condition on the average that it is improbable that a scarcity of suitable food supply could have impelled a migration. The data, moreover, on the numbers of eggs and nymphs found in the different *tablas* give strong indications that the infestation had progressed from *tabla* 1 toward 9 and that it had been, on the whole, recent. If the decrease in numbers of the adult conchuelas and other species of Pentatomids in Ceceda A, *tabla* 14, had been due to a migration, a similar decrease would have been unlikely to have occurred in the *planta* cotton in Zaragoza where the food supply was ample. The *planta* cotton in Ceceda A, *tabla* 16, separated from *tabla* 14 by *tabla* 15 (which was planted in corn), showed on July 29 an average of between 2 and 3 adult conchuelas for each 100 plants. No actual estimates of the numbers of the insects present had been previously made, but from casual observation it is practically certain that the general decrease in numbers had occurred on this *tabla* as well as on the others examined. Other observations in various places confirm the belief that the diminution in the numbers of the insects occurred generally throughout the plantation. Messrs. J. P. Conduit and J. A. Vaughan informed the writer that after August 1 the bugs never appeared anywhere on the plantation in what seemed destructive abundance, although a few were constantly present in various sections. During the first week in December, no frost having occurred, the author could find no specimens of the conchuelas in the cotton fields, although within two weeks a live specimen had been seen at the gin, having been accidentally brought in with seed cotton.

The seasonal history at Barstow, Tex., in 1905, showed a similar record to that at Tlahualilo. The conchuela there was very abundant about the middle of July, and, while by no means uncommon on August 11 and 12, it was evident that a considerable reduction in numbers had taken place during the previous 2 or 3 weeks. On September 12 it was found that only a slight further reduction in the number of adults had taken place, but nymphs were comparatively scarcer. A month later Mr. J. C. Crawford, of the Bureau of Entomology, found that nymphs in the fourth and fifth instars were much more abundant than they had been on the dates of the two preceding examinations; the adults were slightly more abundant than on September 12, and mostly soft, indicating that they had recently matured. On November 14 Mr. Crawford, in a few hours' search where the bugs had previously been abundant, could find no nymphs and only a half dozen adults, all of which had attained the ordinary degree of firmness and were therefore not recently matured as were those collected on the preceding visit.

HIBERNATION.

The conchuela appears to hibernate exclusively in the adult stage. Observations have been recorded under the subject of duration of the nymphal stages which indicate that it is highly improbable that immature forms ever survive even one-half of the winter season. No field observations have been made upon the hibernation of this species owing to the fact that as cold weather approached the surviving adults were so scarce, even where they had been previously most abundant, that to obtain positive results more attention than it has been practicable to give would have been required. Nineteen adults—10 females and 9 males—in confinement at the laboratory at Dallas furnished some data on the subject. Shortly after the middle of November no more food was provided and dead leaves were put in with the bugs in the lantern-globe breeding cages which were in an open shelter protected only from rain. The lot included a specimen (female) which became adult on August 14, and one which became adult on August 16 (male), 2 females which were collected at Clarendon, Tex., on September 19, and 8 males and 6 females collected at Barstow, Tex., on October 13. On December 1 all were alive; on December 19, when next noted, all were alive except one of each sex collected on October 13; on January 17 one of the same lot was observed crawling in a cage, the others being hidden in the leaves, while on March 8 an examination showed that 15 were dead and 4 had escaped during the writer's two months' absence from the laboratory. Whether or not these four specimens which escaped survived the winter is of course unknown, but as they left the cage after January 1 it may be presumed that they were more vigorous than the others. Perhaps in the field the bugs are capable of finding more suitable hibernating conditions than were provided.

In general, Pentatomids hibernate among dead weeds, in crevices under the loose bark of posts and trees, and in rubbish of various kinds. Uhler's green plant-bug is reported[a] to burrow in loose soil for the purpose of hibernating, and a similar observation[b] has been made in the case of the predaceous bug *Podisus serieventris* Uhl. Doubtless many Pentatomids, like other insects, attempt to hibernate in places where their chances of surviving the winter are slight, and it seems doubtful that Pentatomids which bury into the soil often survive the winter except where there is little or no rainfall.

Pentatomids are among the earliest insects to emerge from hibernation in the spring, although apparently only a small percentage passes the hibernating period successfully. Both sexes hibernate in many, if not in all, species. Regarding the appearance of the conchuela in the spring at Tlahualilo, Mr. J. P. Conduit, under date of March 10, 1906, in a letter to the writer says: "In spite of the cold weather we have had, the conchuela is still with us, and two or three live ones have already been picked up in various places." In northern Mexico and western Texas the first eggs are probably deposited shortly after the average daily mean temperature becomes constantly above 70° F. Ordinarily, this would occur early in April. The slow rate of production, however, in April and May temperature seems to prevent a large increase in numbers of the insects before June 1.

---

[a] Bul. 57, South Dak. Exp. Sta., p. 40, 1898.

[b] The Gypsy Moth, by Edward H. Forbush and Charles H. Fernald, Mass. Board of Agr., 1896, p. 403.

DESTRUCTIVENESS.

INDIVIDUAL CAPABILITIES.

As a basis for determining the amount of damage done to cotton bolls by individual conchuelas an examination was made on July 17, 1905, of 104 bolls upon which one or more adults were observed feeding. These bolls were opened and the number of punctures found on the inside of the carpels was recorded. One hundred bolls showed positive injury, and the remainder did not show enough discoloration to justify their inclusion with those believed to be ruined, although the two smaller ones would very likely have failed to mature if left on the plants. These 4 bolls were in diameter approximately one-half an inch, three-fourths of an inch, one and one-eighth inches, and one and one-fourth inches, and showed on the inner side of the carpels, 2, 5, 19, and 32 punctures, respectively. The results of the examination of the damaged bolls are summarized in the following table:

TABLE XXV.—*Results of examinations of 100 bolls upon which one or more specimens of the conchuela had been observed feeding in the field.*

Approximate diameter.	Number.	Badly damaged.	Slightly damaged.	Total number of punctures.	Average number of punctures per boll.	Maximum number of punctures per boll.	Minimum number of punctures per boll.
Inches.							
$\frac{1}{2}$	1	0	1	3	3	3	3
$\frac{5}{8}$	7	7	0	119	17	34	15
$\frac{3}{4}$	14	10	4	266	19	34	3
$\frac{7}{8}$	15	10	5	420	28	41	9
1	23	21	2	1,150	50	88	35
$1\frac{1}{8}$	28	20	8	1,484	53	141	22
$1\frac{1}{4}$	8	5	3	504	63	136	8
$1\frac{3}{8}$	4	2	2	172	43	68	28
Totals and summary	100	75	25	4,118	41	141	3

Data have now been given from which we may calculate approximately the amount of damage that a single conchuela is capable of doing. It has been shown that in cotton fields in midsummer each insect spends on an average about 78 per cent of its time feeding on cotton bolls or in round numbers about 1,100 minutes per day. At the rate of 1 puncture for each 20 minutes while feeding, 55 punctures per day would be made by each adult of these insects. The average number of punctures (41) in the damaged bolls referred to in Table XXV is equivalent, therefore, to the number one adult may make in about three-fourths of a day.

Estimates based upon actual counts and examinations in various parts of Ceceda A, *tabla* 14, places the number of bolls about the middle of July in the entire *tabla* at a little over 2,500,000 and the number damaged by bugs at a little more than 1,125,000. Other estimates which have already been referred to placed the number of conchuelas on the entire *tabla* at about 60,000. At the rate of one boll destroyed for each three-fourths of a day, it may be calculated that on July 15 the bugs had been in the field an average of 16 days each.

Estimates made after December 1, the details of which will be found elsewhere, placed the destruction by bugs in Ceceda A, *tabla* 14, at approximately 28 bales, not taking into consideration the bolls which were shed from the plants as a result of injury by these insects. The estimate of 60,000 conchuelas in the entire *tabla* was based on data obtained on July 15, after which there was a slight increase. Reference to Table XXVI will show that an estimate of 65,000 bugs is not too high for the maximum number of live conchuelas in this *tabla* at any time in July. For each 2,300 bugs, therefore, about one bale of cotton was destroyed. Considering the loss of one bale of cotton as equivalent to the moderate sum of $45, on the average each bug in the *tabla* destroyed cotton to the value of about 2 cents. This estimate can not be considered as representing even approximately the amount of damage by a single conchuela except under conditions similar to those described. General deductions of wider application may, however, be drawn from the data given.

From a comparison of the average maximum and minimum number of punctures per damaged boll in Ceceda A, *tabla* 14 (Table XXV), it is evident that the bolls were much fed upon by the bugs after they had received sufficient injury to result in complete destruction. Fortunately such feeding prevents a maximum amount of damage. The average of the ruined bolls of the various sizes with the minimum number of punctures is 15.4, or about one-third of the average number of punctures for all bolls. Even this number is greater than usually necessary for the destruction of bolls, as the data given show. On the other hand, many punctures are made in bolls which have reached such a stage of maturity that there results either no appreciable damage or only a staining of the lint to a greater or less degree.

The habit of the conchuelas of congregating on individual plants and even on individual bolls has a tendency to result in an excess of feeding punctures above the number necessary to cause destruction. Data have been given in Table III showing that at Dallas, Tex., in a field where plant-bugs were less abundant than in Ceceda A, *tabla* 14, at Tlahualilo, the average number of punctures per destroyed boll was 28. For convenience we may suppose that in a field infested by the conchuela, where the damaged bolls average 28 punctures per boll, it is desired to estimate the amount of damage the individual bugs may accomplish. At the average rate of 56 punctures per day, which is the estimated number, the bugs would have averaged 2 bolls per day destroyed instead of $1\frac{3}{4}$ bolls per day estimated in Ceceda A, *tabla* 14. As the percentage of damaged bolls increased, the daily damage per bug would diminish. If the increase in the number of new bolls was sufficient to prevent an actual increase in percentage of damaged bolls, the average daily injury for each bug would remain fairly constant at 2 bolls per day, and the ultimate damage, if in the same ratio as that which obtained at Tlahualilo in the field, to which the data refer, would be 60 per cent more than estimated for that field, or an equivalent of $3\frac{1}{5}$ cents for each bug.

From estimates made at Tlahualilo on the numerical status of the insects in July and on the percentages of ruined bolls in December, the relationship of the number of bugs present during the period of maximum abundance and the damage accomplished during the season may be presented in tabular form as follows:

TABLE XXVI.—*Relation of number of conchuelas to amount of damage.*

Field.	Number of adult conchuelas per 100 plants, July 23-25, 1905.	Number of adult conchuelas per row, July 23-25, 1905.	Average number of bales good cotton per acre.	Average number of bales ruined cotton per acre.	Percentage of ruined cotton.
Zaragoza B, *tabla* 1, east quarter	9.6	30	0.412	0.246	37
Zaragoza B, *tabla* 3, west quarter	1.7	3.5	.644	.11	14
Ceceda A, *tabla* 14, west quarter	46	46	.216	.221	50

The percentage of injury in Ceceda A, *tabla* 14, is so far above the ordinary that it may be properly considered as representing an extreme case, while the individual conchuelas, for reasons given, accomplished a minimum amount of damage, equivalent to about 2 cents. The maximum amount of damage for the individual conchuelas would be difficult to determine without a long continued series of observations, but it is probably equivalent to not more than 2 or 3 cents above the minimum amount. These estimates, while necessarily only approximating actual conditions, will serve to give a general idea of the damage an individual conchuela or other plant-bug is capable of causing. A knowledge of this point is an essential step in the determination of the practicability of various remedial measures.

REDUCTION IN YIELD OF INFESTED COTTON FIELDS.

As has been stated, the estimated loss to the cotton crop of 1903 at Tlahualilo was between 1,200 and 1,500 bales. Accordingly this loss for the entire acreage in planted cotton—amounting to about

19,000 acres—would average between 0.063 and 0.079 bale per acre. It is certain that this estimate was not too high, as it was based solely on the damaged and ruined bolls in evidence in the cotton fields at the close of the picking season and no consideration whatever was given to the bolls shed as a result of the injury by the insects. In the season of 1904 fewer of the bugs were present than in the preceding season and the average yield per acre of planted cotton amounted to 0.472 bale per acre, being an increase of 0.161 bale per acre. This increase is believed to be partly due to the difference in the number of bugs present in the cotton fields in the two seasons referred to.

In July and December, 1905, field observations throughout the plantation of over 22,000 acres at Tlahualilo gave data from which it is believed an estimate of damage has been made which is more accurate than any estimate of insect damage based on actual field examination ever attempted for as large an acreage. It was found that bug damage ranged from none at all in restricted areas to 31.6 per cent and for the entire plantation averaged very close to 8 per cent. This does not include the bolls which were shed from the plants. These numbered probably less than 2 per cent and their loss was not necessarily detrimental to the crop as they did not, like those damaged bolls that persisted, continue to receive nutriment from the plant. The entire yield at Tlahualilo in 1905 amounted to about 15,000 bales. The loss of about 8 per cent represents, therefore, about 1,200 bales of cotton. The methods used in the examinations upon which this estimate is based will be explained hereafter.

A striking contrast to the conditions at Tlahualilo was observed about 40 miles distant in the southwestern portion of the Laguna district near the cities of Gomez Palacio and Lerdo. Here, for some obscure reason, persistent search failed to show the presence of the conchuela while other plant-bugs were of remarkably rare occurrence in cotton fields. As a consequence plant-bug injury was difficult to find and, at the most, amounted to only a small fraction of 1 per cent.

The most detailed study of the losses due to plant-bugs was made at the Tlahualilo plantation in 4 blocks heretofore referred to, namely, Ceceda A 14, Zaragoza B1, Zaragoza B2, and Zaragoza B3. In the first the work extended throughout the block while in the last 3 blocks the studies were local and represented in each case conditions which may have been characteristic of only a small part of the entire block of 120 acres. In July, 1905, many examinations of green bolls were made for the purpose of determining the percentage of damage, but later it was shown that data of this kind obtained at that season of the year were of little significance. Thus in one locality as high as 70 per cent of all bolls in July were ruined by plant-bugs while later increases in the number of bolls and decreasing destructiveness of the insect lowered the percentage of damaged bolls to about 31.

Method of estimation of losses.—Final estimates of the losses due to plant-bugs at Tlahualilo were made during the first week in December, 1905. Growth of the bolls had practically ceased, although no frost had occurred. Many green bolls had attained a mature size and in all probability would open under the influence of the first frosts. Estimates for each section of a field were based on exact counts and the classification of all bolls on 25 plants of a row, selecting 5 consecutive plants at each end and 3 groups of 5 consecutive plants each, at points between the end groups, to equitably represent the entire row. The bolls produced by each plant were classified as unopen, empty burrs, perfect bolls, slightly stained, badly stained, and destroyed. Included in this estimation as unopened were only such bolls as had reached mature size and were likely to open and produce good lint when not injured by insects. ''Empty burrs'' indicate that from these the lint matured and was picked or had fallen out. In either case as far as this investigation is concerned these should be associated with the perfect bolls. Classed as perfect bolls were only those which showed no trace of noticeable stain due to plant-bug attack. Included as slightly-stained are those which plainly show stain, although probably worth picking in the sense that the increased bulk gained thereby would probably offset the possible decrease in value per pound due to the stain. ''Badly-stained'' bolls contained no lint that could be profitably picked, although not more than one lock in any boll or about 10 per cent of all locks in this class was actually destroyed. ''Destroyed bolls'' included no lint that a picker would often intentionally pick, and were characterized by open or partly-open carpels showing a discolored, matted mass of partially developed lint in at least two locks of each boll, with any locks not thus affected badly stained and damaged sufficiently to prevent ''blowing.'' Classification as regards the last four grades was in many cases necessarily a matter of personal opinion, but in averaging it is believed this feature is largely eliminated, as on the whole the differences are quite distinct. Bolls damaged by bollworms are omitted from these considerations.

Damage to cotton in Ceceda A, No. 14.—Five examinations were made according to the methods described above. One was about 50 feet from the east end, 1 about the same distance from the west end, and 3 at points dividing the block into 4 approximately equal parts. The results of these 5 examinations of 25 plants each are summarized as follows:

TABLE XXVII.—*Classification of bolls on average plant, Ceceda A 14, with reference to plant-bug damage.*

Examination No.	Unopen.	Empty burrs.	Perfect, open.	Slightly stained, open.	Badly stained, open.	Destroyed.
1	9.6	1	9.56	3.48	5.2	8.12
2	13.7	4.4	22.3	5.72	7	7.52
3	10.6	3.8	16	6.2	6.5	10
4	11.3	1.68	13.2	5.4	5.4	7.5
5	7.6	1.92	10.6	9.4	7.1	7.2
Average....	10.56	2.56	14.33	6.04	6.24	8.07
Per cent....	22.1	5.3	30	12.6	13	17

The average number of bolls per plant throughout the block according to the above data is 47.8. Data previously collected showed an average of 93 plants per row in this block which consisted of about 1,660 rows. There were accordingly in round numbers 154,000 plants in the block and about 7,370,000 bolls.

Tests by officers of the Tlahualilo plantation showed that the cotton grown at that place averaged about 63 bolls of seed cotton per pound. It can be readily calculated from this data that if all the bolls in the block produced good lint there would be a yield of approximately 78 bales for the 120 acres in the block. These bolls and their equivalents in bales of cotton are here given in tabular form.

TABLE XXVIII.—*Classification of bolls in entire block, Ceceda A 14, with reference to plant-bug damage.*

Classification.	Estimated number of bolls.	Number of bales of cotton represented.
Unopen	1,629,000	[a]16.37
Empty burrs	391,000	4.13
Perfect and slightly stained, open	3,139,000	33.23
Badly stained, open	958,000	[b]9.13
Destroyed	1,253,000	[c]15.25
Total	7,370,000	78

[a] An examination showed that about 5 per cent of unopened bolls were ruined by plant-bugs; consequently 0.86 bale has been deducted from the number of bales represented.
[b] About 10 per cent of the total number of locks in badly-stained bolls were destroyed; consequently 1.01 bales were deducted.
[c] Including 0.86 bale, or 5 per cent, of unopen bolls (see note [a]) and 1.01 bales, or 10 per cent, of badly-stained bolls (see note [b]).

According to the writer's estimate, the maximum possible yield in this block would be 78 bales, less the number of bales represented in the above table by the empty burrs and the destroyed bolls. This gives 58.73 bales or 0.49 bale per acre. The actual yield as finally recorded at the office of the Tlahualilo Company was 55 bales for the block or 0.46 bale per acre.

Regardless of the amount of cotton ginned, in computing the actual destruction we should include the badly-stained bolls with the destroyed bolls. A considerable part of the badly-stained cotton is regularly left by pickers on account of its being imperfectly opened out and not easy to handle. Furthermore, as will be shown in discussing the effect of plant-bug injury on the quality of the lint, the picking of such lint is a distinct disadvantage, probably more than offsetting the increased weight attained. In Ceceda A, No. 14, therefore, the actual loss in 1905 may be considered to be equivalent to about 24.38 bales, or 0.2 bale per acre.

Damage to cotton in Zaragoza.—Three examinations were made in Zaragoza, one in each of the first 3 blocks, following the plan heretofore outlined of examining 25 plants per row. The data obtained represent local conditions only and do not necessarily indicate either the damage or the yield throughout each block. It should be noted, however, that the final yield of the 360 acres comprising the 3 blocks was 187 bales, whereas the examinations from which the data in the following table were obtained would indicate a yield of 193 bales.

TABLE XXIX.—*Local examinations in Zaragoza with reference to cotton damaged by plant-bugs.*

Block.	Bolls not ruined.					Bolls ruined.				Unopen bolls.
	Lint picked and fallen from burrs.[a]	Perfect.	Slightly stained.	Total.	Equivalent bales per acre.	Badly stained.[b]	Destroyed.	Total.	Equivalent bales per acre.	
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*		*Per ct.*
Zaragoza B 1 (east end)	39.56	16	6.7	62.26	0.49	9	17.14	26	0.174	11.7
Zaragoza B 2 (east end)	24.98	15.4	11.3	51.68	.521	13.2	19.92	33	.255	15.4
Zaragoza B 3 (west end)	63.5	10	5	78.5	.61	3.7	11	14.7	.11	6.3

[a] Deducting 2.44 per cent, representing approximately the number of ruined locks present in empty burrs.
[b] Adding 2.44 per cent of ruined locks present in empty burrs.

EFFECT OF PLANT-BUG ATTACK ON QUALITY AND MARKET VALUE OF LINT.

The market value of each bale of cotton is determined by examination of samples of the lint by experts who judge of its relative quality. This grading of the staple limits the use to which each bale may be put. Stained cotton is the least desirable of all grades and generally brings a selling price of about 50 per cent of the average unstained grades. Tables XXVII and XXIX are illustrations of instances wherein the percentage of slightly-stained cotton has been determined in the field. This class may include as many of the entire number of bolls as 11 per cent, or 17 per cent of the lint picked, omitting bolls completely ruined. It is obvious that such inferior material reduces the value of the better grades with which it may be mixed.

At Tlahualilo the crop of 1902–1903 included 1,277 bales of cotton, or 11.2 per cent, grading below "strict good ordinary," and classed as "stained." The crop of 1903–1904, which was damaged by bugs to greater extent than any other crop, included 1,812 bales, or 23.5 per cent, of this class of cotton, while the crop of 1905–1906 included 885 bales, or 6.6 per cent. Near the cities of Lerdo and Gomez Palacio, in another section of the Laguna district, as has been heretofore stated, the conchuela was apparently entirely absent and other Heteropterous insects were of exceptionally rare occurrence in cotton fields. Stained cotton in the fields in this locality is either difficult or impossible to find. A plantation near Lerdo, belonging to the same company as the one at Tlahualilo, produced over 2,000 bales of cotton as the crop of 1905–1906. The author's field observations as to the absence of plant-bugs and stained cotton in these cotton fields in July and December, 1905, received verification in the classification of baled cotton by the buyers, inasmuch as not a bale of the entire crop was classed as "stained."

NATURAL CONTROL.

Weather Influences.

Hard rains doubtless destroy many young Pentatomid nymphs, but such rains seldom occur in the regions where the conchuela is most abundant. At Tlahualilo, after an unusually heavy rainfall in July, 1905, Mr. J. A. Vaughan found nymphs in large numbers crawling on the ground along the banks of an irrigation canal several miles from the cultivated fields. These nymphs were mostly in the fifth instar and had undoubtedly been beaten from the mesquite by the rains. Two results of importance might follow such an occurrence: First, a large number of the nymphs might die without reaching food; second, the nymphs thus forced to migrate might overrun cultivated lands with serious effect upon the crops.

Parasites Attacking Eggs.

The writer has recently described as *Telenomus ashmeadi* Morrill (fig. 8; Pl. V, fig. 2), an important species of egg-parasite which has been found, both in western Texas and in Mexico, to effectively check the multiplication of the conchuela by midsummer.[a] The seasonal history during several years as noted by reliable observers indicates that this result is accomplished with considerable regularity. Were it not for these insects, damage to cotton at points in the Laguna district in Mexico and western Texas would be so great that this crop could not be profitably produced. The importance of these insects in western Texas in 1905 has been discussed by the writer in a previous bulletin[b] and their general economic importance and their life

[a] American Naturalist, XLI, pp. 417–430, 1907.
[b] Bul. 64, Pt. I, Bur. Ent., U. S. Dept. Agr., pp. 9–10, 1907.

history and habits treated of in connection with the description of the species.

The following table summarizes the data on parasitism by *Telenomus ashmeadi* obtained during the season of 1905:

TABLE XXX.—*Parasitism of eggs of the conchuela by Telenomus ashmeadi in 1905.*

When collected.	Locality.	Egg-batches.		Eggs.		
		Number collected.	Number parasitized.	Number.	Per cent from which parasite emerged.	Per cent from which bugs hatched.
1905.						
July 7	Tlahualilo, Durango, Mexico	2	2	75	77.4	0
July 12	do	9	7	229	75.0	22
July 17	do	11	9	490	49	21
August 11-12	Barstow, Tex	6	5	181	[a] 22	19
September 12	do	13	13	246	54	8
Summary		41	36	1,221	55.5	14

[a] Fifty-one per cent contained parasites; 25 per cent failed to emerge.

As stated by the writer in previous publications, the percentage of eggs from which adult parasites emerge does not indicate necessarily the number of bug eggs which are actually prevented from hatching by these beneficial insects. Both in the laboratory and in the field many parasites reach maturity, but for some unknown reason fail to emerge. In many cases the parasites make holes with their mandibles in the egg-shells of the bugs in which they are incased, nearly large enough to permit of escape, and then die, apparently becoming exhausted by their efforts. Other eggs in parasitized batches fail to hatch, or produce adult parasites, containing nothing but a shriveled, brownish, and structureless mass. The failure of such eggs to produce nymphs seems to be usually due to parasitism. Possibly in such cases the larva of the parasite died soon after having accomplished the destruction of the host egg. The table leaves unexplained the failure to hatch of about 30 per cent of

FIG. 8.—*Telenomus ashmeadi*, an important egg parasite of *Pentatoma ligata:* Adult female and antenna of male. Highly magnified. (Author's illustration.)

the total of over 1,200 eggs collected in the field. Of 156 eggs, representing the five batches collected in the field from which no parasites were reared, only 1 egg failed to hatch. It has been stated that in the laboratory all but about 7 per cent of fertile eggs hatched. Even allowing for eggs destroyed by predaceous insects and the small percentage which normally fails to hatch, it is evident that the total percentage of conchuela eggs destroyed by Proctotrypid parasites is from 15 to 25 per cent above the percentage shown in the table from which parasites actually matured and emerged.

Parasites Attacking Adults and Nymphs.

The only parasite of the conchuela attacking the adults and nymphs which has come under the writer's observation, is the Tachinid fly *Gymnosoma fuliginosa* Desv. (Pl. III, figs. 9, 10). The female of this species deposits her eggs on the adults and nymphs in the fifth nymphal instar, usually near the margin, on the anterior half of the body (Pl. III, fig. 9). So far as observed, the percentage of these bugs which are parasitized by this fly is not large. Observations at Tlahualilo, Mexico, and at Barstow, Tex., in 1905, indicated that it was never more than 5 per cent. Under favorable conditions these Tachinid flies might attain a high degree of usefulness, but it is probable that they seldom exert much influence toward the reduction of the numbers of the conchuela and other Pentatomid pests.

Predatory Enemies.

INVERTEBRATES.

No one of the invertebrate enemies of the conchuela or of other Pentatomids has, in the writer's experience, shown itself to be of any great importance. Taken together, however, they form a group entitled to consideration.

Attacking eggs.—Nymphs of other species of Pentatomids as well as of the conchuela itself may destroy eggs in the field. The only species observed actually engaged in feeding on unhatched eggs of the conchuela is *Thyanta custator* Fab., the specimens being in the fifth instar. The well-known predaceous Anthocorid, *Triphleps insidiosus* Say, doubtless is as fond of the eggs of Pentatomids as of the eggs of other insects. The same may be said of the larvæ of various species of Chrysopa, although specific observations have not been recorded in either case. It is not uncommon to find the remains of eggs of the conchuela which have the almost unmistakable appearance of having been destroyed by predatory insects provided with mandibles. Entire batches consisting of as many as 14 eggs have been found in this condition with the circumstances indicating that a single insect had been responsible for the destruction of each batch. It is probable that the insects concerned in this work were either Coccinellid beetles or ants. As regards insects of the former group, there is no direct evidence of their connection with the destruction of eggs mentioned, but in a cotton field a small undetermined ant has been observed to work assiduously for several minutes attempting to separate an egg from a batch. This observation gives basis for the supposition that various species of ants are somewhat beneficial as destroyers of the eggs of Pentatomid pests. The destruction of eggs by any of the insects mentioned is not always productive of the best results, for it is possible, and in some cases probable, that a large part of the number thus destroyed might have produced adult Proctotrypid parasites, the great value of which has been discussed.

Attacking nymphs.—Even newly-hatched nymphs of the conchuela, as well as most other Pentatomids, are provided with glands which produce offensive volatile fluids. The value of such secretions as protection against spiders and predaceous insects is problematical. Predaceous Pentatomids are cannibalistic in many cases, and it is not to be presumed that such insects discriminate between the flavor of their own and other species. The writer has observed a nymph of *Podisus maculiventris* Say attacking a much larger nymph of *Euschistus fissilis* Uhl.—both species of Pentatomids which give off disgusting odors when disturbed. Only one predaceous Hemipteron (*Zelus renardii* Kol.) has been observed to feed on the nymphs of the conchuela. This has so far been observed only in the laboratory, but the circumstance indicates that it is of frequent occurrence in the field. This Reduviid is common in the cotton fields in both Texas and Mexico, and the nymphs not only voraciously attack one another but any other insect which crosses their path. The adults frequently capture and suck the juices from bees of various kinds which visit the cotton blooms. In confinement an adult destroyed 4 nymphs of the conchuela within 24 hours. Nymphs of the Reduviid readily attack nymphs of the conchuela, and one specimen of the former was reared to maturity with its diet limited to nymphs of the Pentatomidæ. Many other species of Reduviidæ are commonly found in cotton fields and doubtless may be relied upon to destroy a small percentage of the nymphs of injurious Pentatomids.

Among other orders of insects the author has but one record of predaceous forms attacking nymphs of the conchuela. A larva of an unknown Syrphid fly on a cotton leaf, supplied as food to nymphs of the conchuela in the second instar, quickly destroyed two of the young bugs. Credit for this observation is due Mr. W. W. Yothers of the Bureau of Entomology.

Nymphs of the conchuela have been found on cotton plants enmeshed in spider webs, but spiders have never actually been observed feeding on this Pentatomid, although an immature spider about one and one-half millimeters long, shortly after being brought into the laboratory from a cotton field, killed and partially ate a first-instar nymph of a Pentatomid of the genus Thyanta.

Attacking adults.—No invertebrates are known to attack adult conchuelas, nor has the writer found any reference on this point in the case of other Pentatomids. Broken and empty shells of adults have been found in cotton fields in midsummer, but there is no direct evidence to show this to be the work of predatory enemies, although it may be suspected.

BIRDS.

In spite of much evidence to the contrary, scattered in various scientific publications, it is the prevalent idea that the offensive odor of bugs protects them from birds. Without this supposition the object and origin of the odoriferous glands may be difficult to explain, but studies in the feeding habits of insectivorous birds has shown that in most cases Pentatomid bugs are eaten at least to the extent of the proportion of their numbers to the numbers of other insects of the same and larger size. Further, it would seem that some birds, like the crow, possess a predilection for insects of pungent or otherwise strong taste or odor. Careful studies have been made of the feeding habits of about 20 common American birds. Almost without exception Pentatomids (variously referred to as "stink bugs," "soldier bugs," and "Pentatomids") are included in the diet of each of these birds, amounting on the average to about 3 per cent of all the food.

Thus far no specific observations have been made for the purpose of determining the extent to which birds feed upon the conchuela. It is evident, however, that there is some important influence combined with egg parasitism to produce in midsummer the marked reduction in number of these insects observed both in Mexico and in Texas. The egg-parasites effectually check the multiplication of the pest after the month of July, but the diminution in numbers of the adults remains unexplained. In the laboratory, protected from their enemies, the life of the adult conchuela extends over many weeks, 27 specimens collected at Tlahualilo between July 6 and July 10 averaging over two months each.

It is inconceivable that the difference between field and laboratory conditions should be so great that, of the insects of the field on July 10, over 60 per cent should die from natural causes before August 1, while in the laboratory less than 5 per cent should die during the same period. Furthermore, if the numerical decrease in question had been due to natural exhaustion of vitality of the adult insects, it would be expected that many dead specimens would have been found in the cotton fields. As a matter of fact, dead specimens were exceedingly rare and the few found gave evidence of having been destroyed by some enemy rather than of having died from natural causes. As has been shown, the decrease in number is a general and not a local occurrence, and it takes place without regard to the abundance of food. These circumstances seem to point to the strong probability that birds are the useful agents in the reduction of the numbers of the adults of the conchuela.

ARTIFICIAL CONTROL.

Under the heading, "Artificial control," will be discussed only those measures which have little or no application except for the conchuela, together with such measures as have been the object of especial observation during the observation of that pest.

PREVENTIVE MEASURES.

Clearing land of mesquite.—As a means of obviating in a large measure the destruction by the conchuela, the prevention of spring multiplication of the pest on mesquite in the vicinity of cotton fields is of prime importance. Near Llano, Tex., Mr. J. C. Crawford, of this Bureau, on September 3, 1905, found an excellent example of the conditions which may result from the neglect of a breeding place of plant-bugs. As would be expected from its previous history elsewhere, the conchuela was in comparatively small numbers at that season of the year, but associated with it were two other plant-bugs, which will be treated later, *Largus succinctus* L. and *Nezara hilaris* Say. These three pests were breeding on a group of about 4 or 5 mesquite, located just outside of the cotton field. In the cotton field the damage to the bolls and the abundance of the plant-bugs in the section close to the mesquite, as compared with other parts of the field, gave almost conclusive evidence that the presence of the trees mentioned was largely or entirely responsible for the conditions found. In this and similar cases, therefore, the removal of the mesquite would unquestionably result in considerable benefit to the cotton, repaying the trifling cost many times over in a single season.

Under conditions such as those at Tlahualilo, where the cotton and surrounding mesquite land are under the same management or ownership, the policy should be adopted of removing, as fast as practicable, the mesquite, which experience has shown to be an element of danger. Where farms are comparatively small and a diversity of crops is grown, as at Barstow, Tex., the results might not be as striking as elsewhere, but concerted effort among landowners toward the eradication of mesquite growing in and around cultivated lands is recommended.

Prevention of excessive multiplication on alfalfa and other plants.—In addition to mesquite, alfalfa is the only other food plant which has thus far shown itself likely to harbor the conchuela in numbers which might prove disastrous to cotton. Various grains, however, will also bear watching for the purpose of locating and treating cases of excessive multiplication. In a previous paper, dealing with the conchuela at Barstow, Tex., in 1905, the author considered at length the subject of the control of this insect in the alfalfa fields, a brief recapitulation of which will suffice in this connection.

At both Tlahualilo and Barstow, in 1905, were notable instances of the development of enormous numbers of the conchuela in alfalfa fields. At the former place the bugs derived their entire food supply from the stems and leaves of the plants, while at the latter locality more than ordinary multiplication occurred only where an attempt was made to produce a crop of seed before the middle of August. The advantage is in favor of the crop used only for forage, for the shorter time between the cuttings permits of the maturity of but comparatively few of the insects, and the problem to be solved consists of the treatment of the nymphs and the prevention of their migration to neighboring cotton fields. An uncut border a few feet in width around an infested alfalfa field will serve to trap the crawling insects which then may be destroyed by spraying with a strong solution of kerosene emulsion. If heavy infestation be restricted to limited areas of the field, hand picking of the adults by children or other cheap labor and destroying the nymphs by spraying may be advisable. Gasoline blast torches have been used for destroying the conchuelas and may sometimes be useful under circumstances where no vegetation except weeds or other noxious plants will be affected. The longer period required for the maturity of a seed crop of alfalfa, together with the abundance of favored food (alfalfa seed), affords most favorable conditions for the development of countless numbers of the conchuela. Great care should be exercised, therefore, wherever this pest is likely to occur in destructive numbers, in selecting a season of the year when a seed crop of alfalfa can be grown profitably and without disadvantage to cotton or other neighboring crops. In western Texas an attempt to produce a seed crop has been shown by past experience to be practicable only after the middle of August, when the destructive season of the conchuela has passed.

Field Measures.

HAND-PICKING.

Extent of experiments and methods used.—In cooperation with Mr. J. P. Conduit and Mr. J. A. Vaughan, manager and assistant manager, respectively, of the Tlahualilo plantation, experiments were conducted in July, 1905, for the purpose of determining the utility of hand-picking as a practical remedial measure against the conchuela. In this work many native boys ranging from 9 to 15 years of age were employed.

These worked on different sections of the plantation and in several gangs of from 6 to 50 boys each, the work of each gang being under the direct supervision of a man selected for the purpose from among the laborers. The time possible for the author to devote to this phase of the investigation of the conchuela did not permit of as detailed a study as was desirable, yet it is believed that the experiments are by far the most extensive ever conducted along the line of hand-collecting of insect pests.

After testing various receptacles for containing the bugs as they are collected in the field, a dipperlike tin vessel, with a cover consisting of a detachable funnel, was devised[a] and found to serve the purpose in an ideal manner. The constructive details of this receptacle are shown in figure 9. A slight jar of the boll or leaf upon which the bug is resting is sufficient to cause it to fall through the funnel into the chamber below, from which there is practically no chance for its escape until the receptacle is filled to the opening. The contents should then be emptied into a pail containing a mixture of water and kerosene in the proportion of two-thirds to one-third, respectively.

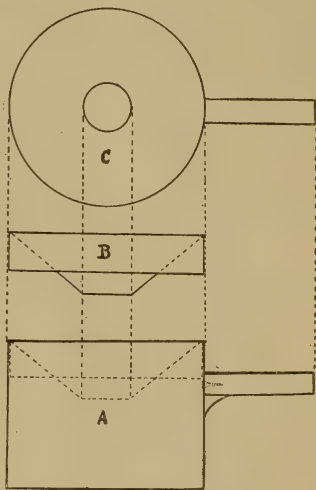


FIG. 9.—Plan for the construction of a collecting can for use in hand-picking cotton plant-bugs: A, Main part of can, made of tin and with a wooden handle; B, funnel-shaped cover; C, vertical projection showing cover with opening in the center and vertical projection of handle at right. (Original.)

Results of experiments.—The removal of many thousands of the conchuela from the cotton fields could not have other than direct beneficial results while, as an experiment, useful information concerning the practice of hand-picking of plant-bugs was obtained.

The greatest obstacle to be overcome in order to obtain the best results from hand-picking was found to be lack of thoroughness. There was much variation, however, in regard to this point and it was soon evident that it is dependent almost entirely upon the efficiency with which the boys engaged in picking the bugs were supervised. A series of examinations was made in two *tablas* of 120 acres each for the purpose of determining the number of bugs present on the plants before and after picking. It was found that in one *tabla* about 21 per cent, and in the other about 33 per cent, had been removed. From the fact previously stated that in clear weather fully 90 per cent of the bugs occupy conspicuous positions on the plants it is evident that the lack of thoroughness in the above-mentioned

[a] Credit is due Messrs. Conduit and Vaughan for their ideas in this connection.

instance is no argument against the effectiveness of the operation. Moreover, it will be shown that the advantages derived from the removal of a third or even a fifth of the insects from the plants amply repaid the expenditure.

An exact count gave approximately 775 bugs to a pint; this was used as a basis for estimating the number of conchuelas picked. The average number of bugs picked per boy per hour varied, according to the abundance of the insects and the efficiency of the supervision, from 8 to 85. As it was not considered advisable to teach the boys to distinguish between even such widely different insects as grasshoppers and Pentatomid bugs, insects were collected indiscriminately.[a] The list of insects found in a lot thus captured on July 12 gives an idea of the comparative abundance of the principal conspicuous and most easily captured insects in a cotton field. Unless otherwise stated the insects in the following list are adults.

List of insects captured in a hand-picking experiment in a cotton field at Tlahualilo, Mexico.

		Number.
Hémiptera	3,753	
Pentatoma ligata Say (conchuela).		
Adults		3,637
Nymphs		75
Thyanta sp		16
Pentatoma sayi Stål. (grain bug)		5
Largus succinctus L		15
Oncopeltus fasciatus Dall		3
Lygæus turcicus Fab		2
Coleoptera	250	
Epitragus sp		200
Allorhina nitida L. (fig-bloom beetle)		45
Hippodamia convergens Guér. (lady-beetle)		5
Orthoptera	17	
Brachystola magna Gir. (lubber grasshopper)		16
Gryllus sp. (cricket)		1
Lepidoptera	4	
Deilephila lineata Fab. (white-lined sphinx) larvæ		2
Estigmene acræa Dru. (salt-marsh caterpillar)		2
Hymenoptera	1	
Bombus sp. (bumblebee)		1
Total		4,025

Cost of hand-picking.[b]—In Table XXXI specific examples are given showing the cost of hand-picking of the conchuela in its relation to the numbers of the insects obtained.

---

[a] In estimates of the number of conchuelas based on bulk at the rate of 775 per pint, due allowance was made for the space occupied by other species of insects.

[b] In referring to cost in Mexico, equivalents in the United States currency are used.

TABLE XXXI.—*Cost of hand-picking of the conchuela.*

Date.	Number of boys employed.	Total number of hours.	Number of conchuelas collected.	Average number of conchuelas per boy.	Expense of picking.	Number of bugs destroyed for each cent of expense.
1905.						
July 12	4	20	729	182	$0.50	14.5
July 13	14	70	6,200	428	2.25	27.5
July 14	22	110	5,400	227	3.25	16.6
July 25	25	125	1,500	60	3.50	4.3
July 26	25	125	1,600	65	3.50	4.6
Summary	90	450	15,429	171	13.00	11.+

On July 25 and 26 the work in the *tabla* to which the above data refer was unsatisfactory, owing to incompetent supervision. Accepting, however, 11.+ as the average number of bugs collected and destroyed for each cent of expense for a total of $135 expended in 1905 for hand-collecting at Tlahualilo, it is estimated that approximately 180,000 of the insects were collected and destroyed. If each of these insects at the time of its removal from the field had been capable of causing one-half as great damage as the data under individual capabilities show to have been accomplished under conditions of heavy infestation [a] the total loss prevented by this expenditure would be equivalent to over $1,800. The profit may be considered, therefore, as about twelve times the investment.

Length of time required for hand-picking.—Bugs may be collected much more quickly on small or medium-sized plants than on large plants. In examining plants for the purpose of obtaining data on seasonal history the writer on one occasion examined and made a record of the number of bugs found on 1,892 plants in 2½ hours. Considering that the recording of the data occupied about the same length of time as would have been necessary to collect the insects, it would require about 6 hours at the rate given to collect the Pentatomids found in conspicuous positions on the plants in 1 acre. The native boys engaged in picking the bugs at Tlahualilo averaged about 30 minutes to each 300 plants, or about 7 hours per acre.

Practicability of hand-picking in the United States.—While the per diem cost of labor is much greater in the States of our cotton belt than in Mexico, where the experiments recorded were undertaken, this probably would be to a great extent (if not entirely) offset by greater efficiency. Especially good results should be obtained when hand-picking can be practiced under the direct supervision of the owner or some other person materially interested in the cotton. It

[a] Individual capabilities for damage have been shown to be greatest when infestation is lightest.

is believed that the data given in connection with the study of individual capabilities of the conchuela will be useful in the determination of the expense a cotton grower can afford to incur for hand-picking of the conchuela and other Pentatomid bugs when appearing in threatening numbers. It may be said summarily that the practicability depends on the available abundance of cheap labor and on the acreage of cotton that it is desired to treat.

OTHER METHODS OF COLLECTING BUGS FROM COTTON PLANTS.

In addition to collecting by hand, a test was made of the possibility of collecting the immature conchuelas by jarring them into a piece of canvas or cloth placed around the stalk of the infested cotton plants. Certain modifications of this method might be useful where the numbers of immature bugs on each plant is large, or where machines, such as have been devised but proven unsuccessful for the collection of the boll weevil and bollworm, might give good results in the collection of both nymphal and adult stages of the plant-bugs.

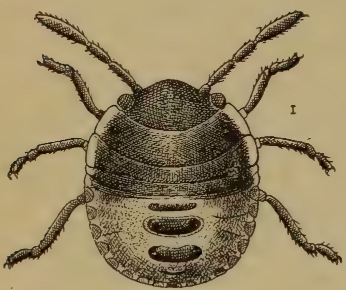


FIG. 10.—The grain bug (*Pentatoma sayi*): Nymph, first instar. Enlarged 21 diameters. (Original.)

CONTACT INSECTICIDES.

Adult Pentatomid bugs, in general, are known to be little affected even by strong solutions of contact insecticides. For ordinary field treatment insecticides, regardless of efficiency, are impractical for use against such insects as the conchuela. Their use might, however, be advisable under such conditions of excessive infestation as have been described as resulting from the migration of nymphs in 1905 at Tlahualilo. As suitable materials for making and applying kerosene mixture were not available, a test was made of cottonseed-oil soap solution, using one-half pound of soap in 4 gallons of water. This was found to destroy nymphs when thoroughly sprayed, but only 3 or 4 per cent of the adults succumbed to the same treatment.

TRAP CROPS AND ATTRACTION TO LIGHTS.

Early in the season, before bolls are put on by the cotton plants, a few mesquite bearing heavy crops of beans might serve a useful purpose by attracting the conchuelas. For good results it would be necessary that the development of the insects be carefully watched and treatment applied before the first of the spring nymphs reach maturity. Unless proper attention can be given, however, as has been indicated in the discussion of preventive measures, it is inadvisable to allow mesquite to grow in the vicinity of cotton when it can be avoided. Observations thus far on the feeding habits of the conchuela have given us no reason to expect that a trap crop can ever be successfully used to divert the attention of the insect from the cotton after the bolls become suitable for food.

Under date of May 29, 1906, Mr. J. H. Vaughan, of Tlahualilo, Mexico, in a communication to the writer stated that the conchuela had already appeared on alfalfa. This directs attention to the advisability of giving close attention to this crop and of taking advantage of its attractiveness as a breeding place for the conchuela early in the season, to check its increase through means that have been suggested.

The adult conchuela evidently never flies except during daylight. Many Pentatomids are commonly attracted to lights, but normally this species feeds almost continually at night, and in the laboratory either remains motionless, if not feeding, or, if feeding, continues uninterruptedly when an electric light is brought within a few feet of a cage in which specimens are confined.

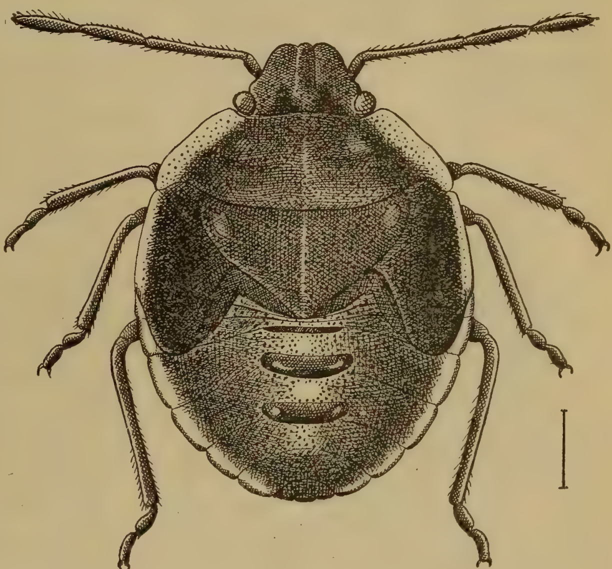


FIG. 11.—The grain bug: Nymph, fifth instar. Enlarged 6 diameters. (Original.)

THE GRAIN BUG.

(*Pentatoma sayi* Stål.)

At Tlahualilo, Durango, Mexico, the grain bug (figs. 10, 11) has been observed to be of frequent occurrence on cotton and to resemble the conchuela in its habits, life history, and seasonal history. At Barstow, Tex., where grain crops were accessible, no specimens were collected on cotton.[a] The preference of this species for the seed of grains and of alfalfa will probably be sufficient protection against its occurring in injurious abundance in cotton fields in this country.

[a] Bul. 64, Pt. I, Bur. Ent., U. S. Dept. Agr., p. 2, 1907.

Its distribution in the cotton belt is apparently restricted to western Texas, for there is no instance known to the writer of a specimen being taken east of the semiarid region of that State

PENTATOMID BUGS OF THE GENUS EUSCHISTUS.

The several species of Euschistus, the genus to which the brown cotton-bug belongs, have never attracted much attention from economic entomologists. Townend Glover [a] briefly described a Pentatomid which with little doubt belongs to this genus and noted that the species was abundant on cotton in Georgia in 1854 and in Florida in 1855, piercing the bolls and sucking their juices. The species referred to is probably *Euschistus punctipes* Say (*variolarius* Pal. Beauv.), as it is this one which the same author figured with the insects that attack young bolls in his "Manuscript Notes from my Journal." [b] The late Dr. Wm. H. Ashmead [c] recorded *E. pyrrhocerus* H. Schf. as not of rare occurrence in cotton fields in Mississippi and noted that it punctures new shoots and terminal branches.

FIG. 12.—The brown cotton-bug (*Euschistus servus*): Nymph, first instar. Enlarged 21 diameters. (Original.)

So far as known to the writer these are the only published records of injury to cotton by species of Euschistus. Injury to tobacco by *E. variolarius* has been reported by Prof. H. Garman, [d] and by *E. fissilis* Uhl. to wheat by Prof. F. M. Webster. [e] Dr. J. A. Lintner [f] is responsible for the statement that the former species "feeds upon plants and animals interchangeably." Mr. A. H. Kirkland [g] has found *E. politus* to be partly predaceous.

In Texas *E. servus* Say is by far the most common representative of the genus found in the cotton fields and is the only one upon which special observations have been made in connection with the studies reported upon in this paper. The species was described in 1831 under the name *Pentatoma serva*. No observations have heretofore been recorded on the biology of the insect. *Euschistus impictiventris* Stål and *E. tristigmus* Say are the only other members of the genus which the writer has found upon cotton.

---

[a] U. S. Agricultural Report for 1855, pp. 93–94.

[b] Plate 16.

[c] Insect Life, Vol. VII, p. 320, 1895.

[d] Bul. 66, Ky. Agr. Exp. Sta., pp. 33–34, 1897.

[e] Rep. Dept. Agr. for 1885, p. 317.

[f] 2d Rep. N. Y. St. Ent., p. 146, 1885.

[g] 44th Ann. Rep. Sec. Mass. St. Bd. Agr., 1896, pp. 406–407, 1897.

THE BROWN COTTON-BUG.

(*Euschistus servus* Say.)

DISTRIBUTION.

Dr. P. R. Uhler states[a] that *Euschistus servus* (Pl. I, fig. 2; text figs. 12, 13) inhabits Texas, New Mexico, California, "Dakota," Illinois, Maryland, and the Southern States generally. Mr. E. P. Van Duzee, who possesses the most extensive collection of the Pentatomidæ of America, states[b] that he has not seen types of this species from north of New Jersey and Ohio or west of Kansas, Texas, and eastern New Mexico. In Texas the species is of common occurrence throughout the eastern half of the State, being much more common in the northern portion of this section than in the southern portion. Toward the western and northwestern portions of the State the species gradually diminishes in numbers, possibly owing partly to decrease in cotton acreage. In Louisiana the brown cotton-bug is found throughout the State, though apparently, as in Texas, is more common in the central and northern than in the southern portion.

FIG. 13.—The brown cotton-bug: Nymph, fifth instar. Enlarged 6 diameters. (Original.)

FOOD PLANTS.

The brown cotton-bug has been taken on several other plants in addition to cotton, but specific records of actual feeding have not been made except in the case of specimens found feeding on the fruit of the orange in Florida,[c] and a specimen which the writer has observed feeding on green fruit and twigs of peach in confinement. The agents of the Bureau of Entomology who were connected with the cotton boll weevil investigations have collected this species in Texas and Louisiana on the following plants: Helianthus (three localities), corn (two localities), *Heterotheca subaxillaris* (two localities), *Rud-*

[a] Bul. U. S. Geol. and Geog. Surv., No. 5, second series; List of Hemiptera, p. 20, 1876.

[b] Trans. Amer. Ent. Soc.; XXX, p. 45, 1904.

[c] Insect Life, Vol. V, p. 264, 1893.

beckia sp. (one locality), *Rubus* sp. (one locality), peach (one locality), and evening primrose, *Gaura parvifolia* (one locality). In addition to these records, Scott and Fiske[a] have reported specimens of the brown cotton-bug abundant among material obtained incidental to extensive experiments in jarring for the plum curculio in Georgia.

LIFE HISTORY AND HABITS.

Four female and 1 male specimen and many nymphs of the brown cotton-bug were under observation in the laboratory. Egg-laying records of only 3 specimens are available, but these seem to show that the capacity of this species in this respect is fully equal to that of the species heretofore considered. The maximum number of eggs deposited by a single specimen was 162, the specimen concerned being collected on cotton on August 19, 1905. In confinement, a specimen collected in August lived 72 days, three specimens collected in September lived 90, 73, and 30 days, respectively, and a specimen collected in April lived 45 days. The last specimen probably had over-wintered as an adult and was therefore several months old at the time the record began.

The average incubation period of 5 batches of eggs of the brown cotton-bug corresponded to within 8 hours with the average of 21 egg-batches of the conchuela. At an average daily mean temperature of 78.9° F., the average incubation period of 5 batches of eggs was found to be 4 days and 17 hours. The duration of the nymphal stages corresponds closely with that of the conchuela.

Observations thus far, in the regions where these studies were made, have not shown any decided preference of the brown cotton-bug for any particular food plant early in the season, but after the appearance of the bolls upon the cotton plants comparatively few specimens are found outside of the cotton fields. Doubtless weeds growing in profusion along the roadsides and fences furnish favorable breeding places in early summer for the bugs, which later turn their attention to the cotton.

On the average this bug deposits fewer eggs per batch than does the conchuela or grain bug. For 16 batches which have come under the writer's observation, the average number per batch was 16.4, the maximum being 34, and the minimum 5. Forty-two per cent were deposited in batches of 14 and its multiple.

The brown cotton-bug is occasionally attracted to lights, but not in sufficient numbers to lead to the belief that light trapping in badly infested cotton fields would give good results.

SEASONAL HISTORY.

In the latitude of Dallas, Tex., the hibernated individuals of both sexes of the brown cotton-bug are fairly common about or soon after

---

[a] Bul. 31, Div. Ent., U. S. Dept. Agr., p. 34, 1902.

April 1. A specimen confined on a peach tree deposited 2 egg-batches, containing in all 44 eggs, before the middle of May, 1906. Nymphs which hatched from one of these batches were in the second instar on May 13, but, as they disappeared soon after, definite information concerning the appearance of adults of the first generation was not obtained. From this and other records of eggs of this species collected in the spring of 1906, however, it can be safely considered to be between the 1st and the middle of June. A comparative study of the developmental periods of various Pentatomid bugs which have been under the writer's observation leads to the belief that it is probable that in the cotton-producing States a maximum of five generations per annum is possible, although four generations is doubtless a more common number, and three generations the most common of all. As with other Pentatomids whose egg-laying periods may extend over several weeks with each female, it is improper to speak of the generations as "broods," for the reason that individuals of from one to three different generations may and doubtless do occur together after the maturity of the first generation. The brown cotton-bug is most abundant in cotton fields during August and September, but no rapid increase or decrease in its numbers during the season has thus far been observed.

DESTRUCTIVENESS.

The usual association of the brown cotton-bug with other plant-bugs in the cotton fields has made advisable the general consideration of damage to cotton bolls resulting from the attacks of this and certain other species, which has been given in the introductory pages. The similarity of the feeding habits of the various Pentatomid bugs which attack cotton bolls indicates that the studies made concerning the individual destructive capabilities of the conchuela are fully applicable to the other species. Fortunately the brown cotton-bug has not as yet shown itself likely to appear over large territories in such abundance as has the conchuela. It has been observed in limited areas comprising only a few acres each, in numbers which caused destruction of the majority of the bolls, but thus far experience has shown this species to deserve the importance herein given, not on account of sporadic outbreaks in excessive numbers, but through its fairly constant and widespread occurrence throughout a large and important cotton-growing section.

NATURAL ENEMIES.

Species of Pentatomids of the genus Euschistus appear to be unmolested by Tachinid parasites. Examination of hundreds of specimens of species of this genus, including pinned material in collections and live specimens in the fields, has not thus far resulted in the finding of evidence of parasitism by these flies in any instance, even when in the same fields parasitized specimens of other genera are numerous.

A Proctotrypid parasite, *Trissolcus euschisti* Ashm., has been recorded as having been reared from the eggs of *Euschistus servus* in Kansas. It has been stated in connection with the subject of egg parasites of the conchuela that the important agent in checking the multiplication of that species, *Telenomus ashmeadi* Morrill, in the laboratory does not hesitate to oviposit in the eggs of *Euschistus servus* and that adult parasites have duly emerged in such cases. This parasite is not at present known to occur in cotton-growing sections where the brown cotton-bug is found in abundance, but doubtless other Proctotrypids have more or less influence on the rate of multiplication of this bug.

PENTATOMID BUGS OF THE GENUS NEZARA.

THE GREEN SOLDIER-BUG.

(*Nezara hilaris* Say.)

HISTORY.

The frequent injuries by the green soldier-bug (Pl. I, fig. 3; text figs. 14, 15) to various crops and its wide distribution throughout the United States have resulted in its being one of the most generally known plant-bugs. A good general historical account of the species has been given by Sanderson in a previous bulletin of this Bureau.[a] The bug was first recognized as a cotton pest in 1855, Townend Glover [b] referring to its abundance on cotton in Florida and briefly describing the nature of its injury, evidently misidentifying it specifically. It was figured in 1878 by the same author[c] with insects injurious to cotton under the name *Nezara pennsylvanicus*. This error in identification has been indicated by Comstock.[d] A correspondent of the Division of Entomology[e] reported damage to cotton in Florida in 1890 by the green soldier-bug, and Sanderson (l. c.) briefly mentions damage to cotton in Texas from this insect in 1903 and 1904.

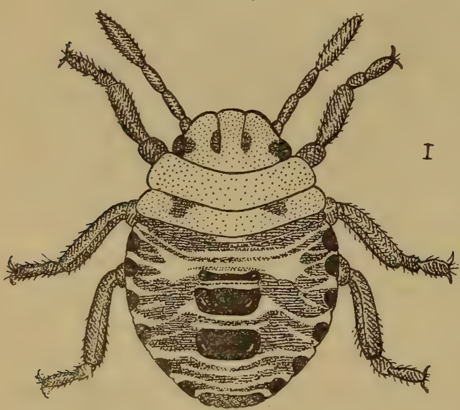


FIG. 14.—The green soldier-bug (*Nezara hilaris*): Nymph, first instar. Enlarged 21 diameters. (Original.)

[a] Bul. 57, Bur. Ent., U. S. Dept. Agr., pp. 47–49, 1906.
[b] Agricultural Report for 1855, p. 93.
[c] Manuscript Notes from My Journal, etc., pl. 16.
[d] Report on Cotton Insects, 1879, p. 167.
[e] Insect Life, Vol. III, p. 403, 1891.

DISTRIBUTION.

Mr. E. P. Van Duzee [a] writes as follows in regard to the geographical distribution of the green soldier-bug:

This is a showy but very common insect throughout the northeastern United States and Canada. Toward the south its range extends through the Southern States and West Indies to Brazil. In the West it occurs in Kansas, Iowa, Colorado, Montana, Utah, Arizona, and Texas, and perhaps over all the Western States.

This is the most common Pentatomid found on cotton throughout our Southern States, although it is frequently exceeded in abundance locally by other species.

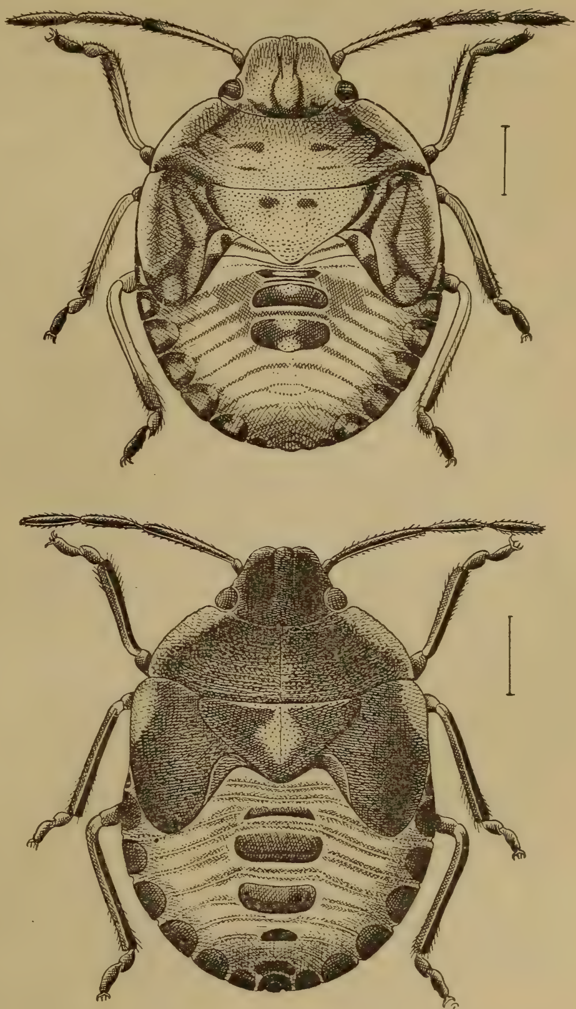


FIG. 15.—The green soldier-bug: Nymph, fifth instar; light and dark types. Enlarged 6 diameters. (Original.)

FOOD PLANTS.

The green soldier-bug, like the Pentatomid cotton pests which have been considered in the foregoing pages, is a very general feeder. A correspondent of the Division of Entomology in 1883 [b] reported the insect as occurring in abundance in Florida on tomatoes, egg-plant, turnip, mustard, peas, and oranges. Professor Sanderson [c] has compiled from the publications and correspondence files of the Bureau of Entomology the following additional list of food plants

[a] Trans. Amer. Ent. Soc., Vol. XXX, p. 58, 1904.

[b] Insects affecting the orange. By H. G. Hubbard, 1885, p. 160.

[c] Bul. 57, Bur. Ent., U. S. Dept. Agr., pp. 47–49, 1906.

which have been reported as injured by the green soldier-bug: Beans, cabbage, corn, cotton, peaches, and okra.

At Amherst, Mass., the writer has found nymphs of this species on maple trees and both nymphs and adults on European linden. The trees of the species last mentioned were fruiting and the bugs were breeding on them in unusually large numbers, feeding almost exclusively on the fruit. At Llano, Tex., he has found these insects feeding on the seed-pods of mesquite growing in close proximity to cotton fields.

LIFE HISTORY AND HABITS.

Specific records which are available indicate that eggs are deposited by the green soldier-bug in batches averaging a larger number of eggs than is the case with either the conchuela, the grain bug, or the brown cotton-bug. The eight batches which have come under the writer's observation averaged 40 eggs per batch, ranging from 27 to 52. A female specimen which died in the laboratory was found on dissection to contain 53 fully developed eggs.

The period of incubation of the eggs of this species has never been determined, but it is safe to assume that it is practically the same as that of the other Pentatomids investigated in the preparation of this report. Sanderson records the developmental period from the hatching of the eggs to the appearance of the adult in September and October, 1904, as 39 days, the observation being made in northern Texas, and the inclusive period from September 2 to October 11. Three adults, taken in a cotton field on October 19, 1905, lived in the laboratory until December 1, when they were used in a hibernation test under out-of-door temperatures. All three specimens were alive on December 19, but on March 8 two were dead, while the third had escaped from the cage in which the specimens had been confined.

The green soldier-bug, in cases heretofore recorded and in all cases which have come under the writer's observation, has shown a preference for the cotton bolls, as have other cotton-infesting Pentatomids. The insect does not, however, confine its attacks to the seed and fruit of its food plants, as reliable reports state that pea vines, orange twigs and leaves, and cabbage leaves have been attacked to the extent of causing serious damage. It has long been known that this species is sometimes predaceous, and owing to the lack of an adequate understanding of the nature of the injury to cotton due to plant-bugs, many have inferred that the good accomplished through the destruction of caterpillars outweighed the injury resulting from the bugs' feeding on the plant. This is far from representing the true status of the insect in the cotton field, for on the whole the predaceous habit is exceptional, and beyond occasionally diverting the bug's attention from the cotton bolls is of practically no economic importance.

DESTRUCTIVENESS.

The green soldier-bug has shown itself to be of importance as a cotton pest not only owing to its widespread occurrence but also to the fluctuations in its numbers, which result in considerable local damage from time to time. An instance of this kind has been mentioned by Professor Sanderson.[a] The correspondent referred to, Mr. R. L. Taylor, of Help, Bosque County, Tex., has kindly furnished additional information concerning his experience with the insect. This is of sufficient interest to present in summarized form at this place, as it represents the experience of a cotton grower whose observations were made and conclusions arrived at independently of previous knowledge of the destructive capabilities of the insect. The accuracy of Mr. Taylor's observations is sustained by the close correspondence between his description of the effects of the green soldier-bug's attack and the effects of the attack of the conchuela, which has already been considered in detail. He writes that the insect was first noticeably abundant in 1901, and it was observed that year that many bolls failed to open perfectly; in some instances, from as many as 30 bolls on a plant not more than 5 opened and produced good lint. The insects were also abundant in 1902 and damage to bolls was again noticed. In 1903 the damage was not so severe, but much staining of lint was believed to be due to the work of the bugs. A local cotton buyer claimed that the condition of the lint was due to frost, although Mr. Taylor states positively that there had been no frost at the time (October). Whenever the bugs were present in numbers it was observed that the cotton was "spotted," that is, one, two, or three locks of a boll opened, while the remainder in each case failed to open. Shedding of badly damaged bolls was also noted in 1902, but this was probably confined mostly to bolls less than one-half grown, as was observed in the case of damage by the conchuela.

Bosque County, in which Help is situated, was first infested by the boll weevil in 1902, and the first damage to cotton in the county was observed in 1903. It should be noted that there is therefore no possibility of the confusion of injury by boll weevil attack with that of the green soldier-bug.

NATURAL ENEMIES.

No Tachinid parasites have thus far been reared from *Nezara hilaris*, and in only one instance has the writer found a specimen to

[a] Bul. 57, Bur. Ent., U. S. Dept. Agr., pp. 47–48, 1906.

which an egg of one of these flies had been attached. This specimen was a female collected by Mr. F. C. Pratt, at Boerne, Tex., on beans, September 29, 1905. On October 12 the specimen died, but dissection showed no trace of the parasite.

The eggs of the green soldier-bug, however, are frequently parasitized. At Amherst, Mass., on July 15, 1902, large numbers of eggs were found on the leaves of European linden, and of about 250 collected more than 90 per cent produced Proctotrypid parasites.

From a batch of 27 eggs collected on September 29, 1905, by Mr. Pratt at Boerne, Tex., 15 parasites were reared. These proved to belong to the genus Trissolcus.

Professor Sanderson has referred to a report from a correspondent of the Bureau of Entomology, to the effect that a specimen of *Euthyrhynchus floridanus* L. had attacked and killed a specimen of the green soldier-bug, but this should probably be considered as, at the most, only an exceptional occurrence.

NEZARA VIRIDULA L.

The species *Nezara viridula* L. (fig. 16), which is readily distinguished from all other members of the genus by the shorter osteolar canal, has been found in many parts of the world. In the United States it occurs throughout the cotton belt. It has been reported as injurious to potato vines in India,[a] and in this country to sweet potato vines in Louisiana [b] and to oranges in Florida.[c]

Mr. W. A. Hooker, at that time an agent of this Bureau, who was located at Quincy, Fla., from October 23 to November 9, 1905, found this bug very abundant at that place, destroying potato vines and occurring commonly on cotton plants. The infested potato vines comprised a small patch of about one-fourth of an acre, and late in October it was estimated that there were on each vine an average of between 3 and 5 adults and 15 and 20 nymphs. The attacked vines turned dark, beginning at the tips of the branches—which seemed to be the favorite feeding place—and finally wilted. As the tubers had not attained their mature size the crop was much reduced. These bugs were in sufficient numbers on cotton plants in the vicinity to cause considerable damage, although the potato was evidently the more preferred plant.

Mr. Hooker took several specimens in Florida which had been attracted to light of ordinary kerosene lamps in houses and the writer has taken a specimen at a 16-candle power electric light at

---

[a] Insect Life, Vol. II, p. 61, 1889.
[b] Insect Life, Vol. V, p. 261, 1893.
[c] Insect Life, Vol. V, p. 264, 1893.

Victoria, Tex. In this connection it has been observed that in the laboratory at night adults of this species stop feeding, become restless, and fly about in the breeding cage when an electric lamp is turned on in the room.

On cotton the writer has taken a specimen of *Nezara viridula* on a boll at Cameron, La., and one at Johnsons Bayou, La., both on October 10, 1904, and has taken a fourth-instar nymph at Calvert, Tex., August 27, 1903, and a fifth-instar nymph at Victoria, Tex., November 10, 1904. Mr. F. C. Pratt found adults of the species common on turnip at New Braunfels, Tex., on October 27, 1905.

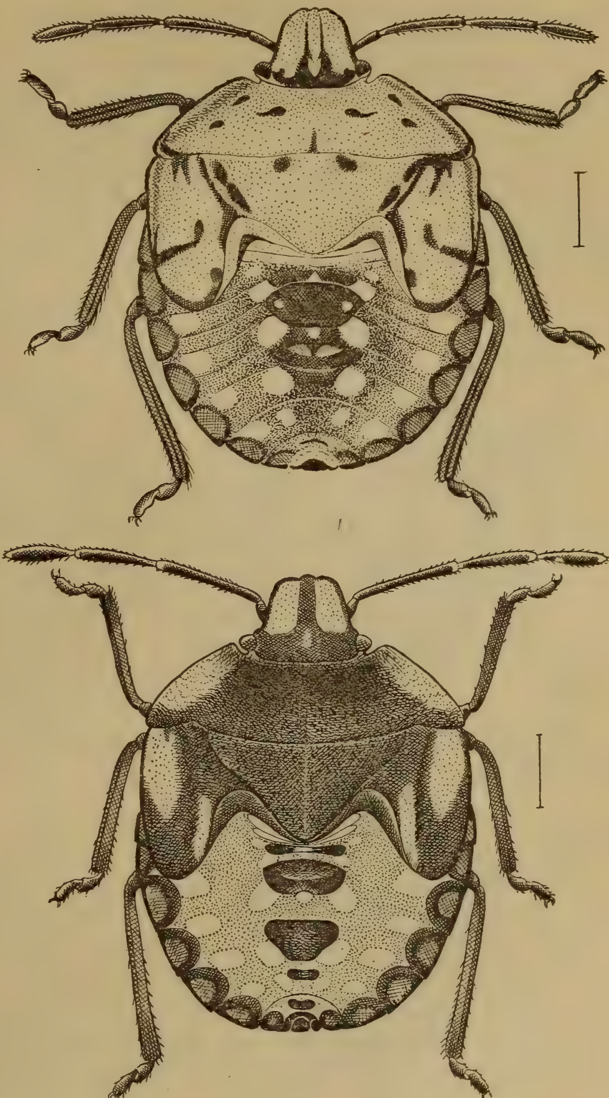


FIG. 16.—*Nezara viridula:* Nymph, fifth instar; light and dark types. Enlarged 6 diameters. (Original.)

Of 39 specimens collected by Mr. Hooker at Quincy, Fla., in stages susceptible to parasitism by Tachinids, in only one instance was a Tachinid egg found attached to a bug. This bug was in the fifth nymphal instar and became adult 4 days after the egg was first observed and died 10 days later, but upon dissection no evidence of the presence of an internal parasite could be found.

PENTATOMID BUGS OF THE GENUS THYANTA.

(Plate I, fig. 4; text figs. 17 and 18.)

IDENTITY AND HISTORY OF SPECIES CONCERNED.

The writer has carefully examined a series of over 80 specimens which appear to represent a single species of the genus Thyanta and finds that the variation is so wide that while the majority are undoubtedly *T. custator* as described by Fabricius, several agree fairly well with the original description of *T. perditor* Fab. and *T. casta* Stål. Variations are found in size, form of humeral angles, proportionate lengths of the segments of the antennæ, and color and markings of the body, antennæ, and wing membranes, which might readily be mistaken for specific characters.

FIG. 17.—*Thyanta custator:* Nymph, first instar. Enlarged 27 diameters. (Original.)

These latter two species—if in fact they are valid—have not as yet been sufficiently characterized to distinguish them from the variations of the insect generally recognized as *Thyanta custator* Fab. Injury to crops by this species[a] was first recorded by Prof. E. D. Sanderson, who reported its occurrence in 1903 in unusual numbers in northern Texas, where it seriously injured oats, corn, and sorghum, and was also found in numbers on milo maize and cowpeas. The frequent occurrence of this insect on cotton bolls has also been noted by Sanderson.

DISTRIBUTION.

Uhler states in regard to the distribution of *Thyanta custator* that the species inhabits upper and lower California, Texas, Arizona, Colorado, "Dakota," and the Atlantic region generally from Quebec to Florida.[b] According to Mr. Van Duzee, it occurs in greatest abundance toward the South and West.[c] In Texas it is one of the most common Pentatomid bugs and is especially abundant in the northwestern part of the State. Except in northern Texas and Oklahoma, it seems to be of too rare occurrence on cotton to be worthy of consideration as a pest.

---

[a] At first determined as *Thyanta perditor* Fab. and afterwards redetermined as *T. custator* Fab. Compare Bul. 46, Div. Ent., U. S. Dept. Agr., p. 94, 1904, with Bul. 57, Bur. Ent., U. S. Dept. Agr., p. 49, 1906.

[b] Bul. U. S. Geol. and Geog. Surv., No. 5, Second series, List of Hemiptera, p. 23, 1876.

[c] Trans. Amer. Ent. Soc., XXX, p. 53, 1904.

FOOD PLANTS.

Sanderson[a] has noted injury by this species to oats, corn, and sorghum, and its occurrence upon milo maize, cowpeas, and cotton. It has been observed by the writer feeding in considerable numbers on mesquite beans and records of the specimens in the collection of the Bureau of Entomology indicate the wide range of plants upon which the insect has been collected.

LIFE HISTORY AND HABITS.

Observations on life history were made upon 6 female specimens. Three specimens captured at Dallas, Tex., in early September produced a total of 377 eggs in 130 days, the average per specimen being 4 more than that of 14 females of the conchuela collected on September 12. The maximum longevity of the specimens under observation was 39 days except for one specimen, which matured on October 8, and hibernated, being alive on December 19.

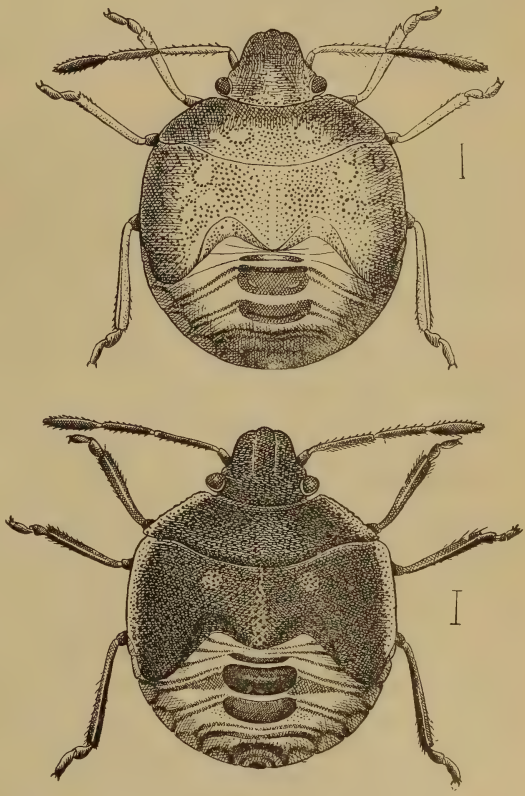


FIG. 18.—*Thyanta custator:* Nymph, fifth instar; light and dark types. Enlarged 10 diameters. (Original.)

The incubation period of the eggs of this species agrees closely with the species discussed in the preceding pages. At an average daily mean temperature of 79.3° F., the average incubation period of 4 batches was 4 days and 15 hours. The duration of the nymphal stages seems to be considerably more brief for *Thyanta custator* than for the conchuela and other Pentatomids heretofore discussed. The writer's records show that the nymphs of *Thyanta custator* develop as rapidly at an average daily mean temperature of 64.7° F. as do the nymphs of the conchuela at an average daily mean temperature of 82° F.

---

[a] Bul. 46, Div. Ent., U. S. Dept. Agr., p. 94, 1904.

Records based upon 14 batches of eggs deposited in the laboratory indicate that the average number of eggs deposited per batch is high as compared with most Pentatomids. These records gave an average of 31.4 eggs per batch, the range in number being from 10 to 42.

In its selection of food plants *Thyanta custator* has thus far exhibited a preference for grains and cotton, although this may be only the natural consequence of the fact that these are the principal crops grown in the section of the cotton belt where this Pentatomid is most abundant. At Tlahualilo, Durango, Mexico, where this bug was common in July, 1905, it was not found on alfalfa as were several other cotton-infesting plant-bugs, nor has it thus far been reported as occurring in alfalfa fields in Texas. A specimen of *Thyanta custator* in the fifth nymphal instar, immediately after being brought into the laboratory from the cotton field, fed upon eggs of the conchuela, exhibiting the only instance of a predatory habit which has been observed in this species.

In the cotton fields this bug is commonly found feeding on the cotton squares and bolls—when feeding being frequently completely hidden by the bracts. This habit of concealment, together with its small size and inconspicuous color, makes it much more difficult of detection when present on cotton plants than are the other cotton-infesting Pentatomids which have been dealt with in the foregoing pages. The preference of the bug for the bolls over other portions of the cotton plant is fully as well marked as it is in the case of the conchuela.

Gregariousness is also as well marked a characteristic of this species as of the conchuela.

In October, 1897, Mr. J. D. Mitchell, in testing, at Victoria, Tex., the possibility of trapping the cotton boll weevil by lights, captured 4 specimens of *Thyanta custator* in a one-night trial of 3 lights.[a] A specimen was taken at a light by Mr. J. C. Crawford at San Antonio, Tex., in May, 1905, and one by Messrs. Crawford and Pratt at Cotulla, Tex., on May 12, 1906. It is possible that trap lights might be successfully used against this insect in badly-infested fields of grain or cotton, for in the localities above mentioned where specimens have been captured by this means the species is comparatively scarce and the chances of capture proportionally reduced.

SEASONAL HISTORY.

The writer has found *Thyanta custator* in cotton fields in greatest abundance in September and October. In view of its occurrence in more or less destructive numbers in grain fields in northern and northwestern Texas it seems likely that the time of its appearance in greatest numbers in cotton fields may be dependent upon the harvesting

[a] Bul. 18, Div. Ent., U. S. Dept. Agr., p. 88, 1898.

of grain crops. During the first week in November, 1904, these bugs were found in large numbers inside the bracts of cotton bolls in various localities in northwestern Texas, commonly known as the "Panhandle." Feeding was not observed in any case, the bugs appearing in a hibernating condition in the most protected location the cotton plants afforded, quiet and exhibiting signs of life only when disturbed. In 1905 this species was rarely found in the cotton fields in the vicinity of Dallas, Tex., during August, but on September 9 it was noted as much more numerous than the brown cotton-bug (*Euschistus servus*), which occurred in fairly large numbers in August, and had shown no diminution in numbers.

A nymph of *Thyanta custator* in the fifth instar was collected by Mr. F. C. Pratt, at Kerrville, Tex., on May 30, 1906, this being the earliest spring record of the collection of a specimen in this stage, as far as known to the writer.

NATURAL ENEMIES.

Eggs of Tachinid flies are frequently found attached to adults of *Thyanta custator*, but as none of these parasites has as yet been reared to maturity, they are unknown specifically. On examination of 113 specimens of this Pentatomid in the collection at the laboratory of the Bureau of Entomology, at Dallas, Tex., 14, or about 12 per cent, were found to be parasitized.

In the laboratory *Telenomus ashmeadi* Morrill has been reared from the eggs of this species and egg-batches have been collected in the fields from which parasites had emerged.

OTHER PENTATOMIDS FREQUENTING OR ATTACKING COTTON.

In addition to the species mentioned in the foregoing pages the following Pentatomids are not infrequently found on cotton plants: *Murgantia histrionica* Hahn, *Podisus maculiventris* Say, *Podisus acutissimus* Stål, *Proxys punctulatus* Pal. Beauv. and *Stiretrus anchorago* Fab. With the exception of the first named—the harlequin cabbage-bug—these species are normally predaceous, but it is probable that all predaceous Pentatomids will feed more or less on plant juices when the supply of caterpillars or other insect food is insufficient. Of the five species mentioned, the harlequin cabbage-bug alone feeds exclusively on plants. This bug is never found widely distributed in cotton fields and is rarely met with in sufficient abundance to cause noticeable damage. Mr. W. A. Hooker found this bug in unusual abundance on cotton at Farmersville, Tex., on September 2, 1904, and discovered the source of infestation to consist of a small cabbage-patch located about 10 rods distant. Somewhat similar conditions have been noted in other instances.

INSECTS OF THE SQUASH-BUG FAMILY (COREIDÆ) INJURIOUS TO COTTON.

THE LEAF-FOOTED PLANT-BUGS.

(*Leptoglossus phyllopus* L., *L. oppositus* Say, and *L. zonatus* Dall.)

A review of the economic status of the northern leaf-footed plant-bug (*Leptoglossus oppositus* Say) and the banded leaf-footed plant-bug (*Leptoglossus phyllopus* L.) was presented by Dr. F. H. Chittenden in an early bulletin of this series.[a] In a later bulletin a more extended account of the former species, including description of all the immature stages and observations on the life history and habits, was given by the same author.[b] Both of these species are commonly found in greater or less abundance in cotton fields throughout the various cotton-growing States. *L. zonatus* Dall. is of comparatively rare occurrence in the United States, and probably for this reason no record of its attacking cotton in this country is available, although the author has noted its injury to cotton bolls in Mexico, where it is more abundant.[c]

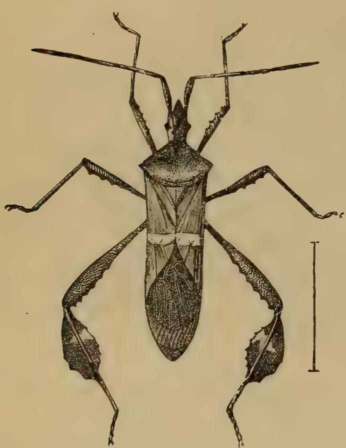


FIG. 19.—The leaf-footed plant-bug (*Leptoglossus phyllopus*): Adult. Twice natural size. (After Hubbard.)

LEPTOGLOSSUS PHYLLOPUS L.

Leptoglossus phyllopus (Pl. I, fig. 6; text fig. 19) is the most common species of the leaf-footed plant-bugs found in cotton fields. Doctor Chittenden has recorded its principal cultivated food plants, showing it to be an almost omnivorous plant feeder and one likely to cause serious local damage to many crops, both fruit and vegetable. Ashmead, in recording his observations made in July, 1893,[d] mentioned the insect as of common occurrence in cotton fields in Mississippi, sometimes as many as 3 or 4 together being observed on a single boll.

About 20 adults of this species were observed by the writer on a single cotton plant near Mason, Tex., on October 20, 1905. They began to take wing when the writer was quietly watching from a distance of several feet and in less than a minute only 2 or 3 specimens remained. On the whole, however, these bugs were not very numerous in the locality named, not exceeding, on the average,

[a] Bul. 19, n. s., Div. Ent., U. S. Dept. Agr., pp. 44–48, 1899.
[b] Bul. 33, n. s., Div. Ent., U. S. Dept. Agr., pp. 18–25, 1902.
[c] Bul. 54, Bur. Ent., U. S. Dept. Agr., p. 33, 1905.
[d] Insect Life, Vol. VII, p. 320, 1895.

1 specimen to every 10 plants. Prof. Wilmon Newell, secretary of the State Crop Pest Commission of Louisiana, and his assistants, while inspecting cotton fields for the Mexican cotton boll weevil in Rapides Parish, La., in September, 1905, found this species of leaf-footed plant-bug very abundant. The following quotation from Professor Newell's notes, which he has kindly permitted to be used in this bulletin, illustrates the degree of importance these insects may attain in consideration of the individual destructiveness of plant-bugs, as shown in the studies of the conchuela.

On September 7, in western Rapides Parish, adults of this species were found in abundance in cotton fields, usually resting or feeding on green bolls. In two or three fields near Forest Hill, these insects were so abundant as to average at least 2 adults to each stalk of cotton. Their damage in the aggregate must be considerable. Hemipterous nymphs found on the bolls appeared to be of this species. Between September 1 and 10 these bugs were found in greater or less abundance in every cotton field inspected in Rapides Parish.

The author considers the species of plant-bug here discussed fully the equal of the conchuela in individual destructive capabilities. The data given in Table XXVI (p. 57) show that in one cotton field damage by the conchuela amounted to about 50 per cent when the bugs were about one-fourth as numerous as were the leaf-footed bugs in the 3 fields near Forest Hill, La., referred to by Professor Newell.

On September 9, 1905, a female was taken in coitu and brought to the laboratory. It was supplied with fresh cotton bolls daily, but produced no eggs and died on October 28, the forty-ninth day of its confinement in the breeding cage. Upon dissection only 1 egg was found; this was of mature size and color, closely resembling in size, structure, and color the eggs of *L. oppositus*, described and figured by Dr. Chittenden. H. G. Hubbard[a] has stated that the normal food plant of this bug in the South is a large thistle. Mr. F. C. Pratt observed adults in considerable numbers on dockweed (*Rumex* sp.) near San Antonio, Tex., on April 19, 1906, feeding and copulating, and on thistles near Baton Rouge, La., on April 22, 1906.

Professor Newell found on May 19, 1905, in Sabine Parish, La., adults of *L. phyllopus* in abundance upon stems and seed-pods of "bear grass" (*Yucca filamentosa*), a common weed in the western part of that State and generally found in greater or less abundance in and around all cotton fields. In many cases the adults occurred upon the "bear grass" so abundantly that the stems and seed-pods were literally covered with them, and in several cases two or three dozen specimens were collected from the stems and seed-pods of a single plant. The insects could not be found on any other plant and seemed to depend entirely upon the "bear grass" for their subsistence at that season of the year.

---

[a] Insects affecting the Orange, p. 169, U. S. Dept. Agr., Div. Ent., 1885.

LEPTOGLOSSUS OPPOSITUS SAY.

Leptoglossus oppositus (figs. 20, 21) is of somewhat less common occurrence in cotton fields than *L. phyllopus*, but east of the Mississippi River and north of Florida it apparently exceeds that species in general abundance. It has been referred to by Dr. Chittenden as the "northern leaf-footed plant-bug."

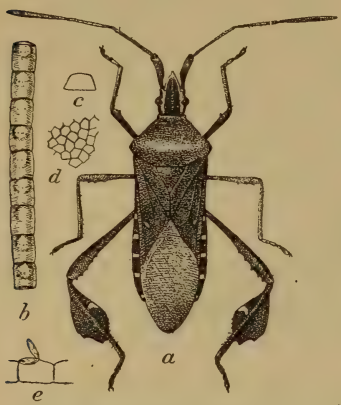


FIG. 20.—The northern leaf-footed plant-bug (*Leptoglossus oppositus*): *a*, Mature bug; *b*, string of eggs; *c*, egg from end; *d*, sculpture of egg; *e*, egg from side, showing opening from which young has escaped. *a, b, c, e*, Natural size; *d*, about twice natural size. From Chittenden.

On September 21, 1905, in Menard County, Tex., the writer found, on two bolls which were situated close together on a cotton plant, between 25 and 30 specimens of this species in the third nymphal instar. Twenty specimens were collected and brought to the laboratory at Dallas. These molted between September 21 and 23. On September 29, 2 molted again although 3 specimens were still in the fourth stage on October 3. One of those which molted on September 29 became adult on October 21; all others died before reaching maturity.

Prof. H. Garman, entomologist of the Kentucky Agricultural Experiment Station, records the finding of nymphs supposed to be

FIG. 21.—The northern leaf-footed plant-bug: *a*, Nymph of first instar; *b*, second instar; *c*, third instar; *d*, fourth instar; *e*, fifth instar. Enlarged about 3 diameters. From Chittenden.

this species in large numbers on Spanish bayonet or "bear grass" (*Yucca filamentosa*) at Lexington, Ky., July 7, 1899. With this exception information concerning wild food plants of this species is wanting but with little doubt various weeds, including thistles and "bear grass," will be found to be included in the list.

Leptoglossus zonatus Dall.

Leptoglossus zonatus was observed by the writer to be fairly numerous in cotton fields at Tlahualilo, Durango, Mexico, in September, 1904, but in the same locality, in July, 1905, not a specimen was found although cotton fields were visited daily during the month. It is not likely that this bug will ever become common in cotton fields in this country except possibly in certain districts in the semiarid region of western Texas.

OTHER COREIDS KNOWN TO ATTACK COTTON.

In the Agricultural Report for 1855, Glover mentioned *Acanthocephala femorata* [a] (Pl. I, fig. 5) as an insect frequently found in cotton fields in Florida. Professor Comstock [b] in his Report on Cotton Insects, 1879, quotes from a statement by Mr. W. Trelease, to the effect that these bugs were several times observed to catch and suck the juices from the bodies of cotton caterpillars, *Alabama* (*Aletia*) *argillacea* Hbn. It was consequently concluded that at that time the knowledge concerning the habits of the bug favored its being considered a friend of the cotton grower. Ashmead [c] stated in regard to this species as observed by him in Mississippi in 1893 that it was "captured several times puncturing young bolls and while not especially numerous does considerable damage."

The flat-horned Coreid (*Chariesterus antennator* Fab.) is recorded by Ashmead as common in cotton fields in Mississippi. Prof. E. D. Sanderson [d] has given brief notes on two species, *Corizus pictipes* Stål and *Jadera hæmatoloma* H.Schf., which are frequently found on cotton, although by themselves not in sufficient numbers to do appreciable damage. In addition to the above-mentioned species of Coreids the writer has occasionally found on cotton a strikingly marked bug, *Hypselonotus fulvus* De G., which may appropriately be known as the banded-legged Coreid. This insect occurs commonly in southwestern Texas, but is not usually found on cultivated plants.

NATURAL ENEMIES OF COREIDS DESTRUCTIVE TO COTTON.

Mr. R. C. Howell, formerly a field agent of this Bureau, collected, on August 15 at Sulphur Springs, Tex., a batch of 42 eggs of a species of Leptoglossus, which had been deposited on the bract of a cotton square. From these eggs 3 Proctotrypid parasites emerged, which Doctor Ashmead determined as *Hadronotus anasæ* Ashm. This parasite was first reared from the eggs of the squash-bug

---

[a] Referred to as *Anisoscelis* ?, p. 95, Pl. VIII, fig. 9.

[b] Report on Cotton Insects, p. 168, U. S. Dept. Agr., 1879.

[c] Insect Life, Vol. VII, p. 320, 1895.

[d] Bul. 57, Bur. Ent., U. S. Dept. Agr., pp. 46–47, 1906.

(*Anasa tristis* DeG.) by Doctor Ashmead in 1886. During the summer of that year it was found in Florida that about 30 per cent of the eggs of *Anasa tristis* were parasitized by this insect. A closely related Proctotrypid has been reared by Ashmead from the eggs of *Acanthocephala (Metapodius) femorata* Fab.

A Tachinid fly, *Trichopoda pennipes* (fig. 22), has been reared from *Leptoglossus oppositus*. Doctor Chittenden[a] states that eggs of this fly were frequently noted, attached to the thorax of adults of this bug, in the vicinity of Washington, D. C., in 1901. The fly has previously been reared from adults of the squash-bug. It occurs in Texas, Mississippi, Florida, and in probably all of the cotton-growing States. It seems to be of little consequence as a natural check to the leaf-footed plant-bugs in Texas, for among 58 specimens of *L. phyllopus* and 24 specimens of *L. oppositus* in the collection of the Bureau of Entomology at the laboratory at Dallas, Tex., only a single specimen of the latter species bore a Tachinid egg. This was attached to the upper surface of the head of an adult male specimen collected by Mr. F. C. Bishopp at Paris, Tex., on August 26, 1905.

FIG. 22.—*Trichopoda pennipes*, a Tachinid parasite of Coreid plant-bugs: Adult. Enlarged about 3 diameters. (From Chittenden.)

INSECTS OF THE LEAF-BUG FAMILY (CAPSIDÆ) INJURIOUS TO COTTON.

Thus far the only species of the family Capsidæ which has proved itself of importance as a cotton pest is the cotton leaf-bug (*Calocoris rapidus* Say, fig. 23). This species was first mentioned in this connection by Townend Glover[b] in 1856. It is widely distributed in North America and is found in all the cotton-growing States. Practically all that is known concerning the life history and habits of this insect is presented by Sanderson[c] in a report of observations made in 1904. Investigations thus far have not revealed any practical method of combating the adult bugs, although destruction of nymphs by a spray of kerosene emulsion may be advisable under some circumstances. The practicability of attracting the adults to light has not been thoroughly tested. Hon. J. D. Mitchell, of Victoria, Tex., captured 165 specimens by the use of 3 trap lanterns in a cotton

---

[a] Bul. 33, Div. Ent., U. S. Dept. Agr., p. 25, 1902.
[b] Agricultural Report for 1855, p. 87, Pl. VII, fig. 6, 1856.
[c] Bul. 57, Bur. Ent., U. S. Dept. Agr., pp. 44–46, 1906.

field near Victoria, Tex., on the night of October 1, 1897,[a] while Professor Sanderson reports 6 as the maximum number of the bugs collected at a single trap lantern at Terrell, Tex., in July, 1906.

Under date of July 7 and August 10, 1898, the Bureau of Entomology received from Mr. J. D. Mitchell specimens of a Capsid known to science by the name of *Psallus delicatus* Uhl., which was reported to occur on cotton in large numbers at Victoria, Tex., and to be very destructive to the young bolls.

INSECTS OF THE CHINCH BUG FAMILY (LYGÆIDÆ) INJURIOUS TO COTTON.

The false chinch bug (*Nysius angustatus* Uhl.) has been reported injurious to cotton in Texas and Louisiana by Professor Sanderson,[b] and in Mississippi by Prof. G. W. Herrick.[c] The attack of these insects is for the most part directed toward the young plants before

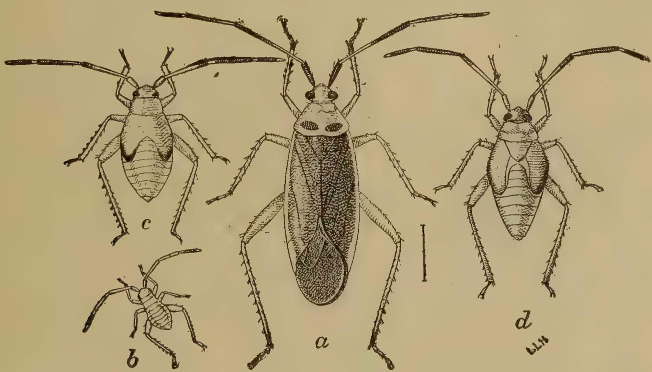


FIG. 23.—The cotton leaf-bug (*Calocoris rapidus*): *a*, Adult; *b*, young nymph; *c*, fourth instar of nymph; *d*, fifth instar of nymph. Much enlarged. (From Sanderson.)

the appearance of the fruit, and the insects should not properly be included in dealing with plant-bugs injurious to cotton bolls.

Two large Lygæids, *Oncopeltus fasciatus* Dall. and *Lygæus turcicus* Fab., were common on cotton at Tlahualilo, Durango, Mexico, in July, 1905, and young of both species were found feeding on alfalfa. They have been observed to attack both cotton squares and bolls. In the collection of cotton insects taken in Texas and surrounding States by the agents of the Bureau of Entomology connected with the cotton boll weevil investigations, only the second species is represented, although both are of common occurrence in Texas. Milkweeds (*Asclepias* spp.) seem to be the natural food plants of both these species. To illustrate the general appearance of bugs of this family a specimen of *Oncopeltus fasciatus* is shown by Plate I, figure 9.

[a] Bul. 18, Div. Ent., U. S. Dept. Agr., p. 88.
[b] Bul. 57, Bur. Ent., U. S. Dept. Agr., pp. 29–31, 1906.
[c] 17th Ann. Rep. Miss. Exp. Sta., p. 31, 1904.

INSECTS OF THE COTTON STAINER FAMILY (PYRRHOCORIDÆ) INJURIOUS TO COTTON.

THE BORDERED PLANT-BUG.

(*Largus succinctus* L.)

This insect (Pl. I, fig. 7; text figs. 24, 25) has been briefly mentioned as a minor cotton pest by Professor Sanderson,[a] who has indicated the more important published references. The insect is generally distributed throughout the Southern States. Lintner has recorded its attack on ripening peaches at San Antonio, Tex., in 1885, but this apparently indicated nothing more than an occasional depredation. The insect has been observed by the present writer to breed in enormous numbers in alfalfa fields at Tlahualilo, Durango, Mexico. It has also been found in certain regions in Texas breeding on a weed, *Solanum torreyi*, and on mesquite, but in each case only when growing in the vicinity of cotton fields. Eggs are deposited in trash in masses averaging, in four instances, 180 eggs each, and ranging from 108 to 215.[b] The eggs hatch in about ten days at an average daily mean temperature of 74° F. while about twice that time is necessary when the temperature is 10 degrees lower. The damage to cotton bolls by the bordered plant-bug is the same as that caused by the Pentatomid and Coreid bugs heretofore discussed. Their preference for the cotton boll is not as strongly marked, however, adults and nymphs being much more frequently found feeding on the outside of cotton squares at the base of the bracts. The writer knows of no instance of this bug occurring in cotton fields in numbers sufficient to cause by itself noticeable damage except as observed in a few fields in Mason and Llano counties, Texas, in 1905. In all cases referred to, the mesquite and the solanaceous weed mentioned above were evidently the chief breeding places and as a rule only near-by cotton plants were damaged. The newly-hatched nymphs have a dark brownish head and thorax, and reddish abdomen. Later nymphal stages are characterized by a greenish or bluish-black color with red markings.

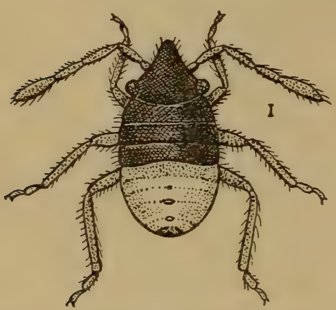


FIG. 24.—The bordered plant-bug (*Largus succinctus*): Nymph, first instar. Enlarged 21 diameters. (Original.)

[a] Bul. 57, Bur. Ent., U. S. Dept. Agr., p. 46, 1906.

[b] Professor Sanderson's record of 215 eggs in a mass is the maximum number referred to above.

THE COTTON STAINER.

(*Dysdercus suturellus* H. Schf.)

The cotton stainer (Pl. I, fig. 8), or "red bug," as it is sometimes called, is a native of tropical America and although long known as a cotton pest it is of limited distribution in this country, where thus far damage to cotton has been reported only from Florida.

Riley and Howard [a] have given the most complete account of this insect that has been published. The differences in opinion among various observers as expressed in published writings concerning the nature of the injury by this insect to cotton have been discussed by the writer under the general subject of injury by plant-bugs.

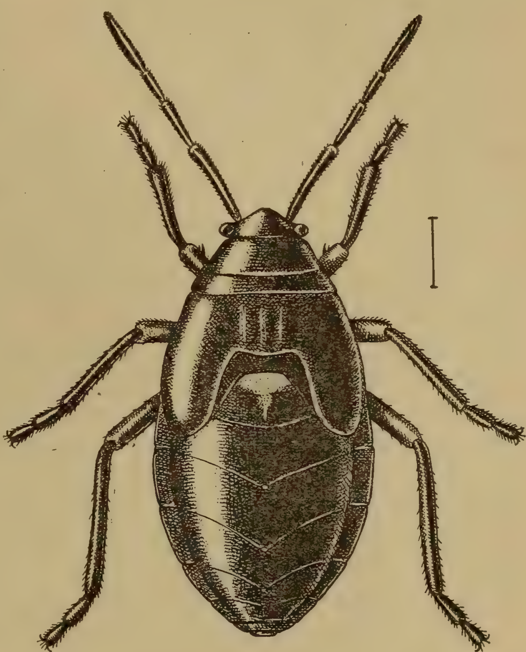


FIG. 25.—The bordered plant-bug: Nymph, fifth instar. Enlarged 6 diameters. (Original.)

Riley and Howard have referred to the records of food plants and supposed food plants. Aside from the cotton and orange, the cotton stainer has been observed to feed on certain undetermined malvaceous plants and has been found on certain species of Hibiscus, on the leaves of guava (Psidium), on Spanish cocklebur (*Urena lobata*), and night-shade (*Solanum nigrum*). The writer has observed these insects breeding in large numbers at Orlando, Fla., on Spanish cocklebur growing in and near orange groves, but has never observed them to feed on citrus fruits, except in cases where they were in confinement. Undoubtedly, as Riley and Howard have indicated, the habit of feeding on oranges is a temporary one and is probably due to the destruction of more natural food plants by frost or other causes.

Mr. H. A. Ballou has given some records of egg-laying of certain West Indian species of cotton stainers, but the writer knows of no published records of this kind concerning the American form here discussed. On October 8, 1906, 4 females and 4 males collected on

[a] Insect Life, Vol. I, pp. 234–241, 1889.

cotton at Hawthorn, Fla., were confined in a cage at the writer's laboratory at Orlando, Fla. Within 24 hours after capture, 334 eggs were deposited and each of the 4 females was observed to be much less robust, presumably, therefore, having deposited eggs. These specimens all died between October 18 and October 25, 1906, during the writer's absence from the laboratory. In all, 465 eggs were deposited by the 4 females, an average of 116 eggs each. These were deposited both loosely in the sand at the bottom of the cage and in masses containing up to about 100 each. The eggs do not form compact masses, nor do they adhere to any object when freshly deposited. When covered by as much as one-fourth of an inch of loose sand the nymphs were unable to free themselves from the eggshells and died in all cases as far as observed. On October 26 an adult female was taken in coitu on cocklebur at Orlando, Fla., being selected from a large number on account of its abdomen being the most dilated, presumably with eggs. Upon dissection 78 full-sized eggs were found. It is possible that a few, not exceeding 6 eggs, were destroyed in dissecting. It seems probable that about 80 or 85 eggs is the largest number which one female may deposit at one laying, and this observation furnishes additional evidence that each of the 4 females heretofore referred to deposited eggs on more than one occasion.

Gregariousness is a very strongly marked habit in this insect and is of great importance in its control in the cotton fields.

The writer's observation in a cotton field at Hawthorn, Fla., in October, 1906, showed that the cotton stainer's injury to immature bolls (Pl. III, figs. 2–7) exhibits the same characteristics as that by the Pentatomids and other plant-bugs which have been treated of herein. This injury, often resulting in complete destruction of the entire boll affected, or of one or more of its locks, is generally considered by cotton growers in Florida to be due to climatic conditions. It seems, however, to be more frequently ascribed to too much rain, whereas, as has been stated, in Texas the plant-bug injury of this kind is more often ascribed to dry weather. In one field the writer has estimated that not less than 15 per cent of all bolls were destroyed by the feeding of cotton stainers during the growing season. It is important that the source of this ordinary plant-bug injury be recognized. Brief observations at Hawthorn in 1906 cleared up much of the uncertainty in regard to the nature of the yellowish stain of the lint which is the generally recognized result of attack by the cotton stainer. Mr. Johnson, of the firm of Smith & Johnson, cotton ginners at Hawthorn, is well informed concerning this insect and its work. It is his observation that the staining of the lint is due to the bug's attack on the immature bolls and on the seed at the time of opening, the brownish-yellow color being derived from the injured seed rather than from the excrement of the bugs. The writer's observations support this view in regard to the source of the stain, for an examination of a considerable amount of seed cotton which had been badly stained by the bugs showed almost invariably that the stain was most intense immediately surrounding the seed. (Pl. II, fig. 3.) Sometimes it is only the fibers at one end of the seed that are affected, but more often all of the fibers attached to a damaged seed are more or less brownish at their bases while at the outer ends they rarely show traces of stain. It is inconceivable that the excrement of the cotton stainers should stain the fiber in such a manner. Moreover, according to the writer's observations the amount of excrement is too small to result in any appreciable damage. On one occasion as many as a dozen adult cotton stainers have been observed on a single plant feeding on the seed of the open bolls with no trace of stain that would be expected if the insects voided their yellowish liquid excrement with sufficient frequency to damage the lint. In the laboratory 8 specimens, including 4 males and 4 females, were confined in a cage, the bottom of which was covered about an inch deep with seed-cotton having pure white fiber. In 10 days, during which the bugs fed on a green cotton boll and a piece of orange rind, the cotton seed and the lint were unstained, although in one or two instances excrement had been voided on the sides of the cage. While there is undoubtedly some staining of the cotton fiber, due to the excrement of the bugs from the evidence at hand, the writer concludes that damage from this source is inappreciable.

At present the cotton stainer is the most destructive cotton pest in Florida and presumably does occasional damage to cotton in Georgia and neighboring portions of South Carolina and Alabama, where its occurrence has been recorded by Dr. L. O. Howard.[a] Its outbreaks are sporadic, however, and rarely occur over large areas. Dr. E. H. Sellards, formerly entomologist at the Florida Agricultural Experiment Station, reports that the cotton stainer was abundant in 1904, and in one instance it was claimed that the complete destruction of 25 acres of long-staple cotton was due to this insect.[b] In 1902, Smith & Johnson, of Hawthorn, ginned about 1,000 bales of long-staple cotton, of which about 200 bales were classed as stained. Fortunately, owing to the gregariousness of the bugs, the badly stained cotton is usually brought to the gins in concentrated lots. The staining of the cotton by the cotton stainer means a loss of about one-half of its value when at its worst. Intermediate prices are brought for different degrees of damage.

Mr. Johnson, who is a member of the firm mentioned above and who has had considerable experience with the cotton stainer, has

[a] Bul. 33, Office Exp. Sta., p. 349; also Farmers' Bul. 47, p. 30, 1896.

[b] Rep. Fla. Agr. Exp. Sta. for fiscal year ending June 30, 1905, p. 27.

found that this insect can be controlled satisfactorily by destroying by hand whenever incipient colonies are found. From the time that the first bolls set until the cotton is picked a cotton grower should keep a close watch for the appearance of the pest and destroy the colonies whenever discovered. Weeds of all kinds and particularly the Spanish cocklebur should either not be permitted to grow in the vicinity of cotton fields or be kept under close surveillance in order that they may be promptly destroyed if the necessity arises.

METHODS OF CONTROL FOR GENERAL APPLICATION.

FARM PRACTICE AND CULTURAL METHODS.

In this country a single species of the plant-bugs dealt with in the foregoing pages rarely demands special treatment, while the combined attack of several, each occurring in moderate numbers, is often of vital importance in the determination of profit or loss to the cotton grower, and for this reason control methods which are generally effective against the various species are of great usefulness.

The cotton boll weevil is gradually revolutionizing the cotton-growing industry in the South, and in addition to making necessary certain modifications of the time-honored methods of cotton production, designed to avoid weevil damage as far as possible, has brought into prominence the several minor cotton pests which now demand intelligent attention. Fortunately the cultural methods for the control of the weevil, designed and tested on a broad scale in the course of the investigations of the Bureau of Entomology, and afterwards administered, and to some extent modified in the light of subsequent work by the Bureau of Plant Industry, are also, in part, of importance in the control of many minor cotton pests, including plant-bugs.

In general, the plant-bugs which attack cotton bolls in the Southern States attain their greatest abundance in August and September, and consequently the earliest maturing cotton suffers the least. The problem of producing an early maturing cotton crop has been one of the more important subjects of investigation in connection with the study of the control methods for use against the boll weevil. This has been considered from an entomological standpoint and put into the form of definite practical recommendations by Mr. W. D. Hunter, in Farmers' Bulletins [a] and in circulars dealing with the boll weevil. Of more importance in the control of the weevil is the destruction in the fall of cotton plants in the field. This practice is, of course, particularly effective as a measure against the boll weevil, which has no other food plant than cotton, but many plant-

[a] Farmers' Bulletins 163, 189, 216, and 344, U. S. Dept. Agriculture.

bugs are doubtless eradicated by the methods of destruction of cotton stalks advocated by the Bureau of Entomology, i. e., by piling in windrows and burning. In addition to the direct destruction of the insects, many nymphs would fail to reach maturity in a well-cleared field, and the adults would be deprived of favorable conditions for hibernation offered by cotton plants left standing in the fields during the winter.

Associated with these methods, and probably of equal importance, is the practice of destroying early in the season wild food plants of the plant-bugs which attack cotton, thus checking the multiplication of the insects which later turn their attention to the cotton bolls. The wide range of food plants known for nearly all the species dealt with in this bulletin indicates the strong advisability of clean cultivation and the prevention of the growth of weeds along fences and roadsides close to cotton fields.

DIRECT METHODS OF COMBATING PLANT-BUGS IN COTTON FIELDS.

Under certain circumstances contact insecticides may be of use against plant-bugs in cotton fields, but only when they occur in such excessive abundance that all methods of collecting are impractical. Kerosene emulsion will probably prove the most effective spray, but before using on a large scale preliminary tests should be made to determine the required strength.

Hand-picking of the conchuela has already been discussed and detailed information regarding this measure given. The good results obtained by the use of this method of control against the cotton stainer or "red bug" in Florida have also been referred to. This is in many cases the only practical method of protecting the cotton crop against severe injury. Its success is dependent for the most part on the size and conspicuousness of the species dealt with and on the efficiency with which the work of the pickers is supervised. The foregoing detailed discussion of the destructive capabilities of plant-bugs indicates the amount which a cotton planter can afford to invest in hand-picking. The season of the year must be taken into consideration in the estimation of this point. In general, it may be said that in midsummer from 10 to 25 cents per hundred, according to the abundance of the pests,[a] or day labor at the rate of 50 cents to $1.25 per day is not too great an investment for collecting the larger species of plant-bugs which may be found attacking cotton bolls. Such expenditures, judiciously made, will undoubtedly result in saving from destruction

[a] The scarcer the bugs the more one can afford to pay per 100 collected, owing to greater individual destructiveness heretofore explained.

cotton worth many times the outlay. It is not urged that all cotton growers begin a systematic search for the presence of bugs in their cotton fields, but there are known to be many whose experience has already shown the extent of the damage chargeable to plant-bugs. For them the investigations here reported should be useful in the determination as to whether or not remedial measures are desirable under their own peculiar conditions. It is hoped that the attention of many others will be directed to this damage where it has previously been unnoticed or, if noticed, misunderstood. By careful attention to the elimination, as far as practicable, of damage by these and other minor cotton pests, an important advance will be made toward the reestablishment of cotton growing upon the profitable basis existent before the advent of the cotton boll weevil.

INDEX.

Page.

Acanthocephala femorata, enemy of *Alabama* (*Aletia*) *argillacea* 91
host of Proctotrypid 92
on cotton 91
Alabama (*Aletia*) *argillacea*, *Acanthocephala femorata* an enemy 91
Alfalfa as trap for *Pentatoma ligata* 68
food plant of *Largus succinctus* 94
Lygæus turcicus 93
Oncopeltus fasciatus 93
Pentatoma ligata 25
sayi 73
Allorhina nitida, hand-picked in cotton field in Mexico 70
Anasa tristis. (*See* Squash bug.)
Anisoscelis in cotton fields 11
Anthracnose, cotton boll. (See *Colletotrichum gossypii*.)
Ants, probable enemies of *Pentatoma ligata* 65
Asclepias spp., food plants of *Lygæus turcicus* 93
Oncopeltus fasciatus 93
Bacillus gossypinus, probable dissemination by plant-bugs 23
Beans, food plant of *Nezara hilaris* 80
"Bear grass." (See *Yucca filamentosa* and *Yucca* sp.)
Bird enemies of *Pentatoma ligata* 66–67
Bombus sp., hand-picked in cotton field in Mexico 70
Brachystola magna, hand-picked in cotton field in Mexico 70
Bumblebee. (See *Bombus* sp.)
Cabbage bug, harlequin. (See *Murgantia histrionica*.)
food plant of *Nezara hilaris* 80
Calocoris rapidus as a cotton insect, general account 92–93
on cotton 11, 12, 92–93
amount of damage therefrom 20
bolls, external evidence of injury 15–17
nature of injury 15
Capsidæ injurious to cotton 92–93
Caterpillar, salt-marsh. (See *Estigmene acræa*.)
Chariesterus antennator on cotton 91
Chinch bug, false. (See *Nysius angustatus*.)
family. (*See* Lygæidæ.)
Chrysopa spp., suggested enemies of *Pentatoma ligata* 64
Coccinellid beetles, probable enemies of *Pentatoma ligata* 65
Cocklebur, Spanish. (See *Urena lobata*.)
Cold (*see also* Temperature).
as a factor in retarding development of *Pentatoma ligata* 40
Colletotrichum gossypii, probable dissemination by plant-bugs 23
Conchuela (see also *Pentatoma ligata*).
amount of damage therefrom 20–21

Page.
Coreidæ injurious to cotton 88-92
Coreid, banded-legged. (See *Hypselonotus fulvus*.)
flat-horned. (See *Chariesterus antennator*.)
Corizus pictipes on cotton 91
Corn, food plant of *Nezara hilaris* 80
Pentatoma ligata 25
Thyanta custator 84, 85
Cotton, amount of damage by *Calocoris rapidus* 20
conchuela (*Pentatoma ligata*) 20-21
Dysdercus suturellus 20
plant-bugs 20-23
boll "rot." (See *Bacillus gossypinus*.)
bolls, plant-bug attack, published descriptions of effect 13-15
enemies, control methods for general application 98-99
damage therefrom 20-23
direct methods of combating them in cotton fields 99-100
disseminators of plant diseases 23
historical review of published writings 11-13
method of estimating losses therefrom 59
nature of injury 13-20
proof of injury 19-20
injury, external evidence 15-17
internal appearance 17-20
proof 19-20
proliferation as result of plant-bug attack 17-19
bug, brown. (See *Euschistus servus*.)
Capsid enemies 92-93
Coreid enemies 88-92
diseases, dissemination by plant-bugs 23
food plant of *Acanthocephala femorata* 91
Calocoris rapidus 11, 12, 92-93
nature of injury 15
Chariesterus antennator 91
Corizus pictipes 91
Dysdercus ruficollis 12
suturellus 11, 12, 95-98
Euschistus 11
impictiventris 74
punctipes 12, 74
pyrrhocerus 74
servus 74-77
tristigmus 74
Hypselonotus fulvus 91
Jadera hæmatoloma 91
Largus cinctus 12
succinctus, nature of injury 15, 94
Leptoglossus oppositus 90
phyllopus 11, 12, 88-89
zonatus 88, 91
Lygæus turcicus 93
Murgantia histrionica 87
Nezara hilaris 11, 12, 78-81

Page.

Cotton, food plant of *Nezera pennsylvanica* ... 12
viridula ... 82–83
Nysius angustatus ... 93
Oncopeltus fasciatus ... 93
Oxycarenus hyalinipennis ... 15
Pentatoma ligata ... 12–13, 15, 25
sayi ... 73–74
Podisus acutissimus ... 87
maculiventris ... 87
Proxys punctulatus ... 87
Psallus delicatus ... 93
St. Andrews cotton stainer ... 12
Stiretrus anchorago ... 87
Thyanta custator ... 84–86
insects in Texas ... 13
leaf-bug. (See *Calocoris rapidus*.)
Lygæid enemies ... 93
method of estimating losses due to plant-bugs ... 59
Pentatomid enemies of the genus Euschistus ... 74–78
Nezara ... 78–83
Thyanta ... 84–87
plant-bugs in Bismarck Archipelago and German East Africa ... 13
Pyrrhocorid enemies ... 94–98
quality and market value of lint as affected by plant-bug attack ... 61–62
reduction in yield of fields infested by *Pentatoma ligata* ... 57–61
stainer (see also *Dysdercus suturellus*).
as an orange pest ... 12
family. (*See* Pyrrhocoridæ.)
nature and cause of injury to bolls ... 14–15
St. Andrews, on cotton ... 12
stainers in West Indies ... 13
worm, destruction by *Nezara hilaris* ... 12
Cowpeas, food plant of *Thyanta custator* ... 84, 85
Cricket. (See *Gryllus* sp.)
Cultural methods against plant-bugs injurious to cotton bolls ... 98–99
Currant, wild. (See *Ribes* sp.)
Deilephila lineata, hand-picked in cotton field in Mexico ... 70
Diseases of cotton, dissemination by plant-bugs ... 23
Dockweed. (See *Rumex* sp.)
Dysdercus ruficollis on cotton ... 12
suturellus (*see also* Cotton Stainer).
as a cotton insect, general account ... 95–98
on cotton ... 11, 12, 95–98
amount of damage therefrom ... 20
Urena lobata ... 95
Egg-plant, food plant of *Nezara hilaris* ... 79
Epitragus sp., hand-picked in cotton field in Mexico ... 70
Estigmene acræa, hand-picked in cotton field in Mexico ... 70
Euschistus fissilis on wheat ... 74
Podisus maculiventris an enemy ... 65
impictiventris on cotton ... 74
on cotton ... 11
politus, partly predaceous in habit ... 74

Page.
Euschistus punctipes=E. variolarius ... 74
on cotton ... 12, 74
pyrrhocerus on cotton ... 74
servus, as a cotton insect, general account ... 75–78
destructiveness ... 77
distribution ... 75
enemies ... 77–78
food plants ... 75–76
habits ... 76
life history ... 76
proliferation of cotton bolls as result of attack ... 18
seasonal history ... 76–77
tristigmus on cotton ... 74
variolarius, *E. punctipes* a synonym ... 74
on tobacco ... 74
Euthryrhynchus floridanus, enemy of *Nezara hilaris* ... 82
Farm practice and cultural methods against plant-bugs destructive to cotton bolls ... 98–99
Fig-bloom beetle. (See *Allorhina nitida*.)
Gasoline blast torches against conchuela ... 68
Gaura parvifolia, perhaps a food plant of *Euschistus servus* ... 76
Grain bug. (See *Pentatoma sayi*.)
Grains, food plants of *Pentatoma sayi* ... 73
Grapes, food plant of *Pentatoma ligata* ... 25
Grasshopper, lubber. (See *Brachystola magna*.)
Gryllus sp., hand-picked in cotton field in Mexico ... 70
Guava, food plant of *Dysdercus suturellus* ... 95
Gymnosoma fuliginosa, parasite of *Pentatoma ligata* ... 64
Hadronotus anasæ, parasite of *Anasa tristis* ... 91–92
Leptoglossus ... 91
Hand picking in control of conchuela ... 68–72
of plant-bugs that destroy cotton bolls ... 99–100
Helianthus, perhaps a food plant of *Euschistus servus* ... 75
Heterotheca subaxillaris, perhaps a food plant of *Euschistus servus* ... 75
Hibiscus, food plants of *Dysdercus suturellus* ... 95
Hippodamia convergens, hand-picked in cotton field in Mexico ... 70
Hypselonotus fulvus on cotton ... 91
Insecticides, contact, in control of conchuela ... 72
Jadera hæmatoloma on cotton ... 91
Kerosene emulsion against *Calocoris rapidus* ... 92
plant-bugs that destroy cotton bolls ... 99
Largus cinctus on cotton ... 12
succinctus as a cotton insect, general account ... 94
association with *Pentatoma ligata* ... 67
hand-picked in cotton field in Mexico ... 70
on alfalfa ... 94
cotton bolls, nature of injury ... 15
Leaf-bug family. (*See* Capsidæ.)
Leptoglossus, host of *Hadronotus anasæ* ... 91
oppositus, as a cotton insect, general account ... 90
host of *Trichopoda pennipes* ... 92
phyllopus as a cotton insect, general account ... 88–89
on cotton ... 11, 12

Page.
Leptoglossus zonatus on cotton.......... 88, 91
Lights not attractive to conchuela.......... 73
Linden, European, food plant of *Nezara hilaris*.......... 80
Lygæidæ injurious to cotton.......... 93
Lygæus turcicus, hand-picked in cotton field in Mexico.......... 70
on alfalfa.......... 93
Asclepias spp.......... 93
cotton.......... 93
Maple, food plant of *Nezara hilaris*.......... 80
Mesquite, food plant of *Largus succinctus*.......... 94
Nezara hilaris.......... 80
Pentatoma ligata.......... 25
Thyanta custator.......... 85
removal as preventive measure against *Pentatoma ligata*.......... 67
Metapodius femorata=*Acanthocephala femorata*.......... 92
Migration of nymphs of Uhler's green plant-bug (*Pentatoma uhleri?*).......... 42
Milkweeds. (See *Asclepias* spp.)
Milo maize, food plant of *Pentatoma ligata*.......... 25
Thyanta custator.......... 84, 85
Murgantia histrionica, cause of failure in hatching of eggs.......... 38
on cotton.......... 87
Mustard, food plant of *Nezara hilaris*.......... 79
Nezara hilaris as a cotton insect, general account.......... 78–82
association with *Pentatoma ligata*.......... 67
destructiveness.......... 81
distribution.......... 79
enemies.......... 81–82
enemy of cotton worm.......... 12
food plants.......... 79–80
habits.......... 80–81
history.......... 78
life history.......... 80–81
on cotton.......... 11, 12, 78–81
proliferation of cotton bolls as result of attack.......... 18
pennsylvanica on cotton.......... 12
pennsylvanicus=*Nezara pennsylvanica*.
wrong determination of *Nezara hilaris*.......... 78
viridula as a cotton insect, general account.......... 82–83
Nightshade. (See *Solanum nigrum*.)
Nysius angustatus on cotton.......... 93
Oats, food plant of *Thyanta custator*.......... 84, 85
Okra, food plant of *Nezara hilaris*.......... 80
Oncopeltus fasciatus, hand picked in cotton field in Mexico.......... 70
on alfalfa.......... 93
Asclepias spp.......... 93
cotton.......... 93
Orange, food plant of cotton stainer (*Dysdercus suturellus*).......... 12
Euschistus servus.......... 75
Nezara hilaris.......... 79
viridula.......... 82
Oxycarenus hyalinipennis, nature of injury to cotton.......... 15
Peach, food plant of *Euschistus servus*.......... 75
Largus succinctus.......... 94

Page.
Peach, food plant of *Nezara hilaris* ... 80
Pentatoma ligata ... 25
Peas, food plant of *Nezara hilaris* ... 79
Pentatoma ligata ... 25
Pentatoma, abundant in cotton fields ... 11
ligata as a cotton insect, general account ... 23–73
activity of adults in relation to temperature ... 35
adults, description ... 25–26
habits ... 43–48
life history ... 29–35
association with *Largus succinctus* ... 67
Nezara hilaris ... 67
Pentatoma sayi ... 47
Thyanta perditor ... 47
bird enemies ... 66–67
cannibalistic habits, abnormal, of adults ... 47
conspicuous position of adults when feeding ... 44–45
control, artificial ... 67–73
in alfalfa fields ... 67–68
natural ... 62–67
cost of hand picking ... 70–71
decrease and increase in numbers during the season ... 48–53
description ... 25–28
destructiveness ... 20–21, 55–62
development of nymphal stages retarded by cold ... 40
distance nymphs can travel for food ... 42–43
distribution ... 24–25
duration of fertility ... 31–32
nymphal stages as affected by cold ... 40
under normal summer temperatures ... 39–40
egg laying ... 43–44
capacity ... 31
monthly and daily rate and relation to temperature ... 30
rate of deposition of individual eggs ... 44
eggs, description ... 26
effect of low temperature on vitality ... 38
hatching ... 38–39
incubation period ... 35–37
life history ... 35–39
number per batch ... 44
proportion hatching in laboratory ... 37
enemies ... 62–67
feeding of adults ... 44–47
nymphs ... 41–42
fertility, duration ... 31–32
fertilization ... 43
flight ... 48
food plants ... 25
gregariousness of adults ... 47–48
nymphs ... 41–42
habits ... 41–48
hatching of eggs ... 38–39

Page.
Pentatoma ligata, hibernation.. 53–54
history.. 23–24
increase and decrease in numbers during the season.......... 48–53
incubation period of eggs, as related to temperature........... 35–37
individual capabilities of destructiveness..................... 55–57
invertebrate enemies attacking adults..................... 66
eggs........................ 64–65
nymphs..................... 65–66
life history.. 29–41
methods of study.............................. 29
longevity of adults collected in the field.................... 32–33
reared to maturity in the laboratory...... 33–34
when deprived of food.................... 34–35
nymphs without food......................... 40–41
method of attack of adults in feeding...................... 46–47
miscellaneous observations on feeding habits of adults....... 47
molting of nymphs.. 41
nymphal stages, duration.................................. 39–41
nymphs, description.. 27–28
habits.. 41–43
length of life without food........................ 40–41
life history... 39–41
molting.. 41
on cotton bolls.. 12–13
nature of injury............................. 15
oviposition. (*See* egg laying.)
parasites attacking adults................................. 64
eggs................................. 62–64
nymphs............................... 64
period between maturity of adults and beginning of egg laying.. 29–30
predaceous habits of adults, abnormal..................... 47
predatory enemies.. 64–67
preventive measures.. 67–68
proliferation of cotton bolls as result of attack............. 17–19
proof of injury to cotton bolls............................ 19–20
rate of deposition of individual eggs...................... 44
reproduction.. 30–32
seasonal history.. 48–54
sexes, proportion.. 32
temperature as related to activity of adults................ 35
incubation of eggs................... 35–37
monthly and daily rate of oviposition......................... 30
low, as affecting vitality of eggs................... 38
sayi, as a cotton insect, general account......................... 73–74
association with *Pentatoma ligata* in the field................. 47
hand-picked in cotton field in Mexico......................... 70
increase and decrease in numbers during the season........... 50–52
on alfalfa... 73
serva=*Euschistus servus*.. 74
uhleri? (*See* Plant-bug, Uhler's green.)
Pentatomid bugs of the genus Euschistus injurious to cotton bolls............. 74–78

Page.
Pentatomid bugs of the genus Nezara injurious to cotton bolls 78–83
Thyanta injurious to cotton bolls 84–87
Pepper, chilli, food plant of *Pentatoma ligata* 25
Plant-bug attack on cotton bolls as affecting quality and market value of lint. 61–62
proliferation as result 17–19
published descriptions of effect 13–15
bordered. (See *Largus succinctus.*)
injury to cotton bolls, external evidence 15–17
internal appearance 17–20
proof 19–20
Uhler's green, hibernation 54
migration of nymphs for food 42
Plant-bugs injurious to cotton bolls, amount of damage therefrom 20–23
control methods for general application .. 98–100
direct methods of combating them in cotton fields 99–100
disseminators of plant diseases 23
historical review of published writings 11–13
method of estimating losses therefrom 59
nature of injury 13–20
leaf-footed, on cotton 88–91
on cotton in Bismarck Archipelago and in German East Africa 13
Plum, perhaps a food plant of *Euschistus servus* 76
Podisus acutissimus on cotton 87
lineatus, dead specimen eaten by *Pentatoma ligata* 42
maculiventris, enemy of *Euschistus fissilis* 65
incubation period of eggs in relation to temperature 37
on cotton 87
serieventris, hibernation 54
Potato, food plant of *Nezara viridula* 82
sweet. (*See* Sweet potato.)
Primrose, evening. (See *Gaura parvifolia.*)
Proctotrypid parasite of *Acanthocephala femorata* 92
parasites of *Nezara hilaris* 82
Proliferation of cotton bolls as result of plant-bug attack 17–19
Prosopis sp. (*See* Mesquite.)
Proxys punctulatus on cotton 87
Psallus delicatus on cotton 93
Psidium. (*See* Guava.)
Pyrrhocoridæ injurious to cotton 94–98
"Red bug." (See *Dysdercus suturellus.*)
Ribes sp., food plant of *Pentatoma ligata* 25
Rubus sp., perhaps a food plant of *Euschistus servus* 76
Rudbeckia sp., perhaps a food plant of *Euschistus servus* 75–76
Rumex sp., food plant of *Leptoglossus phyllopus* 89
Sage, food plant of *Pentatoma ligata* 25
Salt-marsh caterpillar. (See *Estigmene acræa.*)
Solanum elæagnifolium, food plant of *Pentatoma ligata* 25
nigrum, food plant of *Dysdercus suturellus* 95
torreyi, food plant of *Largus succinctus* 94
Soldier-bug, green. (See *Nezara hilaris.*)
spined. (See *Podisus maculiventris.*)
Sorghum, food plant of *Pentatoma ligata* 25

Page.
Sorghum, food plant of *Thyanta custator* 84, 85
Spanish bayonet. (See *Yucca filamentosa* and *Yucca* sp.)
Sphinx, white-lined. (See *Deilephila lineata.*)
Spider attacking nymph of *Thyanta* sp 65–66
Spiders, possible enemies of *Pentatoma ligata* 65–66
Squash-bug family. (See *Coreidæ.*)
(*Anasa tristis*), host of *Hadronotus anasæ* 91–92
Trichopoda pennipes 92
Stiretrus anchorago on cotton 87
Sweet potato, food plant of *Nezara viridula* 82
Syrphid larva, enemy of *Pentatoma ligata* 65
Tachinid parasite of *Nezara viridula* 83
Thyanta custator 87
Telenomus ashmeadi, parasite of *Euschistus servus* in the laboratory 78
Pentatoma ligata 62–64
Thyanta custator 87
Temperature as related to activity of adults of *Pentatoma ligata* 35
incubation of eggs of *Pentatoma ligata* 35–37
Podisus maculiventris 37
monthly and daily rate of oviposition of *Pentatoma ligata* 30
low, as affecting vitality of eggs of *Pentatoma ligata* 38
Thistle, food plant of *Leptoglossus phyllopus* 89
Thyanta casta, close to, if not identical with, *T. custator* 84
custator as a cotton insect, general account 84–87
distribution 84
enemies 87
feeding on eggs of *Pentatoma ligata* 64
food plants 85
habits 85–86
injurious occurrences 84
life history 85–86
proliferation of cotton bolls as result of attack 18
seasonal history 86–87
variations 84
history of species concerned in damage to cotton bolls 84
identity of species concerned in damage to cotton bolls 84
perditor, association with *Pentatoma ligata* in the field 47
close to, if not identical with, *T. custator* 84
sp., hand-picked in cotton field in Mexico 70
increase and decrease in numbers during the season 50–52
killed and eaten by a spider 66
Tobacco, food plant of *Euschistus variolarius* 74
Tomato, food plant of *Nezara hilaris* 79
Pentatoma ligata 25
Trap crops in control of conchuela 72–73
Trichopoda pennipes, parasite of *Leptoglossus oppositus* 92
squash bug (*Anasa tristis*) 92
Triphleps insidiosus, suggested enemy of *Pentatoma ligata* 64
Trissolcus euschisti, parasite of *Euschistus servus* 78
parasite of *Nezara hilaris* 82
"Trompillo." (See *Solanum elæagnifolium.*)
Turnip, food plant of *Nezara hilaris* 79

Page.
Turnip, food plant of *Nezara viridula* 83
Urena lobata, food plant of *Dysdercus suturellus* 95
Weather influences as controlling *Pentatoma ligata* 62
Wheat, food plant of *Euschistus fissilis* 74
Yucca filamentosa, food plant of *Leptoglossus oppositus* 90
phyllopus 89
sp. (Spanish bayonet), food plant of *Pentatoma ligata* 25
Zelus renardii, enemy of *Pentatoma ligata* 65

O

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 87.

L. O. HOWARD, Entomologist and Chief of Bureau.

REPORT ON THE FIELD WORK AGAINST THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

BY

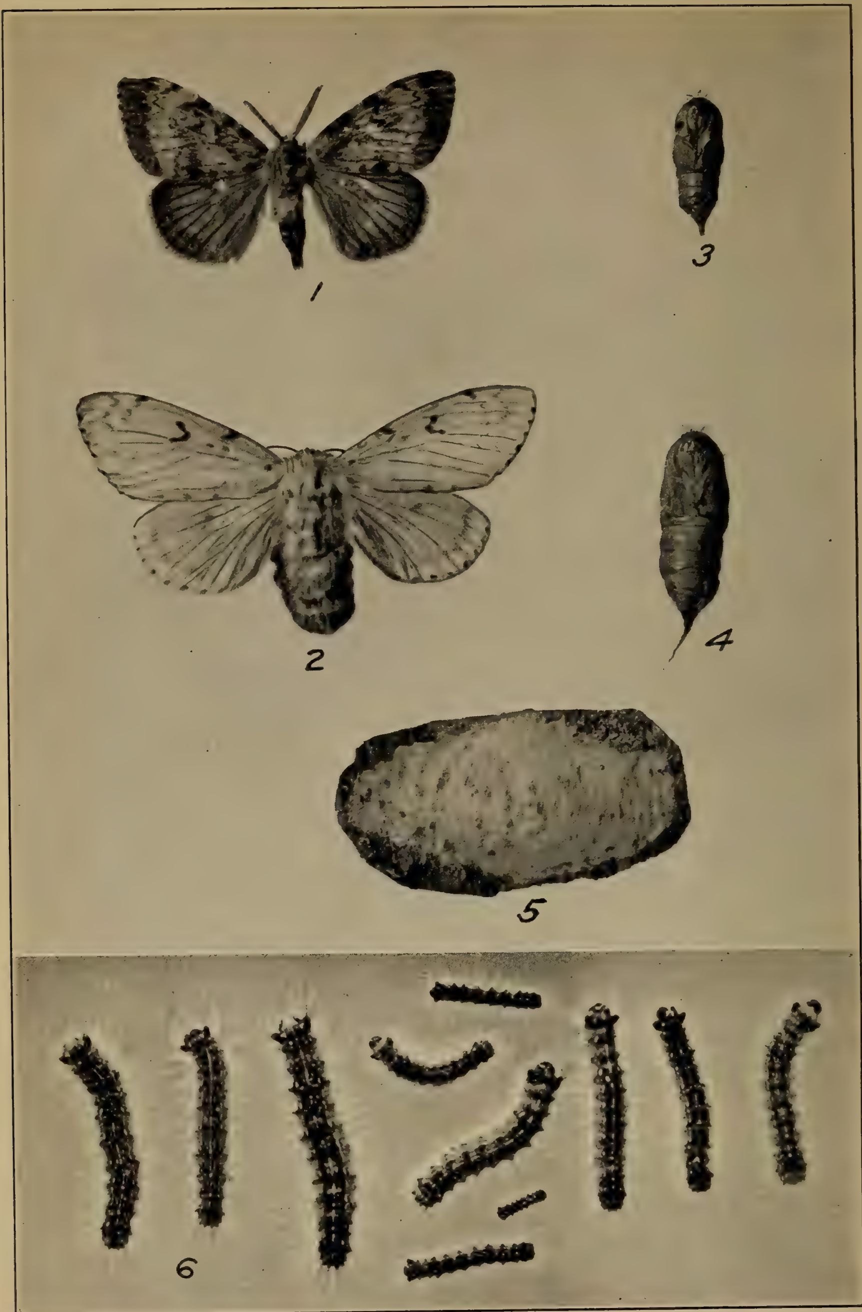
D. M. ROGERS,
Special Field Agent,

AND

A. F. BURGESS,
Expert in Charge of Breeding Experiments.

Issued August 13, 1910.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.



THE GIPSY MOTH (PORTHETRIA DISPAR).

Fig. 1.—Male moth. Fig. 2.—Female moth. Fig. 3.—Male pupa. Fig. 4.—Female pupa. Fig. 5.—Egg cluster. Fig. 6.—Caterpillars; the largest are less than half grown. (Original.)

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 87.

L. O. HOWARD, Entomologist and Chief of Bureau.

REPORT ON THE FIELD WORK AGAINST THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

BY

D. M. ROGERS,

Special Field Agent,

AND

A. F. BURGESS,

Expert in Charge of Breeding Experiments.

Issued August 13, 1910.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1910.

BUREAU OF ENTOMOLOGY.

L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Preventing Spread of Moths.

PARASITE LABORATORY.

W. F. Fiske, *in charge;* A. F. Burgess, H. S. Smith, W. R. Thompson, C. W. Collins, P. H. Timberlake, R. Wooldridge, *assistants.*

FIELD WORK.

D. M. Rogers, *in charge;* H. B. Dalton, Thomas W. Bowmar, H. W. Vinton, D. G. Murphy, I. L. Bailey, H. L. McIntyre, *assistants.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., April 5, 1910.

Sir: The only accounts so far published by the Department of the large-scale work which is being carried on under congressional appropriations in the effort to limit the farther spread of the gipsy moth and the brown-tail moth in New England have been brief statements in the annual reports of the Chief of the Bureau of Entomology. The work has now reached such a stage that a comprehensive account of the work accomplished, the methods of work, and present conditions, is demanded. I therefore have the honor to submit for publication the accompanying manuscript, which includes a report on the field work for preventing the spread of the gipsy moth and the brown-tail moth, and which has been prepared by Messrs. D. M. Rogers and A. F. Burgess, of this Bureau. This report does not include a consideration of the efforts made to import and acclimatize the European and Japanese parasites of the gipsy moth and the brown-tail moth. That matter will be described in another bulletin. I recommend that the accompanying manuscript be published as Bulletin No. 87 of this Bureau.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

	Page.
Introduction	9
Importance of the gipsy moth as an insect pest in this country	9
State work against the gipsy moth in Massachusetts, 1890–1900	11
Record of the gipsy moth in its native home	11
Life history of the gipsy moth	12
The eggs	12
The larvæ	13
The pupæ	15
The adults	16
Methods employed in work against the gipsy moth	16
Scouting	16
Spraying	17
Burlapping	17
Sticky bands	18
Cutting and burning	18
Pruning	19
Treating egg clusters	19
Discovery of the brown-tail moth in America	20
European history of the brown-tail moth	21
Life history of the brown-tail moth	21
The eggs	21
The larvæ	21
The pupæ	22
The adults	23
Poisoning effect of brown-tail hairs	24
Natural enemies of the gipsy and brown-tail moths native to America	26
Progress of the state work in Massachusetts, 1890–1900	27
Discontinuance of the state work in Massachusetts	28
Conditions in the infested territory at the close of the state work	29
Funds expended by the State during the progress of the work	29
Results of discontinuance of the work	30
State work resumed in Massachusetts	31
Beginning of work by the National Government	37
Work by the State of Massachusetts	47
Work in the State of Maine	50
Work in the State of New Hampshire	53
Work in the State of Rhode Island	54
Work in the State of Connecticut	56
Inspection of lumber and forest products	57
Danger of introducing the gipsy moth and brown-tail moth from foreign countries	60
Experimental work in the control of the gipsy and brown-tail moths	62

	Page.
Methods now used in fighting the gipsy moth	63
Cost of methods employed	69
Value of natural enemies in controlling gipsy and brown-tail moths	70
The introduction of parasites and natural enemies of the gipsy and brown-tail moths	71
Value of the work of suppression to the farmer and fruit grower	72
Suggestions to the owners of private property in the infested districts	72
The outlook	74
The more important American publications on the gipsy and brown-tail moths.	77
Index	79

ILLUSTRATIONS.

PLATES.

Page.

PLATE. I. The gipsy moth (*Porthetria dispar*). Fig. 1.—Male moth. Fig. 2.—Female moth. Fig. 3.—Male pupa. Fig. 4.—Female pupa. Fig. 5.—Egg cluster. Fig. 6.—Caterpillars .... Frontispiece.

II. Woodland area in Massachusetts defoliated by the gipsy moth 9

III. Fig. 1.—Egg clusters of the gipsy moth on trunk of apple tree, Wallingford, Conn., December, 1909. Fig. 2.—Egg clusters of the gipsy moth on stone wall 12

IV. The brown-tail moth (*Euproctis chrysorrhœa*). Fig. 1.—Cocoon. Fig. 2.—Male moth. Fig. 3.—Female moth. Fig. 4.—Egg cluster on leaf. Fig. 5.—Caterpillars feeding on leaf 22

V. Woodland at Lexington, Mass., completely defoliated by the gipsy moth 38

VI. Same woodland at Lexington, Mass., as that shown in Plate V, the following year, illustrating beneficial effects of control work ... 38

VII. View of woodland near roadway at Weston, Mass., showing effect of control measures against the gipsy moth 44

VIII. Lumber piles at York, Me., infested with egg clusters of the gipsy moth 60

IX. Fig. 1.—Pine grove killed by the gipsy moth. Fig. 2.—Pine trees that have been protected from the attacks of the gipsy moth 62

X. One of the ten high-power spraying outfits used in the gipsy moth work of the Bureau of Entomology 66

XI. High-power spraying outfit in use in treating roadside trees 66

XII. View showing contrast between trees protected from the gipsy and brown-tail moths and those unprotected 72

XIII. Map showing dispersion and present distribution of the gipsy moth in New England, and limits of area infested by the brown-tail moth, in 1909 74

TEXT FIGURES.

FIG. 1. Roadside view in Massachusetts, showing oak and ash trees, the former killed by the gipsy moth (*Porthetria dispar*) and the latter practically uninjured 14

2. Pine trees killed by the gipsy moth 15

3. Trunk of pine tree, showing tanglefoot band and egg clusters that have been treated with creosote 19

4. Winter webs of the brown-tail moth (*Euproctis chrysorrhœa*) 22

5. Oak tree in winter, showing webs of the brown-tail moth at tips of the branches 23

6. Brown-tail moths on electric light pole, Somerville, Mass., July 2, 1908. 24

Page.
FIG. 7. Hairs of the caterpillar of the brown-tail moth, highly magnified...... 25
8. Equipment for roadside work against the gipsy moth, used by employees of the Bureau of Entomology.................................. 39
9. Roadside where thinning operations are being carried on, showing tools and equipment used in the work.............................. 40
10. Employees of the Bureau of Entomology treating egg clusters of the gipsy moth with creosote, using an ordinary paint brush and a brush attached to a long pole...................................... 41
11. Roadside which has been cleared of brush and the trees banded with burlap and tanglefoot... 42
12. Gipsy-moth scout's outfit, consisting of climbing irons, mirror, cleaning knife, can of creosote, and brush............................. 43
13. Roadsides badly infested by the gipsy moth......................... 44
14. Same road shown in figure 13, after the completion of thinning operations against the gipsy moth...................................... 45
15. Map showing roads in Massachusetts where the brush has been cut, the trees thinned, and those remaining treated by employees of the Bureau of Entomology to prevent the spread of gipsy-moth larvæ on vehicles.. 46
16. Pile of 120,000 webs of the brown-tail moth, gathered and destroyed at York, Me.. 51
17. Roadside area, showing how the grass has been induced to grow by thinning out the trees and clearing away the underbrush in gipsy-moth control work.. 64
18. Spraying a roadside, using a combination tower and hand nozzle, so as to throw two streams... 68
19. Map of New England, showing the present area infested with the gipsy moth and the brown-tail moth..................................... 73
20. Neglected apple orchard in which the trees have been killed by the gipsy moth.. 74
21. View of a hill where all the timber was cut to prevent its destruction by the gipsy moth; pile of logs in the foreground..................... 75
22. Map of New England, showing areas infested by the brown-tail moth from 1897 to 1909.. 76

WOODLAND AREA IN MASSACHUSETTS DEFOLIATED BY THE GIPSY MOTH. (ORIGINAL.)

REPORT ON THE FIELD WORK AGAINST THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

INTRODUCTION.

For nearly two decades eastern Massachusetts has suffered enormous loss to its forest, orchard, and shade trees, as well as to ornamental plantings which beautify many of the large country estates, by reason of the depredations of the gipsy moth (*Porthetria dispar* L.) (see Pl. II), and for the latter half of this period by the combined injury caused by this insect and the brown-tail moth (*Euproctis chrysorrhœa* L.). Both of these insects were introduced from Europe. During the past few years the situation became so serious, owing to the spread of these insects into Maine, New Hampshire, Rhode Island, and Connecticut, that appropriations from the National Government were urged by the States affected, and, owing to the great danger that these pests would become disseminated over the entire country, funds have been appropriated by Congress to assist in securing their control and of preventing further spread. The purpose of this report is to sketch briefly the life histories of the insects concerned, their habits since their introduction into this country, a statement of the injury caused by them here and in their native homes, and to discuss the methods used for their control, in order that this work may become better understood and the danger of the presence of the pests more thoroughly appreciated in sections which are not now infested. Free use has been made of the reports already published by the State of Massachusetts and other New England States, where warfare against these insects has been carried on in the past.

Acknowledgment and thanks are due to Dr. W. E. Britton, state entomologist of Connecticut, for the use of Plate III, figure 1, and to Prof. E. F. Hitchings, state entomologist of Maine, for the use of Plate VIII and text figure 16.

IMPORTANCE OF THE GIPSY MOTH AS AN INSECT PEST IN THIS COUNTRY.

During the summer of 1889 great injury was caused to the foliage of the street trees and of those on private estates in Medford, Mass., a city about 5 miles north of Boston, by caterpillars which appeared in enormous swarms. In many cases the trees were completely defoliated, and the insects crawled into the houses and upon the fences and walks, so as to become a public nuisance in the neighborhood. Specimens were sent to the office of the Massachusetts state board of agriculture at Boston, and were transmitted to Prof. C. H. Fernald, at Amherst, and, in his absence, were determined by Mrs. Fernald as the gipsy moth of Europe. An investigation in the neighborhood showed that this insect had been quite abundant and had caused considerable damage for a number of years, but, owing to the belief of most of the residents that it was one of the common native caterpillars, no action had been taken in the matter. As a result of persistent inquiry among the inhabitants of the infested section it was determined that some of these insects were introduced from Europe, probably in the egg stage, by Prof. Leopold Trouvelot, a French naturalist, about the year 1869. At that time this gentleman was conducting experiments with silkworms, and also with some of the American species of silk-spinning caterpillars. The evidence seems to show that some of the egg clusters, or young caterpillars, which he secured from Europe, escaped from his house where the experiments were being conducted, and, as he was aware of the dangerous nature of the insect in its native home, he destroyed all the caterpillars that could be found in the neighborhood and made public the fact that it had escaped. At that time the section in which he resided adjoined a large area of waste land, which was overgrown with sprouts and brush, and here the species became established. Its slow development as a serious pest was undoubtedly due to the fact that this area was burned over periodically by brush fires which destroyed large numbers of the insects, and also to the prevalence at that time of many insectivorous birds, which doubtless accomplished much in preventing the rapid increase of the species.

So thoroughly were the trees defoliated by the caterpillars that in many cases during the summer of 1889 and 1890 swarms of them practically covered the sides of many houses. Real estate in the neighborhood rapidly depreciated in value and many tenants moved to more congenial quarters of the city. The recorded statements of eye-witnesses of the conditions that prevailed seem almost incredible to one who has had no opportunity to observe the serious damage which this insect causes. Many trees and orchards died as the result of repeated defoliation, and during the winter of 1890, on petition of the city of Medford and the surrounding cities and towns, the matter was brought to the attention of the legislature, and the sum of $25,000 appropriated for abating the nuisance.

STATE WORK AGAINST THE GIPSY MOTH IN MASSACHUSETTS, 1890-1900.

The work against the gipsy moth was placed in charge of a paid commission of three men, appointed by the governor. At the time the work was begun it was thought that only a small area was infested, but on May 9, 1890, the commission reported to the governor that the infested area was "some sixteen times as large as at first represented," and requested an additional appropriation of $25,000, which was granted.

Early in 1891 the commission was abolished by the governor and an unsalaried one appointed which carried on the work for a few months, until a law was enacted by the legislature giving the state board of agriculture authority to use "all reasonable measures to prevent the spreading and to secure the extermination of the *Ocneria dispar* or gypsy moth in this Commonwealth."

The board placed the work under the immediate direction of a committee, later known as the "Committee on gypsy moth, insects, and birds," which was made up of five of its members, who served without pay. Mr. E. H. Forbush, of Worcester, Mass., was appointed director of the field work, and Prof. C. H. Fernald, entomologist to the Massachusetts agricultural experiment station at Amherst, was given supervision of the experimental and scientific work, and energetic measures were at once begun to exterminate the pest, and were continued until February 1, 1900.

RECORD OF THE GIPSY MOTH IN ITS NATIVE HOME.

A perusal of the European literature concerning this insect, which was thoroughly examined and the results presented in the report on the gipsy moth by Forbush and Fernald, published by the Massachusetts board of agriculture in 1896, indicates that it was a pest in nearly all European countries at the time the first entomological writings were published, and there is good reason to suppose that even before that time much serious devastation to trees and forests resulted from it, although it was probably referred to as "the plague," and was believed by the inhabitants to be a scourge sent by the Almighty as a penalty for their wrongdoings. Many cases are on record where this insect became abundant and defoliated thousands of acres of forests, as well as the fruit and shade trees and shrubs in the populated regions. The literature indicates that this moth is abundant periodically and causes enormous loss throughout continental Europe, western Asia, and Northern Africa. It has been found as far north as Stockholm and is known to occur in Algeria. Slight, though not serious, infestations have been reported in England, and this or a closely allied species occurs in Japan, and is said to be present in sections of China. During the year 1909, Prof.

Trevor Kincaid, who was engaged by the Bureau of Entomology, in cooperation with the State of Massachusetts, for the purpose of collecting parasites of this insect in Russia, found during his explorations that thousands of acres of forests were completely denuded, and in other localities trees were dying over large areas as a result of previous defoliations. Dr. L. O. Howard, Chief of the Bureau of Entomology, while visiting, in 1909, the corps of European agents engaged in collecting parasites of the gipsy moth in Europe, found a large forest area near Nantes, France, which was completely stripped by this pest. In fact, the whole European history of this moth is a continuous record of periodical outbreaks of greater or less severity, which have caused enormous damage to trees from the time of the earliest writings on entomology down to the present time. The situation in Japan is not as serious as in Europe, owing to the efficient work of certain parasites which tend to keep the insect under control.

LIFE HISTORY OF THE GIPSY MOTH.

THE EGGS.

(Pl. I, fig. 5.)

The female gipsy moth deposits her eggs in clusters containing normally from 400 to 500 eggs, which are covered with hair from her body; this protects them from the action of the elements and renders their destruction, even by fire, quite difficult. The clusters are fully 1 inch in length and about half as wide, and have the general appearance and color of a small piece of sponge. The number of eggs varies considerably and depends largely on the food supply and the vigor of the caterpillar from which the female develops. In colonies where the food supply has been practically exhausted by the larvæ, egg clusters are often found containing not more than 50 or 75 eggs, while, on the other hand, a number of cases are on record where single clusters contained over 1,000 eggs. The majority of the eggs are deposited about the middle of July, although there is considerable seasonal and individual variation. Females have been found depositing egg clusters as early as June 25 and as late as October 7. Crevices in the bark, holes in trees, stone walls (Pl. III, fig. 2), or rubbish piles are favorite places for the deposition of eggs, as they afford shelter for the full-grown caterpillar about to pupate and protect the pupa and the newly emerged moth. Many clusters are deposited under steps or porches of houses, in outbuildings near infested trees, as well as on the trunks (Pl. III, fig. 1) and on the under side of the branches of the trees themselves. Hatching takes place early in the spring, about the time the trees are coming into leaf. A few cases are on record where the caterpillars hatched in the fall, but this is unusual.

FIG. 1.—EGG CLUSTERS OF THE GIPSY MOTH ON TRUNK OF APPLE TREE, WALLINGFORD, CONN., DECEMBER, 1909. (FROM BRITTON.)

FIG. 2.—EGG CLUSTERS OF THE GIPSY MOTH ON STONE WALL. (ORIGINAL.)

[This wall has been overturned to expose the egg clusters.]

THE LARVÆ.

(Pl. I, fig. 6.)

The newly hatched caterpillars feed upon the small leaves, making "pin holes" in them. As a rule the caterpillars molt five times, but quite a number of cases are on record where an additional molt took place before they entered the pupal stage. The newly hatched caterpillars are about one-eighth of an inch in length and covered with long, slender hairs. During warm weather they feed upon the leaves, but when the temperature is low, or during rainy or unsettled weather, such as is common in early spring, they congregate in masses in the crevices of the bark or on the egg clusters from which they hatched. As the weather becomes warmer in the early summer, they grow rapidly and devour the entire leaves except the woody veins. Until they are about half grown, the caterpillars are able to suspend themselves from the twigs or branches of the trees by means of silken threads spun from their bodies, and in this way they often drop upon animals, carriages, or other moving objects, and may be conveyed to localities where none of the species exists. After the caterpillars have molted the fourth time, which usually occurs about the middle of June, a considerable change in coloration appears. On the dorsum of each of the first five segments behind the head is a pair of prominent blue tubercles, while on the following six segments the tubercles are of a dark-red color. The arrangement and coloration of these tubercles is characteristic of the species. The feeding habits change somewhat with the progress in growth of the caterpillars, for after becoming half grown the caterpillars seem to prefer shelter from the sun and feed for the most part at night or during cloudy weather. During the warm part of the day they remain concealed in crevices in the bark, crawl to the ground, or seek any convenient shelter from the sun. This habit serves as a protection against their natural enemies, and although in moderately infested sections it is usually possible to find caterpillars feeding at midday during sunny weather, still the majority are either in hiding or are feeding in such situations as to be largely protected from direct sunlight. The period spent in the caterpillar stage extends, on the average, from early in May to July 5, or is approximately seven weeks. Egg clusters deposited in cool situations do not hatch as readily as those more favorably located; hence the entire length of the feeding period varies considerably. Larvæ have been found as early as the 1st of April and as late as September 6. In certain areas along the seacoast and on islands which are surrounded by tidewater, the hatching of the eggs is retarded, and pupation takes place much later than where conditions are normal. The full-grown caterpillars measure about 2 inches in length, although there is considerable variation in this respect, due largely to the amount of food available. It is a noticeable fact that in bad colonies, where most of the foliage has been eaten, the caterpillars pupate early in the season before attaining normal size.

This insect has a varied list of food plants; in fact, it will eat almost any kind of vegetation, although it seems to prefer the foliage of oaks (fig. 1), willows, and apple trees. Repeated observations have shown that the ash (fig. 1), juniper, and red cedar are practically immune from attack, while the maple is not injured to any great extent if more desirable food is within easy reach. Grass and garden crops are sometimes seriously injured when the supply of other food has been exhausted.

A few years ago a farmer in Lynn, Mass., stated that with the assistance of his men he collected several bushels of the caterpillars that were

FIG. 1.—Roadside view in Massachusetts, showing oak and ash trees, the former killed by the gipsy moth (*Porthetria dispar*) and the latter practically uninjured. (Original.)

feeding in his field of sweet corn. The caterpillars had stripped the trees in a piece of woodland near by, and, after eating all the foliage from the bushes and low growth, had migrated in countless numbers across the road and attacked the growing corn.

Most of our native leaf-eating insects confine their diet to a small number of food plants, and it is unusual for a species to feed on both deciduous and coniferous trees. The gipsy-moth larvæ, after becoming half grown, feed with avidity on conifers, especially the white pine, and many acres of this, as well as other coniferous trees, have been defoliated and killed in the infested region of New England (fig. 2).

The white pine, as well as the spruce and the hemlock, is unable to survive after one complete defoliation, and when only partially denuded the trees are usually attacked by bark borers and other insects so that death soon follows. The proper treatment of conifers to prevent injury by the gipsy moth will be described farther on in this report.

THE PUPÆ.

(Pl. I, figs. 3, 4.)

After the caterpillars have finished feeding they usually select more or less protected places in which to pupate. Stone walls, rubbish piles, and open spaces beneath porches or outbuildings furnish excellent places for caterpillars to enter the pupal stage. Of course, a large number remain on the trees, where they usually pupate on the under side of the branches, beneath loose bark, or in holes and cavities, or

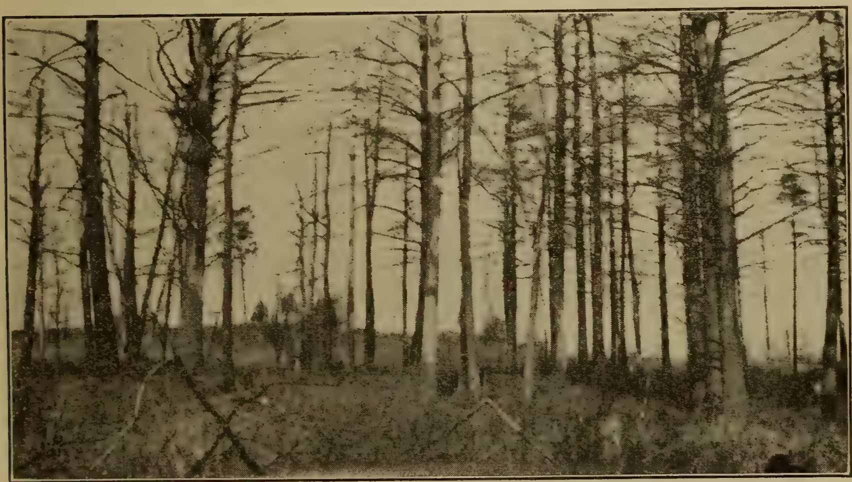


FIG. 2.—Pine trees killed by the gipsy moth. (Original).

descend to the base of the trees before transforming. Previous to pupation the caterpillar spins a few threads of silk in order to attach itself firmly. The body then shortens considerably and pupation is accomplished by the integument of the segments behind the head splitting dorsally and the whole larval skin is forced back to the end of the body, the pupa remaining beneath the network of silk which held the caterpillar in place. The pupa is dark reddish-brown, and the body segments bear yellow hairs, which are arranged in groups. From 7 to 17 days are spent in this stage before the moth emerges. As a rule female pupæ are much larger than those of males, but the sex can always be determined by the struetuve of the last segment of the abdomen.

THE ADULTS.

(Pl. I, figs. 1, 2.)

The male moths ordinarily emerge from the pupæ earlier than do the females. The body of the male is light brown and the wings are considerably darker and have prominent black markings. Male moths are able to fly considerable distances and are especially active during warm sunny weather. The zigzag motion of the flight of these moths is characteristic of the species. The body of the female is light buff. The abdomen, which is very large and almost completely filled with eggs, is densely covered with short yellow hairs which are used by the moth to protect the eggs as they are deposited in the cluster. The wings are white, with prominent black markings, and, although they are apparently of ample size, the female moth is not able to fly on account of the weight of the body. The adult insects take no food, and after mating, which takes place soon after emergence from the pupa, the female begins depositing eggs. As a rule the egg cluster will be found near the pupal case from which the female emerged, but occasionally the moth will crawl a considerable distance, especially if disturbed. When a search for egg clusters is being made the discovery of a female pupal case is indication that an egg cluster is present near by. Sometimes moths which emerge from pupæ that are attached to the branches of trees fall to the ground and deposit their eggs on the trunks of surrounding trees or on leaves or rubbish. By the time the egg cluster is completed, the abdomen has shrunken greatly and in a few hours the moth dies.

METHODS EMPLOYED IN WORK AGAINST THE GIPSY MOTH.

SCOUTING.

As the law enacted by the Massachusetts legislature in 1891 required the state board of agriculture "to prevent the spread and secure the extermination" of this insect, a determined effort was made to ascertain the extent of the area infested. Men were trained so that they were able to recognize the moth in all its stages, and as soon as they had secured sufficient experience the most expert ones were sent into the territory not known to be infested to make a thorough inspection. As a result of this work, it was found that, while the area supposed to be infested in 1890 covered 9 cities and towns in whole or in part and embraced about 50 square miles, the pest had become established in more or less numbers in 30 cities and towns, covering an area of 200 square miles. This spread had undoubtedly been going on for a number of years, and as the thickly settled sections became badly infested the small caterpillars were easily conveyed long distances owing to their habit of spinning down from trees onto vehicles or other moving bodies. Many colonies were discovered on the premises of milkmen and market gardeners who made regular trips to the infested section to distribute their products.

SPRAYING.

It was at first believed that this insect could be successfully controlled, like most other leaf-eating species, by spraying the trees with Paris green, a remedy which was then in common use. Experiments, however, showed that it was impossible to kill the caterpillars with this spray after they became half grown, unless it was used so strong that it resulted in severe injury to the foliage of the trees. Mr. F. C. Moulton, who conducted an extensive investigation with insecticides in the years 1891 and 1892, was able to prepare a new insecticide, arsenate of lead, which could be used in sufficient strength to kill the caterpillars without injuring the foliage. This work was later taken up by Messrs. A. H. Kirkland, F. J. Smith, and A. F. Burgess, under the direction of Prof. C. H. Fernald. A large number of experiments were made, using different formulas, which demonstrated the practical effectiveness of this poison and the proper method of its preparation. The poison as used at that time was made by dissolving the proper amounts of arsenate of soda and acetate of lead salts in separate vessels containing water. These solutions were then brought together and a precipitate, consisting of arsenate of lead, was formed. Usually the fresh precipitate was prepared in the field. In recent years, since this poison has come into general use throughout the country for treating trees infested with leaf-eating insects, it is made by manufacturers in a similar way, and is put on the market in the form of a paste which mixes readily with water, thus preventing the delay occasioned by mixing the raw chemicals and obviating the danger of securing impure materials, which might cause injury to the foliage or crop treated.

Some improvements were made in spraying machinery, which was very crude when we consider the equipment used at the present time. Spraying with the facilities then at hand was a very expensive operation, and in many cases gave unsatisfactory results, especially when large trees were treated. Owing to these facts, and because every effort was being made to secure the extermination of the insect, spraying was undertaken only in a limited way.

BURLAPPING.

The secretive habits of the caterpillars suggested the provision of artificial hiding places, and for this purpose burlap bands were placed about the trunks of the trees. Bolts of burlap were cut into strips about 8 inches wide, which were rolled for the convenience of the workmen. A band was placed around each tree about as high as a man's shoulder and fastened in the center with twine, the upper part being folded down, forming an excellent shelter for the caterpillars. By examining the burlaps frequently and crushing the larvæ underneath great progress was made in destroying the pest. The free edges of the burlap should be kept loose from the trees so that the larvæ can easily crawl under the folds. This method can not be used advantageously until the caterpillars are about half grown, as they do not often seek shelter until that time. The expense entailed is considerable, but it is one of the most effective measures where extermination of the insect is desired.

STICKY BANDS.

Numerous attempts were made to use a sticky material. such as printer's ink, tar, or other substances, applying them to bands of tarred paper on the trunks of trees to prevent the caterpillars from ascending. Several tons of a German product, known as "raupenleim," were tried but none of these preparations proved satisfactory for wholesale use. Success in using such bands was not attained until the material known as tanglefoot came into use, about five years ago.

CUTTING AND BURNING.

In order to prepare infested territory so that it could be treated effectively and economically, it was necessary to cut out and burn the brush and sprout growth, as well as trees that were hollow and partially decayed. This method reduced to a minimum the number of trees to be burlapped or otherwise treated, and by removing the low growth the larvæ were forced to feed on the trees where they could be more easily destroyed.

A method employed against the young caterpillars hatched from egg clusters located in stone walls or rocky areas was to clean out all brush and undergrowth during the winter. As soon as the larvæ appeared in the spring the ground and walls were burned over by using a device known as a cyclone burner. This consisted of a 15-gallon oil tank, on which was mounted a small force pump. The oil was conducted through a hose to an iron extension rod, at the end of which a nozzle of the Vermorel type was fitted. The fine mist of oil forced from the nozzle was ignited and the ground and walls burned over. To secure best results a large ball of flame should be maintained which can be forced into the cracks or cavities in walls or ledges in order to destroy the larvæ. Paraffin gas oil or a light grade of crude petroleum can be used. Two men are required to operate this outfit satisfactorily. The action of the oil soon destroys the hose, so that it seldom lasts more than one season.

PRUNING.

As the female moths deposit their egg clusters under loose bark and in holes and cavities in the trees, and also because the larvæ seek such hiding places, it became necessary to rid the trees of these natural shelters. To accomplish this purpose a considerable amount of pruning and filling of cavities was required. This work had to be skillfully done, especially when fruit or shade trees in cities or towns were treated. Many ingenious methods were devised for carrying on these operations, some of which have been adopted by professional foresters and others who have taken up the business of caring for trees.

TREATING EGG CLUSTERS.

The insect exists in the egg stage nearly nine months in the year and many experiments were tried to determine the most effective method of treating egg clusters. The first method used was that followed in Europe and consisted simply in scraping off the egg masses and burning them. In removing the eggs many were scattered, even if the work was carefully done, and as such eggs hatched in due time it became necessary to secure a better method of treatment. It was found that they could be killed by saturating the clusters with crude coal-tar creosote to which was added a small amount of either coal tar or lampblack to discolor them and enable the workmen to tell instantly the ones that had been treated. (See fig. 3.)

FIG. 3.—Trunk of pine tree, showing tanglefoot band and egg clusters that have been treated with creosote. (Original.)

It was necessary to make a very thorough search of all objects likely to harbor egg clusters if satisfactory results were expected, and this required much climbing of high trees as well as careful ground work. The pupæ and moths were crushed or treated with creosote when found by the workmen.

It was necessary to apply a combination of methods to secure satisfactory results and many localities had to receive special treatment on account of their location and condition of infestation. Methods which could be readily applied in wooded areas were entirely unsuited for use in residential sections.

DISCOVERY OF THE BROWN-TAIL MOTH IN AMERICA.

The work on the gipsy moth resulted in a great reduction of the numbers of the insect and a steady improvement in the condition of the infested territory, in spite of the fact that the legislature seldom granted the appropriations which were deemed absolutely necessary by the board of agriculture, and the availability of the funds was often delayed so that many of the trained men were thrown out of employment for a part of the year, which of course greatly affected the efficiency of the force. To add to the difficulties of the situation complaints were received during the summer of 1897 that trees and shrubs in Somerville, Mass., were being severely injured by an insect which appeared to be new to the region.

An investigation showed that the trouble was caused by the brown-tail moth (*Euproctis chrysorrhœa* L.), an insect well known and at times as noxious in Europe as the gipsy moth.

Careful inquiry indicated that this species was probably imported from Europe a few years before on rose or nursery stock by a local florist. The attention of the governor was called to the matter by the state board of agriculture, and, realizing the seriousness of the pest and the desirability of stamping it out at once, he sent a special message to the legislature, which was then in session, suggesting that action be taken without delay.

A law was passed requiring property owners to destroy the insects on their premises, and the opportunity for stamping out the pest before it could become generally disseminated was lost. As is always the case, some of the citizens and municipalities made every effort to destroy the pest, but through the neglect and indifference of others little permanent good was accomplished.

The following year $10,000 was diverted from the gipsy moth appropriation to "prevent the spread of the brown-tail moth," but the money did not become available for use until after the caterpillars had left their winter webs and begun feeding. Thus the insect was allowed to spread for two seasons after it was discovered, because the work was not taken up promptly under proper supervision. When work was begun it was found that the insect had spread over a large territory and it seemed almost impossible to stamp it out. A detailed account of this insect was prepared by Fernald and Kirkland in 1903 and published by the Massachusetts board of agriculture.

EUROPEAN HISTORY OF THE BROWN-TAIL MOTH.

The brown-tail moth is one of the oldest known pests in Europe and is called in many of the earlier writings "la commune," or the communistic one. It is said to be distributed over central and southern Europe and to extend to Algiers on the south and the Himalayas on the east. It has been found in limited numbers in England and may be present in Japan, although the record from the latter country is somewhat doubtful. Few, if any, species have caused more havoc to foliage than has this one, and many accounts of its destructive work have been recorded. Deciduous forest and fruit trees are often denuded, and even garden crops sometimes suffer from the enormous numbers of the caterpillars. Similar conditions now prevail in some sections of Europe, for during the spring of 1909 thousands of seedling trees, badly infested with the webs of this insect, were shipped to this country from nurseries in France.

Mr. H. L. Frost, of Arlington, Mass., informed the writers that while in Germany during the summer of 1909 he found that the Thiergarten in Berlin, a large park, had been closed to the public owing to the large numbers of larvæ of the insect which were defoliating the trees. The action of the officials in closing this park was in part due to the serious poisoning of people as a result of coming in contact with caterpillars while visiting the grounds.

Dr. L. O. Howard, Chief of the Bureau of Entomology of this Department, states that he observed this insect present in injurious numbers in certain sections of Europe, particularly in France, during the summer of 1909.

LIFE HISTORY OF THE BROWN-TAIL MOTH.

THE EGGS.

(Pl. IV, fig. 4.)

The female brown-tail moth deposits her eggs in a single elongated cluster on the underside of a leaf, usually near the end of a twig, covering it with brown hair from the end of her body. Each cluster is about two-thirds of an inch long and contains from 200 to 400 eggs which are nearly globular, and yellow. The eggs are deposited during the first three weeks in July, and hatching takes place in from 15 to 20 days.

THE LARVÆ.

(Pl. IV, fig. 5.)

After hatching the young larvæ begin feeding on the epidermis of the leaf on which the egg cluster was deposited and later attack others near by. They are gregarious and usually feed on the terminal leaves of the twigs, which are drawn together and held in position by silk spun by the caterpillars. As the season advances more leaves are drawn into the web, and this is lined with silk and serves during the winter as a hibernaculum for the larvæ. The caterpillars do not remain in a single large cell. The web is divided by cross partitions into small pockets in each of which one or more of the larvæ remain during the winter. The webs (fig. 4) are very conspicuous on the trees during the winter, as they are usually located at the tips of the branches. (See fig. 5.) During the first warm days of spring the caterpillars come forth from the webs and begin feeding on the bursting buds. In cases where the trees are badly infested the tiny leaves are devoured as fast as they develop. The caterpillars feed until about the 20th of June before becoming full grown. They molt four or five times in the spring, and when ready

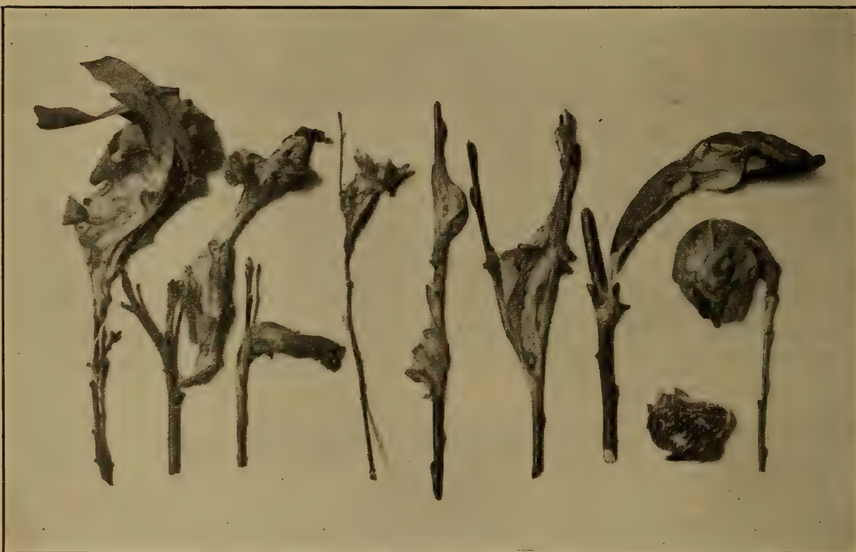


FIG. 4.—Winter webs of the brown-tail moth (*Euproctis chrysorrhœa*). (Original.)

to spin their cocoons are about an inch and a half in length. The body is nearly black and covered with rows of yellow spines and barbed hairs which arise in tufts on the back and sides. There is also a row of nearly white tufts on the full-grown larvæ, which arise along each side of the dorsal abdominal segments. The next to the last two segments each bear a small coral-red tubercle on the dorsal part. As soon as the caterpillars are full-fed they seek shelter and spin up loose cocoons, within which they pupate.

THE PUPÆ.

The cocoons (Pl. IV, fig. 1) may often be found in leaves which have been webbed together by the larvæ, in crevices in the bark,

THE BROWN-TAIL MOTH (EUPROCTIS CHRYSORRHŒA).

Fig. 1.—Cocoon. Fig. 2.—Male moth. Fig. 3.—Female moth. Fig. 4.—Egg cluster on leaf. Fig. 5.—Caterpillars on leaf. (Original.)

under burlaps, beneath the clapboards or under the eaves of houses, or in any situation which affords reasonable shelter. As a rule the cocoons will be found in masses, and, as the silk with which they are constructed is interwoven with hairs from the bodies of the caterpillars, severe poisoning may result in removing them from their resting places. The pupal stage lasts about 20 days, most of the moths emerging during the first 10 days in July. Weather conditions during the spring serve to accelerate or retard the growth of the caterpillars, so that the time of pupation and emergence of the moths varies considerably.

THE ADULTS.

(Pl. IV, figs. 2, 3.)

Both males and females are white and bear a tuft of yellowish-brown hairs at the end of the abdomen, from which the name "brown-tail moth" is derived. Although the abdomen of the female is much larger than that of the male, the female of the brown-tail moth, unlike that of the gipsy moth, is capable of strong flight, and the spread of the species is therefore not handicapped as in the case of the latter species. Both sexes fly more frequently at night than in the daytime, although most of the eggs are deposited during the day. The moths are attracted to strong light, especially electric arc lights in cities and towns, and during the nights when the moths are most abundant the areas around these lights sometimes have the general appearance of a heavy snowfall, due to the great number of flying insects. Stores and houses in the neighborhood are often invaded by the moths, and several cases are on record where merchants have been obliged to close their stores during the height of a moth flight in order to prevent annoyance and trouble caused by the enormous num-

FIG. 5.—Oak tree in winter, showing webs of the brown-tail moth at tips of branches. (Original.)

bers of these insects. The morning following a flight, the houses, telephone poles, and trees in the immediate vicinity of the arc lights are usually well covered with small white moths (see fig. 6); and it is no uncommon thing for lamp trimmers to collect one or two quarts of dead moths inside the globe surrounding a light. The hairs from the abdomens of the moths are poisonous, as well as those from the caterpillars, and a great many persons have been caused severe inconvenience by coming in contact with the adult insects.

FIG. 6.—Brown-tail moths on electric light pole, Somerville, Mass., July 2, 1908. (From Kirkland.)

The moths' habit of flying to lights serves to increase their distribution, especially in the more thickly populated regions.

Large numbers of the insects are killed, however, by coming in contact with the light and many of the survivors are destroyed by birds the morning following the flight. The English sparrow has been observed by Mr. Kirkland to kill large numbers of the moths which remained about the lamps by pulling off the wings and devouring the bodies.

POISONING EFFECT OF BROWN-TAIL HAIRS.

From the time this insect was first found in Somerville numerous reports were received that the caterpillars were poisonous to human beings. Many people were severely affected with what was termed "the brown-tail rash," and much complaint arose on that account.

The best explanation of the trouble was that the barbed hairs of the caterpillars (fig. 7), when they came in contact with human skin, caused severe irritation. The scratching to relieve this itching forced the hairs farther into the tissue, which resulted in a slight swelling and an intense burning and stinging sensation.

When the housewife swept the caterpillars from the porch or brushed down the cocoons, which are interlaced with larval hairs, many were broken, and as a result severe cases of brown-tail rash followed.

The moths are provided with these barbed hairs, but to a less extent than the larvæ, and cases of poisoning have been reported during the flight of moths in the summer.

Broken hairs which float in the air when the caterpillars, webs, or cocoons are disturbed also cause severe internal irritation and poisoning if the dust is inhaled or swallowed in any considerable quan-

FIG. 7.—Hairs of the caterpillar of the brown-tail moth, highly magnified. (Adapted from Kirkland.)

tities. The poisoning has caused very serious illness to men engaged in the work against the moths, in the field, and at the Parasite Laboratory, and each year many are obliged to seek other employment, and not a few have been under a physician's care. The death of one man was due to severe internal poisoning contracted while employed on the work, particularly while turning burlaps.

Underclothes and bedding should not be put out upon the line during the caterpillar season, as the floating hairs may alight on such articles, which, when used, may result in serious poisoning.

During the year 1906 a careful study of this dermatitis was made by Dr. E. E. Tyzzer, of the Harvard Medical School, and a report was published by him.[a]

He concludes from his investigation that the barbed hairs not only cause a mechanical irritation but that they contain a poison which acts directly on the corpuscles of the blood. This results in a breaking down of the corpuscles to a certain extent and in their assuming a jagged outline instead of a circular one.

Such a multitude of people have suffered from this form of poisoning that many remedies have been prepared and sold which are warranted to give relief. During the summer metropolitan newspapers and many of the smaller papers in New England contain advertisements of remedies for the brown-tail rash. The trouble is more serious during hot weather, when persons are perspiring freely, and the skin at this time seems less resistant to the entrance of the spines.

Some of the advertised remedies give a certain measure of relief, but none of the remedies suggested is wholly efficacious. Applications which are cooling to the skin, such as witch-hazel or alcohol, serve to allay the irritation to some extent and reduce the suffering caused by the poison.

The internal irritation which is caused by breathing or swallowing the poisonous hairs is often very serious and no effective remedy has been found.

NATURAL ENEMIES OF THE GIPSY AND BROWN-TAIL MOTHS NATIVE TO AMERICA.

Aside from the experimental work on insecticides and a careful, detailed study of all phases of the life history and habits of the gipsy and brown-tail moths, considerable time was devoted by the Massachusetts authorities to an investigation of the native natural enemies which attack them in the field.

Both species are partially controlled in Europe by parasites and predaceous enemies, and it was desirable to ascertain if the closely related beneficial species in this country were showing any marked tendency toward controlling the pests.

Field observations on birds were made by Mr. Forbush, who was ably assisted in this work by Messrs. J. A. Farley and F. H. Mosher, the late Charles E. Bailey, and numerous other careful observers. A large number of native insectivorous birds were found feeding on

[a] In Second Annual Report of the Superintendent for Suppressing the Gypsy and the Brown-tail Moths, Boston, 1907, pp. 154–168.

the gipsy moth. Many of the observations have been published in the report by Forbush and Fernald already cited.

Unfortunately, conditions in the territory infested were not very favorable to the increase of insectivorous birds, and this, of course, served to limit their activities and usefulness. A few species, among which may be mentioned the crow, while destroying many of the larvæ, undoubtedly aided the spread of the gipsy moth by dropping live caterpillars in uninfested sections.

Field observations were made and work in rearing the insect enemies of these moths was carried on by Messrs. A. H. Kirkland, A. F. Burgess, F. H. Mosher, and others.

A few species of hymenopterous and dipterous parasites were found working in the field and small numbers of the adults were reared at the insectary. Among the predaceous enemies were several species of beetles (Carabidæ) and stink bugs (Pentatomidæ) which were found feeding on the larvæ in the field and were studied in detail in the laboratory.

Although not an insect, the common toad should be mentioned as doing valuable work in destroying such specimens of the insects as came within its reach.

The rapid development and unprecedented injury caused by the gipsy moth after the state work was abandoned show conclusively that native natural enemies are entirely unable to cope with the situation.

PROGRESS OF THE STATE WORK IN MASSACHUSETTS, 1890–1900.

The administration of any extensive public work almost invariably arouses more or less antagonism, and the gipsy moth work was no exception in this respect. In compliance with the provisions of the law which provided for the extermination of this insect, no effort was made to introduce its parasites or natural enemies from abroad, as it would have been necessary to allow extensive colonies of the insect to remain untreated in order to give introduced parasites an opportunity to become established. Some criticism was occasioned by this manner of handling the work and in addition to this many property owners in sections of the State which were not infested failed to see the necessity for making large appropriations to destroy the insect. Active opposition developed in some sections of the infested territory, which was occasioned by ignorance as to the methods of carrying on the work.

Realizing that the work was of a different character from any that had been attempted previously, and that new methods and devices must be employed to handle the problem with any degree of success, great effort was made to test in a practical way any suggestions that seemed to have a bearing on reducing the expense of making the work more effective.

From the time the first state appropriation was made until the close of the work the gipsy moth committee procured expert opinions from the leading entomologists of the country, and during this period a large number of prominent scientists visited the territory, inspected the work, and without exception reported that the extermination of the gipsy moth was not only practicable but feasible and that it could be accomplished provided proper financial support was given the work. In the winter of 1894–1895 an unsuccessful attempt was made to secure national aid in exterminating this insect. A bill, carrying an appropriation for $40,000, was passed by the United States Senate, but it was defeated in the conference committee. During the session of Congress, 1896–1897, an appropriation was made for an investigation of the ravages of the gipsy moth in this country. Dr. L. O. Howard, Chief of the Bureau of Entomology, made several visits to the infested territory and thoroughly examined the conditions and the work which was being done. Mr. C. L. Marlatt, first assistant entomologist, also made a visit to the infested district and investigated the condition of the territory. The report of Doctor Howard[a] highly commended the work which had been done and stated his opinion that the extermination of the gipsy moth could be accomplished. During the winter of 1897 the Massachusetts Society for the Promotion of Agriculture secured the services of Dr. John B. Smith, state entomologist of New Jersey, to investigate the work and report the conditions found. The report strongly favored continuing the work and expressed the opinion that the insect could be exterminated if sufficient funds were appropriated, but the society did not publish the report in full. The condition of the infested territory continued to improve. The residential sections were in excellent condition in 1899, although small numbers of the insect were present. Many woodland colonies had been entirely exterminated, as evidenced by the fact that none of the insects had been found for three successive years. The spread of the brown-tail moth, however, continued each year and little hope was entertained of being able to exterminate it.

DISCONTINUANCE OF THE STATE WORK IN MASSACHUSETTS.

At the annual session of the legislature in the winter of 1900 a special committee was appointed to investigate the gipsy-moth work. After numerous hearings it was reported that the insect need not be considered a serious pest, and further that "we find no substantial proof that garden crops or woodlands have suffered serious or lasting

[a] Bul. 11, n. s., Division of Entomology, U. S. Dept. of Agriculture.

injury or are likely, with that precaution or oversight which prudent owners are disposed to give their own interests, to be subjected to that devastation which one would have the right to anticipate from these reports. It appears to us that the fears of the farmers throughout the State have been unnecessarily and unwarrantably aroused, evidently for the purpose of securing the effect of those fears upon the matter of annual appropriations * * * We do not share these exaggerated fears and the prophesies of the devastation and ruin are unwarranted and in the most charitable view are but the fallacies of honest enthusiasts." As a result of the report of this committee no further appropriation was made for carrying on the work. The tools and equipment which had been used were ordered sold, and the insect was allowed to develop without restriction.

CONDITIONS IN THE INFESTED TERRITORY AT THE CLOSE OF THE STATE WORK.

As before stated, the area found infested in 1891 included 30 towns and cities, covering 200 square miles. Between the years 1891 and 1900 isolated colonies were discovered beyond these limits in Brookline, Burlington, Danvers, Georgetown, Manchester, Newton, and Lincoln. These infestations were given special attention and several of them were practically exterminated before the work was discontiuued. Vigorous measures were enforced over the entire infested territory and all of the worst colonies, including those in the woodlands, had been reduced to such an extent that the extermination of the insect was practically assured. Several towns had been completely cleared of the insect, and the residential sections showed no defoliation, and considerable search was necessary for a nonexpert to secure specimens of the insect.

FUNDS EXPENDED BY THE STATE DURING THE PROGRESS OF THE WORK.

During the progress of the work the following amounts were asked for and received for the suppression of the pest:

Year.	Amount asked.	Amount appropriated.
1890	$50,000	$50,000
1891	50,000	50,000
1892	75,000	75,000
1893	165,000	100,000
1894	165,000	100,000
1895	200,000	150,000
1896	200,000	100,000
1897	200,000	150,000
1898	200,000	200,000
1899	200,000	200,000
1900	200,000	....
Total expenditure	....	1,175,000

RESULTS OF DISCONTINUANCE OF THE WORK.

During the years 1900 and 1901 little notable injury was caused by the gipsy moth and little attention was paid to it.

In the winter of 1902 a small pamphlet was issued by the state board of agriculture setting forth the fact that the moth was increasing to an alarming extent in many of the wooded districts and predicting that unless all signs failed enormous injury would result. Mention was also made of the fact that about 4 square miles had been found infested in Providence, R. I., during the summer of 1901. This was the first infestation found outside the State of Massachusetts, and from its location it was believed that the insects had been purposely liberated by some malicious person.

At this time the brown-tail moth had spread rapidly in a northeast direction throughout eastern Massachusetts and into New Hampshire and Maine. Already many persons were being poisoned severely by the caterpillars, especially in the sections around Boston, where the moths were becoming abundant.

During the next two years the gipsy moth increased to such an extent that thousands of acres of woodland were defoliated. The caterpillars appeared in such swarms as to denude the orchards and ornamental trees in most of the sections which were previously infested. Large areas of pine timber died as a result of the work of the pest, and real estate values rapidly depreciated in the worst infested sections.

Valuable shade trees were killed outright or injured to such an extent that they had to be cut down, owing to their unsightly appearance.

The caterpillars swarmed into the houses, covered fences, and spun down from the trees upon the clothing of pedestrians, so that they became an unbearable nuisance. Some of them fell upon teams or automobiles and were carried long distances and served to establish new colonies. Stories of the immense numbers of caterpillars seem almost incredible. On several occasions trolley cars were prevented from running until the tracks were cleared of the crushed and swarming insects. The following spring it was necessary for many of the motormen to wear veils to keep their eyes and faces free from the caterpillars which swarmed from the trees. Acres of forest died as the result of the ravages of the caterpillars, the injury including both hardwood trees and conifers. In fact, the conditions which existed in Medford in 1890 were very mild compared with those in the area infested in 1904. To make matters worse, the brown-tail moth appeared at this time in alarming numbers. Thousands of persons were poisoned by the hairs of this insect, and young children especially suffered severely. Physicians reported many cases of this kind, and general appeal was made that something be done to abate the nuisance.

During the summer of 1904, Mr. C. L. Marlatt, first assistant entomologist of this Bureau, visited the infested territory and strongly urged that the matter be given immediate attention. In his report on the conditions existing, which has been published in Circular 58, Bureau of Entomology, he stated that at the time his observations were made the property owners in the badly infested section were at a conservative estimate spending more than $200,000 annually in fighting the gipsy moth, and that the results were far from satisfactory owing to the fact that the work was not carried on in a systematic manner. The amount cited represents the largest annual appropriation which had been made by the State before the work was discontinued.

All these factors led to the formation of many local associations which had for their object the destruction of the moths. Many of the infested towns and cities appropriated funds which were used to protect the trees, and the citizens, after becoming thoroughly aroused, fought the pests vigorously as a matter of self-protection. The work, however, was far from effective because it was not properly organized and undertaken in a systematic manner, and while many owners had their premises well taken care of, their efforts were largely nullified by the negligence of careless neighbors or nonresident property owners. This was particularly true on estates adjoining wooded areas which had a small market value.

The brown-tail moth, which had confined most of its energies up to the present time to feeding on fruit and ornamental trees, was now found widely scattered throughout the woodlands, and the trees, especially oaks, in many regions were thoroughly infested with webs of the pest.

STATE WORK RESUMED IN MASSACHUSETTS.

So serious was the situation and so urgent were the appeals for assistance that the Massachusetts legislature took action in the matter in 1905. The law was amended in 1906 and is given in full, as it has formed the basis for similar laws in other States.

[Chap. 381, acts of 1905, as amended by chap. 268, acts of 1906.]

AN ACT To provide for suppressing the gypsy and brown tail moths.

Be it enacted, etc., as follows:

SECTION 1. For the purposes of this act the pupæ, nests, eggs, and caterpillars of the gypsy and brown tail moths and said moths are hereby declared public nuisances, and their suppression is authorized and required; but no owner or occupant of an estate infested by such nuisance shall by reason thereof be liable to an action, civil or criminal, except to the extent and in the manner and form herein set forth.

SEC. 2. The governor, by and with the consent of the council, shall appoint a superintendent for suppressing the gypsy and brown tail moths and shall determine his salary. The governor may, with the consent of the council, remove said superintendent at any time for such cause as he shall deem sufficient. In case of the death, removal, or resignation of the superintendent the governor shall forthwith appoint a successor. On or before the third Wednesday in January in each year the superintendent shall make a report of his proceedings to the general court, which shall be a public document and shall be printed. Said report shall separate so far as is practicable the expenditures on work against the gypsy moth from those on work against the brown tail moth in each city and town.

Sec. 3. [As amended by section 1, chapter 268, acts of 1906.] The said superintendent shall act for the Commonwealth in suppressing said moths as public nuisances, in accordance with the provisions of this act. For this purpose he shall establish an office and keep a record of his doings and of his receipts and expenditures, and may, subject to the approval of the governor, make rules and regulations governing all operations by cities, towns or individuals under this act. He may employ such clerks, assistants and agents, including expert advisers and inspectors, as he may deem necessary and as shall be approved by the governor. He may make contracts on behalf of the Commonwealth; may act in cooperation with any person, persons, corporation, or corporations, including other States, the United States, or foreign governments; may conduct investigations and accumulate and distribute information concerning said moths; may devise, use and require all other lawful means of suppressing or preventing said moths; may lease real estate when he deems it necessary, and, with the approval of the board in charge, may use any real or personal property of the Commonwealth; may at all times enter upon the land of the Commonwealth or of a municipality, corporation, or other owner or owners, and may use all reasonable means in carrying out the purposes of this act; and, in the undertakings aforesaid, may, in accordance with the provisions of this act, expend the funds appropriated or donated therefor; but no expenditure shall be made or liability incurred in excess of such appropriations and donations.

Sec. 4. [As amended by section 2, chapter 268, acts of 1906.] Cities and towns by such public officer or board as they shall designate or appoint, shall, under the advice and general direction of said superintendent, destroy the eggs, caterpillars, pupæ, and nests of the gypsy and brown tail moths within their limits, except in parks and other property under the control of the Commonwealth, and except in private property, save as otherwise provided herein. When any city or town shall have expended within its limits city or town funds to an amount in excess of five thousand dollars in any one calendar year, in suppressing gypsy or brown tail moths, the Commonwealth shall reimburse such city or town to the extent of fifty per cent of such excess above said five thousand dollars.

Cities or towns, where one twenty-fifth of one per cent of the assessed valuation of real and personal property is less than five thousand dollars, and where the assessed valuation of real and personal property is greater than six million dollars, shall be reimbursed by the Commonwealth to the extent of eighty per cent of the amount expended by such cities or towns of city or town funds in suppressing the gypsy and brown tail moths in any one calendar year, in excess of said one twenty-fifth of one per cent.

In the case of towns where the assessed valuation of real and personal property is less than six million dollars, after they have expended in any one calendar year town funds to an amount equal to one twenty-fifth of one per cent of their assessed valuation of real and personal property, the Commonwealth shall expend within the limits of such towns, for the purpose of suppressing the gypsy and brown tail moths, such an amount in addition as the superintendent with the advice and consent of the governor shall recommend. Disbursements made by said last named towns in excess of said one twenty-fifth of one per cent shall be reimbursed by the Commonwealth every sixty days; but in the case of all others the Commonwealth shall reimburse cities and towns annually according to the provisions of this act.

No city or town shall be entitled to any reimbursement from the Commonwealth until it has submitted to the auditor of the Commonwealth itemized accounts and vouchers showing the definite amount expended by it for the purpose of this act; nor shall any money be paid out of the treasury of the Commonwealth to cities or towns, pursuant to the provisions of this act, until said vouchers and accounts have been approved by the superintendent and the auditor of the Commonwealth.

For the purposes of this section the years nineteen hundred and five and nineteen hundred and seven shall be considered half years, and the valuation for the year nineteen hundred and four shall be taken as a basis.

Sec. 5. [As amended by section 3, chapter 268, acts of 1906.] When, in the opinion of the superintendent, any city or town is not expending a sufficient amount for the abatement of said nuisance, or is not conducting the necessary work in a proper manner, then the superintendent shall, with the advice and consent of the governor, order such city or town to expend such an amount as the superintendent shall deem necessary, and in accordance with such methods as the superintendent, with the consent of the governor, shall prescribe: *Provided*, That no city or town where the assessed valuation of real and personal property exceeds six million dollars shall be required to expend, exclusive of any reimbursement received from the Commonwealth, during any one full year more than one fifteenth of one per cent of such valuation, and that no town where the assessed valuation of real and personal property is less than six million dollars shall be required to expend, exclusive of any reimbursement received from the Commonwealth, during any one full year more than one twenty-fifth of one per cent of such valuation. For the purposes of this section the valuation of the year nineteen hundred and four shall be used.

Any city or town failing to comply with the directions of the said superintendent in the performance of said work within the date specified by him shall pay a fine of one hundred dollars a day for failure so to do; said fine to be collected by information brought by the attorney-general in the supreme judicial court for Suffolk County.

Sec. 6. [As amended by section 4, chapter 268, acts of 1906.] The mayor of every city and the selectmen of every town shall, on or before the first day of November in each year, and at such other times as he or they shall see fit, or as the state superintendent may order, cause a notice to be sent to the owner or owners, so far as can be ascertained, of every parcel of land therein which is infested with said moths; or, if such notification appears to be impracticable, then by posting such notice on said parcels of land, requiring that the eggs, caterpillars, pupæ and nests of said moths shall be destroyed within a time specified in the notice.

When, in the opinion of the mayor or selectmen, the cost of destroying such eggs, caterpillars, pupæ, and nests on lands contiguous and held under one ownership in a city or town shall exceed one half of one per cent of the assessed value of said lands, then a part of said premises on which said eggs, caterpillars, pupæ or nests shall be destroyed may be designated in such notice, and such requirement shall not apply to the remainder of said premises. The mayor or selectmen may designate the manner in which such work shall be done, but all work done under this section shall be subject to the approval of the state superintendent.

If the owner or owners shall fail to destroy such eggs, caterpillars, pupæ or nests in accordance with the requirements of the said notice, then the city or town, acting by the public officer or board of such city or town designated or appointed as aforesaid, shall, subject to the approval of the said superintendent, destroy the same, and the amount actually expended thereon, not exceeding one half of one per cent of the assessed valuation of said lands, as heretofore specified in this section, shall be assessed upon the said lands; and such an amount in addition as shall be required shall be apportioned between the city or town and the Commonwealth in accordance with the provisions of section four of this act. The amounts to be assessed upon private estates as herein provided shall be assessed and collected, and shall be a lien on said estates, in the same manner and with the same effect as is provided in the case of assessments for street watering.

SEC. 7. [As amended by section 5, chapter 268, acts of 1906.] If, in the opinion of the assessors of a city or town, any land therein has received, by reason of the abatement of said nuisances thereon by said superintendent or by said city or town, a special benefit beyond the general advantage to all land in the city or town, then the said assessors shall determine the value of such special benefit and shall assess the amount thereof upon said land: *Provided*, That no such assessment on lands contiguous and held under one ownership shall exceed one half of one per cent of the assessed valuation of said lands; and *Provided*, That the owner or owners shall have deducted from such assessment the amount paid and expended by them during the twelve months last preceding the date of such assessment toward abating the said nuisances on said lands, if, in the opinion of the assessors, such amount has been expended in good faith. Such assessment shall be a lien upon the land for three years from the first day of January next after the assessment has been made, and shall be collected under a warrant of the assessors to the collector of taxes of such city or town, in the manner and upon the terms and conditions and in the exercise of the powers and duties, so far as they may be applicable, prescribed by chapter thirteen of the Revised Laws relative to the collection of taxes.

Real estate sold hereunder may be redeemed within the time, in the manner, and under the provisions of law, so far as they may be applicable, set forth in chapter thirteen of the Revised Laws for the redemption of land sold for taxes.

A person aggrieved by such assessment may appeal to the superior court for the county in which the land lies, by entering a complaint in said court within thirty days after he has had actual notice of the assessment, which complaint shall be determined as other causes by the court without a jury. The complaint shall be heard at the first sitting of said court for trials without a jury after its entry; but the court may allow further time, or may advance the case for speedy trial, or may appoint an auditor as in other cases. The court may revise the assessment, may allow the recovery back of an amount wrongfully assessed which has been paid, may set aside, in a suit begun within three years from the date thereof, a collector's sale made under an erroneous assessment, may award costs to either party and may render such judgment as justice and equity require.

If, in the opinion of the assessors, the owner of an estate upon which an assessment as aforesaid has been made is, by reason of age, infirmity or poverty unable to pay the assessment, they may upon application abate the same. Every city or town in rendering an account to the state auditor as provided for in section four of this act shall deduct from such amount as it has expended the total amount it has received for work performed under section six of this act during the term covered by the account: *Provided*, Such work was performed under such conditions as require reimbursement in whole or in part by the state.

SEC. 8. To meet the expenses incurred under authority of this act, there shall be allowed and paid out of the treasury of the Commonwealth, during the period up to and including May first, nineteen hundred and seven, the sum of three hundred thousand dollars. Of this amount seventy-five thousand dollars may be expended during the calendar year nineteen hundred and five; one hundred and fifty thousand dollars, and any unexpended balance of the previous year, may be expended during the calendar year nineteen hundred and six; and seventy-five thousand dollars, and any unexpended balance of the previous years, may be expended during the calendar year nineteen hundred and seven, up to and including May first.

SEC. 9. An additional sum of ten thousand dollars in each of the years nineteen hundred and five, nineteen hundred and six and nineteen hundred and seven may, in the discretion of the state superintendent, be expended by him for experimenting with parasites or natural enemies for destroying said moths, and any unexpended balance of any year may be expended in the subsequent years.

SEC. 10. Chapter two hundred and ten of the acts of the year eighteen hundred and ninety-one and sections one and two of chapter five hundred and forty-four of the acts of the year eighteen hundred and ninety-eight and section two of chapter fifty-seven of the acts of the year nineteen hundred and two, are hereby repealed.

SEC. 11. [As amended by section 6, chapter 268, acts of 1906.] A person who wilfully resists or obstructs the superintendent or an official of a city or town, or a servant or agent duly employed by said superintendent or by any of said officials, while lawfully engaged in the execution of the purposes of this act, or who knowingly fails to comply with any of the rules or regulations issued by said superintendent, shall forfeit a sum not exceeding twenty-five dollars for each offence.

SEC. 12. Valuations of real and personal property of the year nineteen hundred and four shall govern the provisions of this act.

SEC. 13. This act shall take effect upon its passage.

Approved May 8, 1905.

This law is now in force, with a few minor administrative amendments. In the spring of 1909, following the resignation of the state superintendent, an amendment was enacted placing the work in charge of the state forester.

The law provides a cooperative plan for fighting the gipsy moth and brown-tail moth by which each infested city or town is required to appoint a local superintendent and to expend annually a certain amount, based on its valuation, and, after this has been done, subject to the approval of the state forester, reimbursement is allowed by the State in amounts graduated according to assessed valuation. Thus the large cities are required to expend a larger amount before receiving any reimbursement from the State, and then receive a smaller percentage than the towns with small valuations and large areas of woodland, which are very expensive to treat.

Cities and towns with an assessed valuation on real and personal property of $12,500,000 or more shall, after expending $5,000 in any one year, be reimbursed 50 per cent of all further expenditures.

Cities and towns where the assessed valuation ranges between $6,000,000 and $12,500,000, after expending one twenty-fifth of 1 per cent of the valuation, are reimbursed 80 per cent of all further expenditures.

Cities and towns where the assessed valuation falls below $6,000,000 are required to expend one twenty-fifth of 1 per cent and are reimbursed in full for all further expenditures.

The property owner is required to clear his premises of the insects and to expend therefor not more than one-half of 1 per cent, or $5 per $1,000, of the assessed valuation. In case of failure to do this work after proper notice has been served, the premises may be treated by the town officials and the cost, not to exceed the above amount, may be levied and collected in taxes.

The whole purport of the law is to divide the burden between the property owner, the infested municipalities, and the State, and to place the entire work under state supervision in order to secure uniformity of methods and economy of expenditure.

The law provided for an appropriation of $75,000 for the year 1905, $150,000 for 1906, and $75,000 for 1907. An appropriation of $10,000 a year was also made for a period of three years to provide for the expense of introducing the parasites and natural enemies of these insects from abroad and for their propagation and dissemination in the infested district. The latter work was organized in coöperation with the United States Bureau of Entomology under the direction of Dr. L. O. Howard, Chief of the Bureau.

On May 15, 1905, Mr. A. H. Kirkland was appointed state superintendent by Hon. W. L. Douglas, then governor of the State. The wisdom of this appointment was soon apparent in the results secured in organizing a most difficult piece of work and in training a skilled force of men for efficient service, and the State was very fortunate in being able to procure the services of a well-trained entomologist, who brought to the work a thorough knowledge of the conditions to be met, high scientific attainments, and rare executive ability—a combination seldom secured.

The work during the year 1905 consisted in organizing the moth forces in towns in the infested territory and sending the most expert men that could be employed by the central office into the outside districts to determine if the gipsy moth was present. As a result of a hurried inspection it was determined that 124 towns, covering an area of 2,224 square miles, were more or less infested, against 34 towns, covering an area of 359 square miles, in which the moth was known to exist in 1900, when the state work was discontinued. The gipsy moth was also found in several towns north of the Massachusetts line in New Hampshire, to and including Portsmouth, while the colony at Providence, R. I., had increased to a considerable extent. Practically the same methods were used as those adopted when the old work was in progress, although, owing to the increased area infested and the extremely bad condition of the central district, it was necessary to abandon the idea of extermination and use all possible methods to control the insect and to prevent its further spread. The scouting operations which were carried on in the outside infested towns were, of course, done in a rather hurried manner on account of the great pressure of other work and the necessity for immediately taking active measures to destroy the moths in the badly infested towns and cities. Much effort was necessary in order to organize the work and secure a trained force of local men.

This large area, which included thousands of acres of badly infested woodland, was in a much worse condition than in 1904 and it soon became evident that heroic measures must be taken and an enormous amount of work done if any appreciable progress was to be made in preventing widespread injury.

A single case will serve as an illustration of the loss to owners of timber caused by the gipsy moth. A tract of woodland near the Bedford and Billerica town line, belonging to the Hosmer estate, was sought by a portable saw mill operator in 1907, who offered $6,000 for the wood and timber, but, as the owners wanted $6,500, the trade was dropped. The following winter, owing to the presence of the moths in large numbers, the lot was sold for about $3,000, and immediately cut, resulting in loss to the owners of at least 50 per cent in one year. At the time the state work ceased in 1900 this property was 4 miles outside of the infested area.

In 1906 the Massachusetts legislature added $150,000 to the appropriation already made for that year and united with the other New England States in an appeal to Congress to furnish aid.

The brown-tail moth was found to be present, in 1905, as far west as central Massachusetts. It also occurred in the southern counties in New Hampshire and along the coast, specimens having been reported from Eastport, Me., and St. John, New Brunswick. A single insect was found at Providence, R. I., during the year.

BEGINNING OF WORK BY THE NATIONAL GOVERNMENT.

The spread of the gipsy and brown-tail moths caused much alarm in the New England States, and in the fall of 1905 an appeal was made to Congress to assist in the work of controlling these pests. The movement was supported by delegations from Maine, where the work of the year had shown that an area of approximately 4,000 square miles was infested with the brown-tail moth and where energetic measures were being taken to control the insect; by New Hampshire, which was seriously infested with both pests; by Massachusetts, where heroic measures were being taken to control the situation; and by Rhode Island, where a serious infestation of the gipsy moth existed.

On December 4, 1905, a bill was introduced by Representative Ernest W. Roberts, of Massachusetts, providing for an appropriation of $250,000, to assist in preventing the spread and securing the control of these pests. The urgent necessity for action was forcibly brought out by a report from Dr. W. E. Britton, state entomologist of Connecticut, in March, 1906, that a few egg clusters of the gipsy moth had been found in Stonington, in that State.

Owing to the fact that approximately 300 square miles was thickly infested in eastern Massachusetts, ample opportunity was offered for the larvæ to be carried many miles during the early summer, and thus the whole country was in danger of becoming infested.

Later in the season $82,500 was appropriated by Congress. The work was put under the direction of Dr. L. O. Howard, Chief of the Bureau of Entomology, and Mr. D. M. Rogers, then first assistant to state superintendent Kirkland, was appointed special field agent of the Bureau in charge of the field work in New England. This appropriation became available July 1, 1906, and after a conference between the Chief of the Bureau of Entomology, the superintendent of the moth work in Massachusetts, and the special field agent of the Bureau it was decided that the most valuable results could be secured with this appropriation by at once clearing as many roadsides as possible in the thickly infested and much traveled section of Massachusetts. Arrangements were also made to prevent dissemination of the gipsy moth in the outside territory as far as the limited appropriation would allow. A force of 22 men which had been working in the infested district in Rhode Island was carried on the pay roll from July 23, 1906, to May 15, 1907, although the number at the latter date had been reduced to 9 men, so that work in that State could be continued until the state funds were available.

Later in the season scouting parties were organized and a limited amount of work done in the southern parts of New Hampshire and Maine. A more detailed account of this work will be given later in this report.

Owing to the severe infestation in the district around Boston (see Pl. V in comparison with Pl. VI), and to the fact that practically all of the main highways were being used continually during the caterpillar season by automobiles, it seemed necessary to keep the roadsides free from caterpillars if a general dissemination of the pests to distant points was to be prevented. Traffic between Boston and its suburbs, the shore resorts along the coast, and the vacation places in New Hampshire, is particularly heavy during the early summer. At the time of the serious outbreak of the gipsy moth in 1890 the spread of the insect was made possible chiefly by means of teams or carriages that passed through the infested district, and these seldom traveled more than 20 miles in a single day. With the use of the automobile the daily travel often covers a hundred or more miles, so that the danger of spread to remote districts was greatly increased; in fact, recent inspections have shown that the spread of the insect can often be traced directly to this means of conveyance.

A building was rented at Medford at a point within easy reach of the badly infested section where work was to be carried on, the necessary tools and supplies (figs. 8, 9) were installed, and arrangements made for actively beginning the campaign against the moths. Mr. Harry W. Vinton was selected as a special agent to take charge of

WOODLAND AT LEXINGTON, MASS., COMPLETELY DEFOLIATED BY THE GIPSY MOTH.
(ORIGINAL.)

SAME WOODLAND AT LEXINGTON, MASS., AS THAT SHOWN IN PLATE V, THE FOLLOWING YEAR, ILLUSTRATING BENEFICIAL EFFECTS OF CONTROL WORK. (ORIGINAL.)

active operations in the field. Mr. Vinton had served for several years on the gipsy moth work when it was being conducted by the Massachusetts state board of agriculture, and from his long experience and thorough knowledge of the pest and the proper methods of treatment, as well as his familiarity with the infested region, it was possible to begin active operations without delay.

Several trunk roads in Melrose, Saugus, and Wakefield which extended through badly infested woodland were selected, and active cutting operations begun. Crews of men were employed to cut out the brush and worthless trees and to thin the sound timber on a strip 100 feet wide on each side of the highway. The brush was then burned and the egg clusters on the remaining trees and ledges were creosoted. (See fig. 10.) Very little if any work was planned

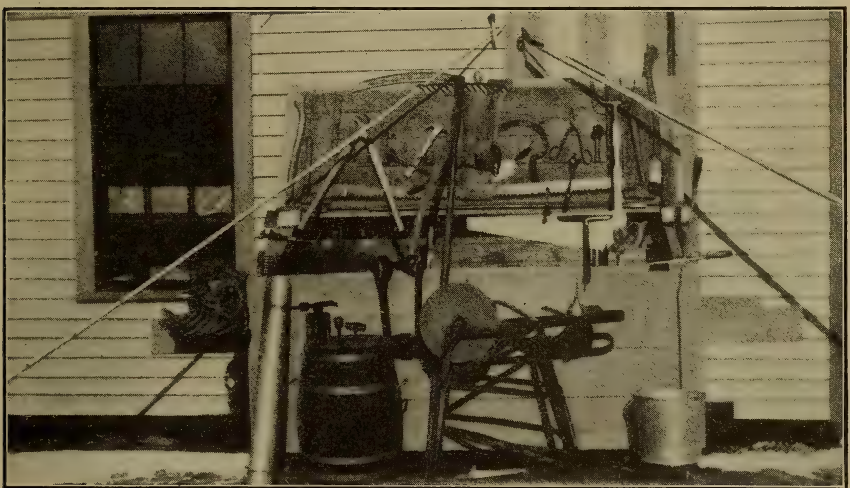


FIG. 8.—Equipment for roadside work against the gipsy moth, used by employees of the Bureau of Entomology. (Original.)

or has been carried out up to the present time in residential parts of the infested district, as the town and city officials, acting under state law, usually keep the trees in such sections fairly free from infestation. The cutting out of these roadways is simply for the purpose of preparing the way for a thorough and economical treatment. It is usually necessary to carefully prune many of the trees in the treated area, and in some cases where they are of special value the cavities in hollow trees are closed with cement, covered with zinc, or sealed with a wooden plug, so that egg clusters can not be deposited in such places, where it is extremely difficult to treat them. In the spring the trees are banded, and burlaps are often used for this purpose. Another method which has come into favor since the gipsy moth work was resumed in Massachusetts is to apply a band of tanglefoot to the trunks of the trees before the eggs hatch. (See fig. 11.) Rough-bark trees should be scraped where this material is to be placed, so that the surface will be smooth enough to apply the band evenly with a wooden paddle. Care should be taken not to remove the inner bark so that the living wood will be exposed. If the tree tanglefoot can be applied evenly, no scraping should be done. This material will remain sticky for several weeks, and prevent the caterpillars from ascending, but the best practice is to draw a comb through the band as the workman walks around the tree. This brings fresh material to the surface and removes any foreign substances which may have collected. The caterpillars are obliged to feed on what low growth remains on the ground and if this has been well sprayed they are soon destroyed. Aside from the roads

FIG. 9.—Roadside where thinning operations are being carried on, showing tools and equipment used in the work. (Original.)

already mentioned a considerable amount of roadside work was done in the towns of Malden, Lynnfield, Lynn, Peabody, Woburn, Lexington, Burlington, Waltham, and Belmont, and the strips cut out during the fall of 1906 and the spring of 1907 and prepared for spring and summer treatment aggregated about 65 miles. Late in April and early in May, 1907, the trunks of the trees in all these strips were banded with tanglefoot to prevent the caterpillars from climbing the trees, as well as to keep such larvæ as migrated from the woodland back of the strips from destroying the foliage. After the caterpillars hatched the strips were sprayed with arsenate of lead, which was used at the rate of 10 pounds to 100 gallons of water. Previous to this time one small and three large spraying machines operated by gasoline engines had been secured. Owing to the limited length of time that the insect is in the caterpillar stage it is necessary to provide equipment so that a large area can be thoroughly sprayed in a short time. This renders impracticable the use of hand outfits for such extensive work. The sprayers used had a tank capacity of between 500 and 600 gallons, and it was possible to treat many acres in a single day. Since the work began a number of improvements have been made in spraying outfits used, which have rendered them more efficient and economical. In addition to the spraying the burlap and sticky bands on the trees were examined from time to time and the caterpillars crushed with steel-wire brushes. In the worst infested places it was necessary to go over the strips daily, and even then in some instances it was almost impossible to kill the caterpillars fast enough to prevent some defoliation on the back edge of the treated strips.

FIG. 10.—Employees of the Bureau of Entomology treating egg clusters of the gipsy moth with creosote, using an ordinary paint brush and a brush attached to a long pole. (Original.)

Early in the fall of 1906 a number of the more experienced men were selected and scouting operations were begun in a limited way in Maine, New Hampshire, and Connecticut. (See fig. 12, showing outfit used by gipsy moth scouts.) This work was continued until June, 1907, and a large number of towns were found infested. In the spring of 1907 it became evident that owing to the discovery of so many infested towns, a larger appropriation would be necessary in order to make anything like a careful examination of the outside territory. In May, 1907, Congress appropriated $150,000 for the purpose of carrying on the work, this sum being available for immediate use. Plans were at once made to clear more roadside areas in the worst infested sections and in the fall to scout thoroughly the towns north of the known infested region. Owing to the great increase in the amount of work which was to be taken up, the territory in

Massachusetts was divided into two sections. Mr. Vinton took charge of the crews in one of these sections, and Mr. David G. Murphy was appointed, June 17, to take charge of the crews in the other division. Mr. Murphy, like Mr. Vinton, had had long experience in fighting the gipsy moth in Massachusetts, and had proved by his previous work with the State to be very capable in taking charge of field work. The roadside work was continued in Massachusetts during the summer and fall, and by the next spring the mileage that had been cut out had been increased twofold over that of the previous year. The strips were treated in practically the same manner as already described and much benefit resulted from this work. Special effort was made in the fall to thoroughly scout the region outside of the towns known to be infested in New Hampshire. The work was handicapped to some extent by inability to secure men with sufficient

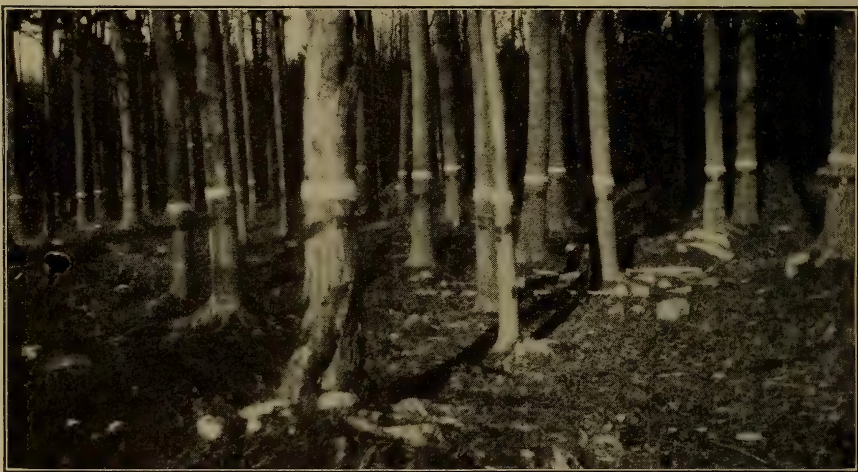


FIG. 11.—Roadside which has been cleared of brush and the trees banded with burlap and tanglefoot. (Original.)

training who were willing to take up this arduous work during the winter. The scouting, however, resulted in the discovery of 17 additional infested towns. Work of a similar character was carried on in Maine, where five more towns were found to be infested.

In the spring of 1908 Congress appropriated $250,000 for the work covering the fiscal year from July 1, 1908, to June 30, 1909. The work of clearing roadsides was vigorously pushed throughout the year so that by the spring of 1909, 170 additional miles of 100-foot strips had been put in good condition for summer treatment. In addition to this amount it was necessary to spray and care for 130 miles of strips that had been thinned during the previous years, so that in the summer of 1909 more than 300 miles of roadside were given careful attention, which undoubtedly prevented many new colonies from becoming established. Over 200 miles of roadway, not yet cut out, which was more or less infested, was sprayed, and this served to further decrease the danger of dissemination. (See figs. 13 and 14.)

Late in the summer of 1908 plans were made to carry on an extensive inspection of the outside territory in New Hampshire and Maine. Owing to the size of the territory to be covered in New Hampshire it was divided into two sections, and Mr. Irving L. Bailey was selected to take charge of the western section and Mr. Henry L. McIntyre was placed in charge of the work in the eastern section. Both were men of extended experience in gipsy-moth work in the field, Mr. Bailey having been employed as an inspector when the insect was being fought by the Massachusetts state board of agriculture, and Mr. McIntyre having had much practical experience in town work for controlling the moths and later in the field work which was being carried on by this office.

About November 1, several crews of the most expert men were sent to New Hampshire and from time to time the force was increased until over 100 men were employed in scouting work in the various towns. Practically all of the territory south of Lake Winnepesaukee and a double tier of towns west of the Merrimac River were examined and most of them were found to be more or less infested. In this work all of the roadways, orchards, and private property were inspected; in fact, all trees were examined except the large forest areas. Several crews were detailed to scout along the main highways north of Lake Winnepesaukee, as these form the main routes of travel for summer tourists to the White Mountains. The principal roads from Ossipee to the mountains as far as Bethlehem and Bretton Woods were carefully inspected; also along the roads on the west side of the mountains through the Pemigewasset Valley. No egg clusters were found north of Ossipee on the eastern or above Meredith on the western roads. While this work was being carried on several crews were engaged in making examinations of the territory surrounding the known infested towns in Maine. This region was found to be in much more satisfactory condition than during the previous year. All work that seemed necessary was done in Connecticut and the condition of this territory showed marked improvement.

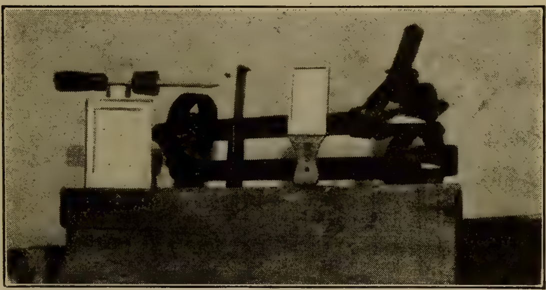


FIG. 12.—Gipsy moth scout's outfit, consisting of climbing irons, mirror, cleaning knife, can of creosote, and brush. (Original.)

The great danger throughout the entire campaign in fighting the gipsy moth has been the existence of large woodland colonies and it has been impossible for either this office, the States, or the individual property owners to keep the moths reduced in territory of this character on account of the vast expense involved. In eastern Massachusetts and southern New Hampshire there are large areas of forest land which are covered with an inferior growth of trees and which are badly infested. In most cases the cost of cleaning up such areas and stamping out the bad colonies would amount to more than the value of the property. This being the case the main attempt has been to keep the roadways through forest areas free from the young caterpillars and to prevent to as great an extent as possible any further spread of the pest. (See Pl. VII.)

FIG. 13.—Roadsides badly infested by the gipsy moth. (Original.)

During February, 1909, Congress appropriated $300,000 to provide for the continuation of the work. This sum was available for the fiscal year beginning July 1, 1909. Since that time work on roadsides has been continued in Massachusetts and up to January 1, 1910, nearly 150 miles of 100-foot strips have been cut out and prepared for spring and summer treatment.

The roadways cut out up to January 1, 1910, aggregate 450 miles of strips. (See fig. 15.) During the period since the government work began about $300,000 has been expended in Massachusetts for labor and transportation of men. This does not include the amounts expended for salaries, rent, tools, equipment, insecticides, supplies, and the expenses that have been paid by the Government for the maintenance of the Gipsy Moth Parasite Laboratory.

Late in October, 1909, 16 scouting crews of 5 men each were sent to the northern portion of the infested district in New Hampshire

VIEW OF WOODLAND NEAR ROADWAY AT WESTON, MASS., SHOWING EFFECT OF CONTROL MEASURES AGAINST THE GIPSY MOTH. (ORIGINAL.)

[On the right is a strip 100 feet wide in which the gipsy moth has been prevented from destroying the foliage and spreading to the road to be distributed by passing vehicles. The trees on the left have been completely defoliated over an area reaching back nearly a mile into the forest. It was necessary to clear the trees from a strip 25 or 30 feet wide in order to protect the treated zone.]

and since that time 5 more crews have been added, making a total of 21 crews, or 105 men, engaged in examining the towns. The first work was taken up in the region surrounding Lake Winnepesaukee and in towns west of the Merrimac River and north of Concord.

January 1, 1910, 41 towns had been scouted and egg clusters were found in 6 towns not previously known to be infested. No egg clusters were found in 6 other towns outside the infested area, and in 4 towns which were found infested and treated last year a careful examination failed to bring to light any egg clusters.

The severe snowstorm and blizzard which prevailed in New England on December 26 resulted in making the roads almost impassable,

Fig. 14.—Same road shown in figure 13, after the completion of thinning operations against the gipsy moth. (Original.)

and coating the trees with snow and ice, and it was necessary to lay off all the scouting crews until weather conditions were suitable to continue the work.

During the season when trees are banded with burlap about 47 men working in Maine were carried on the Bureau of Entomology pay roll, and since that time the number has been increased so that about 60 men engaged in cleaning and scouting have been employed. Small colonies have been found in 3 towns not previously known to be infested. In Rhode Island 53 men were employed during July turning burlap, and on November 21 were transferred from the state pay roll and have been engaged in treating egg clusters and cleaning the trees in the infested territory.

Two men in the employ of the Bureau of Entomology examined the colony at Stonington, Conn., in December and only a single egg cluster was found. A large colony of gipsy moths was found at Wallingford, Conn., December 14. It was visited by Mr. Rogers, December 20, and arrangements were made with Dr. W. E. Britton, state entomologist of Connecticut, to cooperate in every possible way to stamp out the pest.

The above is a brief outline of the cooperative work which has been carried on by the Bureau of Entomology in suppressing the gipsy moth.

Winter webs of the brown-tail moth have been destroyed whenever they have been found in the belts which are being cleared along the roadways. This insect has spread so rapidly that it has been impossible to carry on an active campaign against it, and in Maine and New

FIG. 15.—Map showing roads in Massachusetts where the brush has been cut, the trees thinned, and those remaining treated by employees of the Bureau of Entomology to prevent the spread of gipsy-moth larvæ on vehicles. (Original.)

Hampshire only a moderate amount of good would have been accomplished if an attempt had been made to destroy the brown-tail webs along the roadways and in the orchards, as the woodlands, especially in the southern part of these States, are very badly infested. In many towns property owners have destroyed the webs found on their orchard and shade trees.

The work of suppressing the gipsy moth is carried on in a different way in each of the New England States. In Massachusetts a large annual appropriation is made by the State, and property owners as well as towns and cities are required to assist in the control of the insect.

The work of the Bureau of Entomology in Massachusetts, therefore, has been practically independent of the state work, except that a hearty spirit of cooperation has always existed between the two offices. In Maine the state appropriations have not been sufficient to finance an active campaign against the insect throughout the year, and a system of cooperation has been established between this office and the Maine department of agriculture, so that the work can be continued uninterruptedly. In New Hampshire, owing to the small appropriations made by the State, the greater part of the work has been carried on by the Bureau of Entomology, the state funds being used for urgent calls which it was impossible for this office to attend to. Practically the same conditions hold in Rhode Island as in Maine, while in Connecticut most of the work has been carried on by the State, and the Bureau of Entomology has furnished only such assistance as was deemed necessary to supplement the local work at Stonington and Wallingford. A summary of the work done in the New England States is given herewith.

WORK BY THE STATE OF MASSACHUSETTS.

During the past five years the State of Massachusetts has appropriated $1,195,000 for the purpose of controlling the gipsy and brown-tail moths, and an additional sum of $75,000 has been expended in an attempt to introduce their parasites and natural enemies. The money has been used, in the main, in reimbursing cities and towns in the infested parts of the State which have expended more than was required by the gipsy moth law. A small part of the appropriation has of course been used for maintenance and supervision of the work, and the central office has adopted a system of inspection of the city and town work in order that uniform standards might be enforced and useless expenditures prevented. The men employed as agents and inspectors by the central office have had long experience in fighting these pests, many of them having served when the work was under the direction of the state board of agriculture.

The amount of money expended by the different cities and towns affected has about equaled that appropriated by the State, while many private property owners and state commissions (such as the Metropolitan Water and Sewage Board and the Metropolitan Park and State Highway Commissions) have expended large sums of money, so that the amount expended annually, exclusive of that spent by the Federal Government, has averaged about $750,000 to $800,000.

The result of the work has been to reduce greatly the infestation in the residential sections. This has not been accomplished, however, without vigorous application of all the best-known methods of fighting the pests. Spraying has been carried on in a wholesale way, and at the present time most of the infested towns have purchased high-power sprayers, so that a large area of territory can be covered in the short time that the insect is in the larval stage.

In 1909 over 150 high-power and 250 hand spraying outfits were used in the infested district in Massachusetts.

Unfortunately many of the less valuable woodland sections have received little attention, owing to the pressure of more important work. This results each year in large areas being stripped by the caterpillars, great numbers of which die from starvation and disease, and in this way the infestation for the next year or so is materially decreased. Fortunately these badly infested areas are more or less isolated, as strong effort is made to care for the woodland section that is near roads or lines of travel, so that the danger of spread of the insects from these centers of infestation is reduced as much as possible.

It has been impossible, however, up to the present time, owing to the excessive cost, to do all of such work that could be done to advantage. As the residential areas become freer from the insects more funds can doubtless be devoted to this much-needed work.

In addition to the work already outlined a large amount of scouting has been carried on under the direction of the central office and at state expense. This has been done by skilled and experienced men in the towns outside the known infested territory. All the main roads and orchards have been examined in a section several towns deep around the infested area.

Some of the more important and much traveled state roads have been scouted for long distances and this work in 1907 and 1908 resulted in the discovery, near Springfield and Greenfield, Mass., of small colonies of the gipsy moth.

The infestation near Springfield was located near the state road, which is a favorite route for automobiles between Boston and New York City. The outlying colonies discovered in this way have been treated with special care and many of them have been reduced almost to the point of extermination.

The area infested at the present time in Massachusetts is somewhat larger than that which was found in 1905 when the first scouting operations were begun after the work was resumed by the State. This is what would naturally be expected, as it was at that time impossible to undertake scouting operations over such a large territory with the small force of trained men available.

Doubtless many of the colonies since found developed from caterpillars scattered during the time the moth was allowed to spread without restriction, and more colonies will probably be found in the outside territory. Further scouting should be taken up so that these may be discovered at the earliest possible moment and promptly treated.

Much credit is due to the State of Massachusetts for the energetic manner with which this campaign has been waged. The officials at the state office, under the direction of Mr. Kirkland, and later under Mr. L. H. Worthley and State Forester Rane (in whose charge the work was placed by the last legislature), have accomplished excellent results in spite of the many difficulties which had to be met and overcome.

The work undertaken in Beverly, Manchester-by-the-Sea, Gloucester, and Rockport—the region which is known as the north shore of Massachusetts Bay—and also in the towns of Hamilton, Wenham, and Essex deserves special mention. The value of the woodland in this section is probably greater than any other area of the same size in New England, and this fact, together with the magnificent ocean scenery, has resulted in these towns becoming the summer residences of many prominent citizens from all parts of the country. The gipsy moth threatens the destruction of these valuable forests, and as the land is of little agricultural value the towns concerned would shrink thousands of dollars in valuation, and much of the territory would be uninhabitable during the summer season, thus working a double loss to the sections of the State concerned. During the past two years a special fund for carrying on the work has been furnished on the basis of the State supplying one-third, the city of Beverly and the town of Manchester one-third, and the balance being subscribed by the summer residents. In 1909 over $60,000 was expended, the work being carried on by the state forester's office. Over 2,100 acres of woodland have been thinned, sprayed, and protected from moth injury.

Col. Wm. D. Sohier, chairman of the citizens' committee which raised private funds for carrying on the work, in a report recently issued, says:

> It is perfectly evident that had it not been for the work which was done last year and this year conditions on the north shore from Beverly all the way down through Manchester would have been unbearable. All the trees would have been stripped except on a few private estates, and all the pines and hemlocks would have been killed.

Many improvements in methods have been developed while the work has been in progress. Most of these resulted from suggestions made by different members of the state and government forces. A large number of ideas have been tried out in the field to test their utility, and a considerable number of these have been made cooperatively between the state and governmental offices. The whole effort has been to secure the best results by adopting the cheapest possible methods, and practical suggestions have been received with alacrity.

WORK IN THE STATE OF MAINE.

Webs of the brown-tail moth were found at Kittery, Me., in the spring of 1904 by one of the deputy state nursery inspectors of New Hampshire, and Prof. C. M. Weed, who was then entomologist of the New Hampshire agricultural experiment station, informed Hon. A. W. Gilman, commissioner of agriculture of Maine, of the presence of this insect in the latter State. An examination was made at Kittery and in the vicinity by Miss Edith M. Patch, entomologist of the Maine agricultural experiment station, and through the efforts of the above-named officials considerable work was done in the fall of 1904. Many winter webs were collected and burned. Infestations were found not only in Kittery, but at York, Eliot, and other points to the eastward along the coast. Owing to the large territory over which this insect was spread the matter was brought to the attention of the legislature the following winter and an act passed appropriating $5,000 for the year 1905, and $5,000 for the year 1906, for the purpose of controlling the pest. The office of state entomologist was created and placed under the direction of the state commissioner of agriculture, and Prof. E. F. Hitchings, of Waterville, Me., was appointed to take charge of the work. Many of the towns in the infested section voluntarily raised funds to fight the pest, so that a considerable amount in addition to the state appropriation was available for expenditure during the years mentioned.

Owing to the danger of the State becoming infested with the gipsy moth, an appeal for a national appropriation was urged by the State of Maine, in connection with other New England States, and in the fall of 1906 it was possible for this office to send several scouting parties into the section of Maine nearest the infested area in New Hampshire. As a result of this inspection, egg clusters of the gipsy moth were found at Kittery, Eliot, York, South Berwick, Wells, Kennebunk, and Kennebunkport. Several men examined the principal cities and towns east of Portland, but no infestation was found except a single egg cluster discovered by these men on the grounds of the National Soldiers' Home at Togus, Me., which was 81 miles from the nearest known infested locality. Doubtless this infestation was brought about by inmates or visitors unintentionally conveying some of the insects from the infested territory on their clothing or among their personal effects. The work during the year 1906 was continued in Maine with great vigor. The towns found infested showed a generous spirit of cooperation in fighting not only the gipsy moth but the brown-tail moth. The Old York Transcript, in its issue of January 18, 1907, stated that 120,000 brown-tail webs (fig. 16) were burned in a single day. Most of the money expended for collecting these webs was raised by private subscription or appropriated by the towns involved. In spite of the vigorous work carried on in the brown-tail moth infested section, the insect continued to spread with marked rapidity and was found in many towns east of the known infested area. In the fall of 1907 scouting parties examined the roadways and orchards throughout the gipsy-moth infested territory. This resulted, as might be expected, in the discovery of several vigorous woodland colonies in Kittery and York. Work was immediately begun in clearing out the brush and sprout growth in the infested region, creosoting the egg clusters, and preparing for effective summer treatment. Five new towns were found infested with the gipsy moth as a result of scouting work during the winter of 1907–8, namely, Berwick, North Berwick, Sanford, Lebanon, and Acton.

FIG. 16.—Pile of 120,000 webs of the brown-tail moth gathered and destroyed at York, Me. (From Hitchings.)

The following summer the infested areas were burlapped and given careful attention, especially the one at Togus, where an attempt was made by the Maine department of agriculture to secure the extermination of the insect. The work at this point was especially difficult, owing to the large number of people who visited the home during the spring and summer, and because it was not possible to remove some of the board walks, which furnished excellent places for the moths to deposit egg clusters. The trees surrounding the one infested were burlapped and tended during the summer, and in the fall the grounds were thoroughly scouted for egg clusters. In addition to the caterpillars, pupæ, and moths found when the burlap bands were turned, 40 egg clusters were found and treated.

As a result of the thorough work done only a few caterpillars and no egg clusters were found in the summer of 1908, and although the same methods have been employed as in previous years none of the insects was found in 1909. The last specimen taken was a caterpillar, July 11, 1908. It is probable that this colony has been completely exterminated, although the location and character of the place render it peculiarly liable to future infestation. Since the year 1907 the gipsy moth state work has been under the general oversight of Capt. E. E. Philbrook, and the state force has worked in close cooperation with the government office. The work has been especially difficult, owing to the necessity for training new men, and also because the country along the Maine coast, which is infested, is rough and broken and furnishes opportunity for egg clusters to be hidden in situations where it is almost impossible to find and destroy them. During the winter of 1908–9 scouting work was continued, and small infestations were found in Newfield, Waterboro, Biddeford, Saco, and Scarboro. All the known colonies in Maine have been given most thorough attention, and their condition has improved each year. An important feature of the work has consisted in sending out scouting parties to examine the roadways, orchards, and places likely to be infested outside of the known infested area. This has been done in a limited way, but more work of this character must be taken up in order to determine positively the extent of the infestation. During the fall of 1909 the scouting work was pushed vigorously, not only along the roadways and in the orchards, but crews of trained men were sent into the woodland area to make thorough inspections. Three towns, namely Shapleigh, Gorham, and Dayton, have been found slightly infested, and during the progress of the work a large woodland colony was found in the Agamenticus district in the town of York. The location of this colony is in a region seldom frequented and practically inaccessible to travel. Scouting is being continued for the purpose of discovering any similar colonies that have not yet been found.

The work in Maine has been carefully and thoroughly prosecuted, and the state officials have shown much interest and enthusiasm in meeting this difficult problem. A force of men has been organized and trained to a high degree of efficiency. During the time the work has been in progress it has met with the hearty approval and cooperation of citizens in the infested district. As an example of the esteem in which the work is held it may be stated that during the past year the summer residents and public-spirited citizens of York contributed $1,000 and purchased a power spraying machine, which was turned over to the Maine department of agriculture for treating infested areas.

The amount appropriated by the State from 1905 to January 1, 1910, has been $95,000, and $50,000 additional has been used by the Bureau of Entomology in the moth work in Maine.

WORK IN THE STATE OF NEW HAMPSHIRE.

The first infestation of the gipsy moth in New Hampshire was discovered in 1905 by inspectors from the Massachusetts state office, loaned by agreement between Mr. Kirkland and the New Hampshire experiment station. Three experienced men were detailed and the experiment station sent Mr. W. P. Flint, an assistant in the entomological department, to make an examination of the trees along the roads in the coast towns from Seabrook to Portsmouth. Egg clusters were found in these towns and also in Hampton Falls, Hampton, North Hampton, Rye, and Greenland. Additional scouting was done in Exeter and Nashua, but no evidence of the moth found.

The brown-tail moth had already thoroughly established itself in southern New Hampshire and was causing great injury to orchard, shade, and forest trees.

No state funds were available for moth work. In 1906 a request was made for assistance from this office, soon after the first appropriation was available, but it was too late to do any effective work against the caterpillars, and as no serious outbreak of the pest was evident, scouting was deferred until winter, when an examination showed that the gipsy moth was present in 36 municipalities in the southeastern part of the State.

At the 1907 session of the legislature a law embodying some of the principal features of the Massachusetts law was enacted, and $12,500 appropriated for each of the years 1907 and 1908. The enforcement of the law was placed in the hands of the governor and council with authority to appoint a state agent, if it was deemed necessary. During the first year the burlap work was let out by contract, and Mr. G. E. Merrill, of Hampton Falls, N. H., was employed to inspect the work of the contractors.

All trees within about 100 feet of infested trees in the towns east of Pelham along the Massachusetts border, and the coast towns to Portsmouth, were burlapped and tended, and although some benefit resulted, the amount of money available was entirely inadequate to accomplish satisfactory results. At the close of the year Col. Thomas H. Dearborn, of Dover, was appointed state agent, and has since that time had charge of the moth work.

The appropriations made by the State have not been increased, although the scouting operations of the Bureau of Entomology have resulted in the discovery of the gipsy moth in more than 100 cities and towns. All of Rockingham, Strafford, and Belknap, most of Hillsboro and Merrimack counties, and a few towns in Carroll County are infested—an area of about 3,000 square miles. All the roadsides and orchards in this entire territory have been examined, and similar work has been done in a tier of towns surrounding the infested region, in an attempt to determine the extent of the infestation and to prevent the spread of the pests from colonies along the highways. For three years the greater part of this territory has been inspected in a similar manner.

During the summer thousands of people from all sections of the country visit the State, which is noted for its summer resorts and mountain scenery, and this has been a potent factor in dispersing this insect. Many automobile parties tour the State, and not infrequently trips are made from Boston and vicinity to the White Mountains and lake resorts. During the time the gipsy moth was allowed to develop without interference in Massachusetts, excellent facilities were offered for its dispersion throughout New Hampshire. Travel is unusually heavy at the opening of the vacation season, which is the time when the larvæ are small and most easily carried.

The scouting operations have resulted in locating many colonies in and around summer camps and country houses frequented by vacationists who come from badly infested districts in Massachusetts.

The most serious feature of the problem in New Hampshire is the undoubted infestation of a large part of the thickly wooded area in the southern part of the State. Remedial measures are entirely impracticable, as it is impossible to apply them to such large areas of low-priced forests, owing to the great expense involved.

The greater part of the area is not yet badly infested, but unless the people of the State become aroused and exert themselves to check the gipsy moth serious injury will be caused to the trees and enormous loss is bound to result.

In the residential sections the people will, when the moth increases to an extent to cause serious injury, undoubtedly awake to the situation, and exert themselves to preserve their trees.

The brown-tail moth has been found in an area covering over one-half of the State, and in the entire section east of the Connecticut River watershed and south of Lake Winnepesaukee it is most abundant and is causing great damage. Its presence has caused much complaint from residents and summer visitors, and this has led to effective work being done along the roadways and in some of the towns. Colonel Dearborn has succeeded in awakening considerable interest in this work in certain sections of the State, and some relief from this troublesome pest has been secured where it has been possible to sufficiently arouse public sentiment.

The State has spent $37,500 and the Bureau of Entomology about $90,000 in the work in New Hampshire.

WORK IN THE STATE OF RHODE ISLAND.

The presence of the gipsy moth in Providence was discovered in 1901, and some effort was made by the city and property owners to destroy the insect during the following two years. In 1906, the year after the state work was begun in Massachusetts, a law was enacted in Rhode Island providing for control measures against the gipsy moth. An appropriation of $5,100 was made. This was inadequate for the work, but by means of a cooperative arrangement between the state superintendent, Prof. A. E. Stene, and the Bureau of Entomology it was possible to carry on a vigorous campaign. The original infestation was confined almost entirely to residential property, and at the present time very little woodland in the State of Rhode Island is known to be infested.

Infestations have been found in 11 towns in the northeastern part of the State, extending from the Massachusetts line and including one tier of towns west of the city of Providence. The work which has been done has resulted in the extermination of a large number of small colonies, and those localities in which the moth is now present are of limited extent and are being given careful attention. In many cases the caterpillars or egg clusters were found in brush and undergrowth growing on dumps or unimproved building lots and much work has been required to clean up infestations of this character.

Since the work began practically all of the State has been scouted except the towns north of Westerly along the Connecticut line.

In 1907, $10,000, in 1908, $10,000, and in 1909, $8,000, was appropriated for moth work, and with the help which has been furnished by the Bureau of Entomology great progress has been made. Each year all the trees in the infested area have been carefully examined and fences, buildings, and shrubbery thoroughly inspected for egg clusters. In order to check up the work two experts have gone over the territory after the regular workmen in order to ascertain if any egg clusters had been missed.

During the summer of 1909 about 150,000 trees were burlapped in Providence and surrounding towns. These were visited twice a week during the caterpillar season, and all the insects found were crushed by the workmen. The cavities in a large number of trees in the infested section have been filled with cement or covered with zinc so that work can be more thoroughly done. In order to show the progress which has been made in Rhode Island, it should be stated that during the winter of 1906–7 nearly 80,000 egg clusters were found and destroyed. During the following winter, 1907–8, only 7,500 egg clusters could be found, and in the winter 1908–9 but 1,700 were discovered and treated. It is believed that the moth has been exterminated in 4 of the 11 towns which were infested. The entire territory in this State is in excellent condition, and very little injury now results to the trees, as the insect is present only in small numbers. With persistent work for a number of years it should be possible totally to exterminate the insect in this State, but this can not be accomplished and the region kept free from infestation unless the vigorous work which is now being carried on in the other New England States is maintained. Throughout the period that the work has been in progress in Rhode Island most cordial relations have existed between the state superintendent and this office, and this is one of the factors which has made the work so successful.

The amount appropriated by the State during the four years the work has been in progress is $33,100. In addition to this the National Government has expended about $28,000.

WORK IN THE STATE OF CONNECTICUT.

Adult specimens of the gipsy moth were found by Mr. Ernest Frensch, a local collector of insects, at Stonington, Conn., near the Rhode Island state line during the summer of 1905. He reported the matter early in the year 1906 to Dr. W. E. Britton, state entomologist of Connecticut, who at once made an investigation and found that the report was correct. An emergency fund was available in that State, and was placed at the disposal of the state entomologist for the purpose of stamping out the pest.

The work has been managed in a very efficient manner, and each year such assistance as was desired has been furnished by the Bureau of Entomology. The original infestation covered practically 1 square mile, this having been determined by very careful scouting operations. This colony has been very difficult to treat successfully owing to the broken and rocky character of the ground and to a large number of pastures and brush-covered areas which furnished excellent places in which the eggs of the moth could be deposited. In the autumn of 1906 a determined effort was made by the state entomologist to exterminate the moth in this town, and all brush was cut in the woodland and pastures throughout the infested area. The following summer the trees were burlapped after having been previously pruned and all cavities sealed with cement or patched with zinc. Many stone walls were burned out with a cyclone burner, some spraying was done during the caterpillar season, and a number of trees were banded with tanglefoot. Working on the theory that colonies originated from the introduction of caterpillars by some peddler or milkman or other person making frequent visits over quite a large area, several of the adjoining towns were scouted to determine if other colonies existed from which these caterpillars might have been distributed. No evidence was found, however, of outside colonies. During the summer of 1906 approximately 10,000 caterpillars were destroyed, and during the winter of 1906–7, 118 egg clusters were treated with creosote. By following up the methods already outlined the infestation has decreased each year, and during the summer of 1909 less than 100 caterpillars were killed. The final inspection recently completed revealed the presence of only 1 egg cluster. The condition of this colony in Connecticut is very satisfactory and much credit is due the state entomologist and his assistants for the efficient work which has been done. A small amount of help has been furnished by the Bureau of Entomology when it was desired, and it is evident that extermination can be accomplished by following up the work in a thorough manner, although the territory is a most difficult one to treat.

On December 14, 1909, a letter was received from Dr. W. E. Britton stating that a colony of the gipsy moth had been found in the town of Wallingford, about 12 miles north of New Haven. Several men were immediately sent by him to investigate the matter thoroughly, to determine the amount of territory infested, and to treat egg clusters. On December 20, Mr. Rogers and Doctor Britton visited Wallingford and saw many badly infested trees near the center of the town. The examination which had been carried on previous to that time showed that the moth had spread over approximately one-half of the borough. The principal infestation was located in the rear of a grocery store, and during the caterpillar season delivery wagons and other vehicles must have furnished excellent opportunity for the spread of the insects. Undoubtedly, a considerable area will be found infested after a thorough examination has been made. It is probable that this colony has existed for at least three years, and possibly for a longer time. The total number of egg clusters treated up to January 1, 1910, aggregated over 5,000.

The presence of this bad colony, which is at least 100 miles from the badly infested area in Massachusetts, indicates the probability that other colonies may exist at equally distant points. From the fact that the center of the infestation appears to be near the provision store mentioned, and also because lettuce, cucumbers, and other garden crops were undoubtedly shipped to this point from market gardens near Boston, it is possible that the infestation may have been caused by egg clusters brought in boxes used for transporting these products. If this supposition is correct, it is probable that many points outside the infested district in Massachusetts became infested in this way during the years when no work was done in that State. Every effort will be made to stamp out the pest in Wallingford, and arrangements are on foot to place a sufficient number of men in the town to thoroughly inspect and treat the infested area, and to examine carefully the surrounding territory.

INSPECTION OF LUMBER AND FOREST PRODUCTS.

On March 27, 1909, a letter was received from Mr. A. M. G. Soule, one of the foremen in charge of the scouting work in Maine, which stated that while examining woodland along the railroad near Scarboro Beach, Me., he found a quantity of oak shim wood, which was being used by the section men in repairing the track, badly infested with gipsy moth egg clusters.

An investigation showed that the wood was originally shipped from a badly infested district near Bedford, Mass., and that it had been delivered at various section houses along the railroad between South Lawrence, Mass., and Portland, Me. By following up the deliveries, infested wood from this shipment was found at Kennebunk, Biddeford, Pine Point, and Scarboro Beach, Me. The entire shipment, so far as could be determined, was traced and the egg clusters treated wherever they were found. This discovery emphasized the danger of shipping forest products of all kinds by rail after the egg clusters of the gipsy moth had been laid, and arrangements were at once made to inaugurate a system of inspection by means of which distribution of egg clusters from the infested area to distant points could be prevented. The matter was presented to the Chief of the Bureau of Entomology, and later a letter was sent by the Secretary of Agriculture to the different railroad companies operating in the infested district, requesting their cooperation with the Bureau of Entomology in preventing further spread of this insect. The officials of the several railroads operating within the infested district gave assurance of their interest in the matter, and promised all possible assistance in confining the pest to the present territory. Orders were issued by the railroads to all station agents within this area that after July 1, 1909, forest products would be accepted for shipment only when accompanied by permits or certificates of inspection from this office. As soon as shippers became acquainted with the requirements little delay was experienced, and the order has met with hearty approval and a generous spirit of cooperation. When such material is being forwarded from one town in the infested district to another known infested point, a permit to ship is granted after proper application has been made. The inspection of such shipments is not attempted unless there is special danger of transmitting infested material. On shipments, however, that are destined to points outside the infested territory, inspection is made by employees of this office before a certificate is granted allowing shipments to move. As a result of this work, inspections have been made of 490 shipments, many of which were badly infested. The following table gives the geographical range of the shipments sent out from infested territory from July 1, 1909, to January 1, 1910. Each shipment averaged about a carload lot, although in some cases as high as 10 carloads were examined for a single shipment. Over 1,000 cars of forest products have been shipped from the infested district in Maine during this period. Practically all the lumber region in this State is outside the infested area.

This material consisted chiefly of railroad ties, posts, poles, cord wood, bark, staves, rough lumber, and, in the last few weeks of 1909, small evergreen trees for the Christmas trade. The enforcement of the inspection requirements has resulted in a large amount of additional work for this office, but as several badly infested shipments have been prevented, the expense of the work has been amply justified. A large shipment of lumber consigned to Holyoke, Mass., was found badly infested, and held until it could be thoroughly inspected and treated before it was allowed on the cars. Lumber which was destined to Philadelphia, Pa., and other points as far removed from the infested region was also held up for thorough inspection and certification. This has been the means of preventing a number of colonies from gaining a foothold in States outside of New England.

Number and geographical distribution of lumber shipments forwarded to uninfested points.

CONNECTICUT.

Ansonia, 4.
Bridgeport, 11.
Danbury, 2.
Derby, 2.
Greenwich, 1.
Hartford, 7.
Litchfield, 1.
Lyme, 1.
Meriden, 3.
New Haven, 13.
New London, 2.
Norwich, 2.
Seymour, 6.
Torrington, 2.
Waterbury, 5.

ILLINOIS.

Chicago, 1.

MAINE.

Auburn, 1.
Buxton, 2.
Freyeburg, 2.
Millinocket, 2.
Portland, 35.
Westbrook, 4.

MASSACHUSETTS.

Acushnet, 1.
Amherst, 1.

MASSACHUSETTS—cont'd.

Athol, 3.
Barre, 2.
Fair Haven, 1.
Fall River, 7.
Holyoke, 25.
New Bedford, 4.
Northampton, 1.
Royalston, 1.
Shelburne, 1.
Southbridge, 2.
Springfield, 2.
Ware, 2.
Winchendon, 2.

NEW HAMPSHIRE.

Berlin, 1.
Campton, 1.
Canaan, 2.
Claremont, 1.
Conway, 1.
Gorham, 1.
Greenfield, 4.
Hancock, 2.
Harrisville, 6.
Haverhill, 4.
Keene, 10.
Lisbon, 1.
Madison, 2.
Marlboro, 3.
Newport, 2.

NEW HAMPSHIRE—cont'd.

Peterboro, 9.
Plymouth, 1.
Rumney, 1.
Swanzey, 1.
Winchester, 1.

NEW JERSEY.

Camden, 2.
Edgewater, 1.
Edgeworth, 1.
Helmetta, 1.
Hoboken, 1.
Irvington, 1.
Jersey City, 2.
Keyport, 1.
Newark, 3.
New Brunswick, 2.
Passaic, 3.
Paterson, 1.

NEW YORK.

Albany, 1.
Arden, 1.
Brooklyn, 1.
Claremont Park, 1.
Cornwall, 2.
Dunkirk, 2.
Hornell, 1.
Ilion, 1.
Kingston, 1.

NEW YORK—continued.

Long Island City, 2.
Morris Heights, 1.
Mount Kisco, 1.
New Hartford, 2.
New Rochelle, 1.
New York City, 7.
Oneida, 1.
Peekskill, 1.
Port Chester, 1.
St. Johnsville, 1.
Seacliff, 1.
White Plains, 2.

OHIO.

Sandusky, 5.

PENNSYLVANIA.

Allentown, 1.
Pen Argyl, 1.
Philadelphia, 18.

RHODE ISLAND.

Bristol, 2.
Coventry, 2.
Newport, 2.
Woonsocket, 2.

VERMONT.

Barton, 4.
Bellows Falls, 1.
Brattleboro, 1.
Lyndon, 1.
St. Johnsbury, 1.

DISTRICT OF COLUMBIA.

Washington, 2.

Aside from the certificates required for shipping forest products outside the infested territory, a large number of permits, aggregating 2,624 to January 1, 1910, have been issued allowing the transportation of these products inside the infested district.[a]

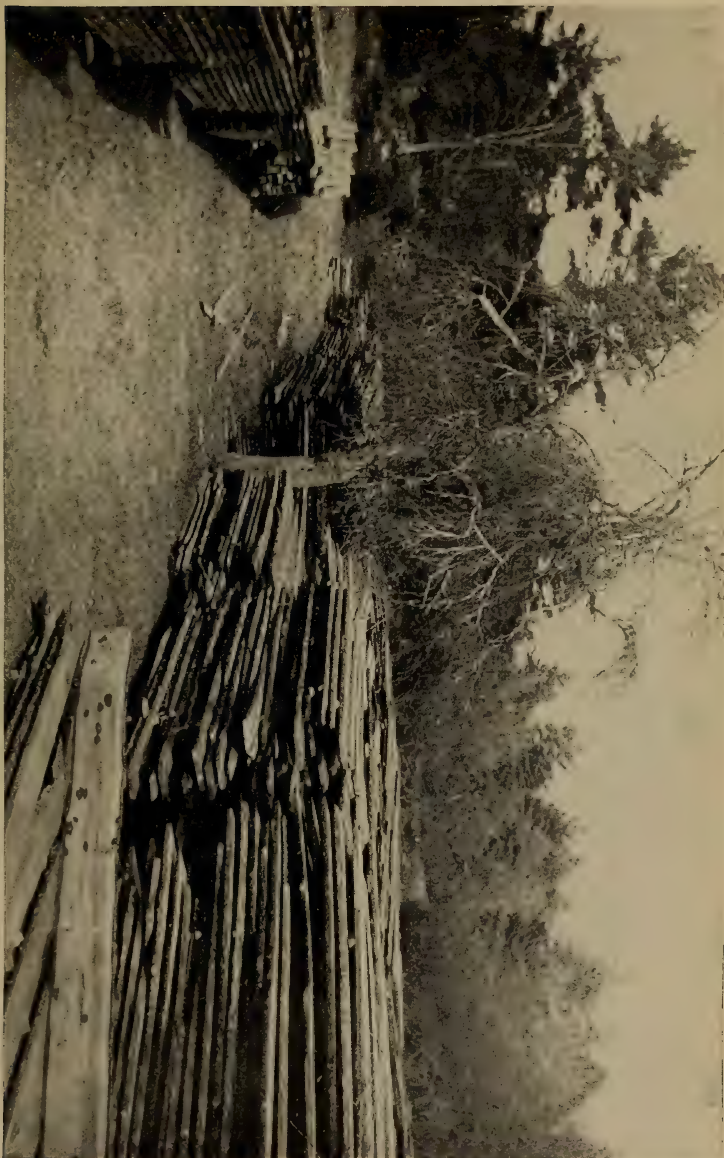
This inspection feature of the work is of great importance and must be well organized and thoroughly enforced if the gipsy moth is to be prevented from becoming established at distant points. This is especially true, since at the present time large forest areas are heavily infested, and in order to harvest the marketable lumber many owners are cutting and shipping. Where large cutting operations are carried on it is customary to use portable sawmills, and the rough lumber is often piled in the woodland where it may remain one or two seasons. This may result in the lumber becoming badly infested with egg clusters. (See Pl. VIII.) A number of cases have been found which indicate that the moth has been spread by the removal of these portable sawmills from one infested area to another where no infestation existed.

The report has recently been received that gipsy moth egg clusters were found in Providence, R. I., on boxes which had been used by market gardeners in shipping their produce. This feature concerning the spread of the moth is very difficult to regulate, and about the only measure seems to be the requiring of shippers of such produce to keep their grounds and premises free from the pest. The thorough inspection and cleaning up of such premises will undoubtedly result in checking the spread of the insect in this way.

DANGER OF INTRODUCING THE GIPSY MOTH AND BROWN-TAIL MOTH FROM FOREIGN COUNTRIES.

The suppression and inspection work which is being carried on in New England of course can not prevent the introduction of these

[a] From January 1, 1910, to May 25, 1910, 227 certificates and 102 permits were issued. Several infested shipments were found, which were carefully treated before being released. In addition to the New England States these shipments were sent to New York, Pennsylvania, Delaware, Virginia, and Ohio.



LUMBER PILES AT YORK, ME., INFESTED WITH EGG CLUSTERS OF THE GIPSY MOTH.

pests from foreign countries, and unfortunately at the present time there is no effective general law which provides for the inspection of nursery stock or other products, coming into the country, on which these insects are likely to be transported. Most of the States have nursery inspection laws which are enforced with special reference to preventing the introduction and spread within the State of the San Jose scale and other dangerously injurious insect pests. Most of these laws are well enforced, and the officials in charge have been provided with sufficient funds to carry on the work. The ports of entry, which are controlled by the United States Government, have not come under the jurisdiction of the State officials, and when inspections were made of stock coming to the United States from foreign countries, they have been carried on at the point of destination. Little attention was given to this feature of nursery inspection work until during the winter of 1909 discovery was made by the inspectors working under the direction of the commissioner of agriculture of New York that seedling nursery stock imported from France was being received at various nurseries in the State, which in many cases bore webs containing hibernating caterpillars of the brown-tail moth. This matter was given immediate attention, and the inspectors in the different States were cautioned, both by the commissioner of agriculture of New York and the Chief of the Bureau of Entomology at Washington, to be on the lookout for such stock. As a result of this warning and of the arrangements made by the Bureau of Entomology with the custom-house officials, notice was sent to inspectors in all of the States of the arrival of any nursery stock shipments in this country, so that an inspection could be made as soon as the stock reached its destination. Most of the States followed up the shipments energetically, and carefully inspected them, but in a few where no funds were available for doing the work the local inspector was deputized by the Bureau of Entomology to examine the importations and the work was paid for out of the appropriation for preventing the spread of moths which had been made for carrying out the campaign in New England.

At the close of the season it was found that brown-tail moths had been found in shipments of stock that had been received in 15 different States, viz, Alabama, Georgia, Illinois, Iowa, Kansas, Kentucky, Maryland, Massachusetts, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, and Pennsylvania. In New York State alone over 7,000 webs were found and destroyed. A single egg cluster of the gipsy moth was found in a shipment received in Ohio.

A bill (H. R. 23252, 61st Congress, 2d Session) "To provide for the introduction of foreign nursery stock by permit only, and to authorize the Secretary of Agriculture to establish a quarantine against the importation and against the transportation in interstate commerce of diseased nursery stock or nursery stock infested with injurious insects, and making an appropriation to carry the same into effect" is now under consideration by the Committee on Agriculture of the House of Representatives and it is earnestly hoped that it may receive favorable action. The urgent need of some legislation of this character should be apparent to any person who has given the matter serious thought. From a financial point of view it is much easier and cheaper to stamp out a few insects before they have had an opportunity to gain a foothold in this country than to attempt to exterminate or suppress them after they have had a chance to multiply and become acclimated.

EXPERIMENTAL WORK IN THE CONTROL OF THE GIPSY AND BROWN-TAIL MOTHS.

During the progress of the field work on the gipsy and brown-tail moths it has been necessary to carry on a limited number of experiments and to make investigations so that more economical methods could be used in destroying these insects. It has been known for years that a single defoliation will cause the death of pine or other coniferous trees and some of the men engaged in the field work reported that small caterpillars of the gipsy moth did not appear to feed on the foliage of these trees. In 1907 Mr. F. H. Mosher, one of the entomologists connected with the Massachusetts work, carried on an extensive series of experiments in feeding newly hatched gipsy-moth caterpillars on pine foliage. The results secured showed that the caterpillars would starve rather than eat the food offered, and as a result of this test it became evident that it was necessary for the small caterpillars to have a considerable amount of deciduous food before they were able to attack pine. Using these experiments as a basis, an extensive field test was made in the spring of 1908 by the Bureau of Entomology in cooperation with the Massachusetts state office.

An area of about 5 acres of pine woodland located in Arlington, Mass., was selected for the test. The woodland was surrounded by farm land upon which were growing many fruit and shade trees, as well as a considerable amount of brush and undergrowth, all of which was very badly infested with the gipsy moth. The pine trees were banded with tanglefoot early in the spring and no other treatment was applied except combing the bands. These trees, as well as the deciduous trees on the surrounding ground, were badly infested with egg clusters of the gipsy moth. After the caterpillars hatched, the deciduous trees were badly defoliated, but no injury resulted to the pines. The small caterpillars in the pine trees, being unable to secure

FIG. 1.—PINE GROVE KILLED BY THE GIPSY MOTH. (ORIGINAL.)

FIG. 2.—PINE TREES THAT HAVE BEEN PROTECTED FROM THE ATTACKS OF THE GIPSY MOTH. (ORIGINAL.)

proper food for their development, either died or spun down to the ground and migrated to the deciduous growth. Owing to the sticky bands on the trunks of the trees it was impossible for the caterpillars to again ascend to the foliage. This experiment was checked up by several other tests made by the state office, all of which showed the same results. (See Pl. IX, figs. 1, 2.)

The practice at present in handling coniferous woodland is to cut out all the deciduous growth which will furnish food for the young caterpillars, and if the pines are well banded with tanglefoot early in the summer, and these bands kept viscid during the caterpillar season, no further treatment is necessary. These experiments have resulted in the adoption of a simple and comparatively cheap method of preventing the destruction of valuable coniferous woodland, and as trees of this character grow satisfactorily in most sections of the infested district it is possible to preserve and develop pine forests at a moderate expense, regardless of the presence of the gipsy moth in surrounding territory.

The greater part of the experimental work has been along the line of developing more efficient spraying methods. The use of the tower on power sprayers, which will be more fully explained later in this report, has resulted in a great saving in cost of treatment. In the summer of 1909 several tests were made with large spraying machines to determine the most effective pressures and the best size of nozzle outlets. The results indicate that on the average a $\frac{1}{4}$-inch nozzle of the type described later in this report will carry the spray 20 feet farther than a $\frac{3}{16}$-inch nozzle, and that it is necessary to maintain a pressure of over 200 pounds in order to secure satisfactory results. There are many opportunities for perfecting the present spraying outfit, and much thought is being given this matter both by the Bureau and state officials as well as by manufacturers who at the present time are selling many spraying machines in the infested region. The activity in perfecting devices will undoubtedly result in better and more economical methods in the future.

METHODS NOW USED IN FIGHTING THE GIPSY MOTH.

Most of the methods used for destroying the gipsy moth have already been mentioned, and a large number of them were in successful use at the time the work was being carried on by the State of Massachusetts during the nineties. Such methods as treating egg clusters, cleaning up brush, thinning infested woodlands, and general clearing-up measures have not been improved to a great extent. The use of burlap has been continued from year to year, but owing to the expense involved in applying and tending it throughout the season it is not now considered as satisfactory a method as the more recent system of banding the trees with tanglefoot. This is especially true since the brown-tail moth became abundant in the orchards and woodlands. Many of the caterpillars of this insect seek the burlaps when they are about to spin their cocoons for the purpose of pupation, and the serious poisoning which results to the men employed when turning such burlaps makes thorough work well-nigh impossible. Every season hundreds of men suffer extremely from this trouble, and in many cases efficient and well-trained workers are obliged to resign rather than attempt to continue on the work. This is leading to a general discontinuance of the burlap method of treating the gipsy moth. The tanglefoot bands are very satisfactory and the men are enabled to work with less discomfort. The methods used in cutting out zones along infested roadways has been in strict accordance with the latest ideas of modern forestry.

FIG. 17.—Roadside area, showing how the grass has been induced to grow by thinning out the trees and clearing away the underbrush in gipsy-moth control work. (Original.)

By adopting the best known methods in thinning and pruning, the trees which remain are in sound condition, and with the care which is given from year to year after the roadways have once been thinned they have a favorable opportunity to make a satisfactory growth. In many of these cleaned areas, which are kept free from undergrowth by mowing them in August, it has been possible to induce a stand of grass which greatly improves the entire appearance and condition of the roadside. (See fig. 17.)

Perhaps the greatest advancement has been made in spraying with arsenicals. Since the discovery of arsenate of lead this substance has practically superseded all other poisons for use against leaf-eating insects of all kinds. During the season of 1909 nearly

500 tons of this poison were used in New England for spraying the trees. Considerable spraying was done to destroy the elm leaf-beetle (*Galerucella luteola* Müll.), and this poison was used exclusively in the work. The best results are secured in spraying for the gipsy moth when the caterpillars are very small, but in covering so large an area it is impossible to provide machines enough to do all the work early in the season. Ten pounds of arsenate of lead to 100 gallons of water is a satisfactory strength to use, but after the caterpillars are half grown it is often desirable to increase this amount to 12 or 15 pounds to the same amount of water. Spraying late in the season after the larvæ are nearly fullgrown is of doubtful advantage, as the caterpillars are very resistant to poison, and as a rule will pupate and transform to moths.

The power spraying machines used in 1909 were superior in every way to any that had been designed previously, and plans for improvements on these machines have been considered for the work next season. Barrel sprayers fitted with hand pumps are used to some extent for treating shrubbery and orchards, and in some cases high trees are treated by using these outfits, especially when it is necessary to prevent buildings from becoming discolored by the poison. [illegible]e of these small outfits is impracticable when it is necessary [illegible]er in a period of six weeks the large areas which must be sprayed, and as a result of varied tests of power outfits a system has been devised for using what is known as "solid-stream spray."

About 1895 Mr. J. A. Pettegrew, who was then superintendent of Prospect Park, Brooklyn, N. Y., constructed a steam spraying outfit [illegible]se in treating the trees which were being severely injured by the elm leaf-beetle. Sufficient pressure was developed to spray high trees from the ground, the shape of the nozzle being such that a solid stream was carried high in the air, where it was broken into a mist. This sprayer was described and illustrated by Dr. L. O. Howard in an article on spraying.[a] Soon after Mr. Pettegrew became superintendent of the Boston city parks he used a similar outfit for spraying.

In 1905, this method of treatment was tested by Gen. S. C. Lawrence, of Medford, Mass., who was carrying on extensive spraying operations to protect the trees from the gipsy moth. This outfit was built by a Boston firm, and was equipped with a high-power gasoline engine instead of with steam to generate power. The experiment was successful and since that time the use of outfits built on the same general lines has been gradually increasing. Mr. George H. Kermeen, one of the representatives of the firm alluded to, was an early advocate of this system of spraying, and in addition to

[a] "The use of steam apparatus for spraying," Yearbook, U. S. Department of Agriculture, 1896.

making improvements in the outfits succeeded in interesting many people in their use.

Experiments were carried on under the direction of Mr. A. H. Kirkland and Mr. L. H. Worthley, and others connected with the state office in Massachusetts, and considerable work along this line has been attempted by Mr. Rogers and others connected with this office, and the results have been of benefit to all workers against the moths. The most successful machine thus far designed is provided with a multiple-cylinder (usually triplex) pump which is connected by a clutch to a gasoline engine of the marine or auto type. The engine is provided with two or more cylinders. The four-cycle type of engine has given the most successful results. A bronze pump is used, as this metal accommodates itself to sudden fluctuations in pressure and is not affected as readily with arsenate of lead as those made of cast iron.

The pump must be capable of delivering 35 gallons per minute and maintain a pump pressure of at least 200 pounds. This requires a 10-horsepower engine. Piping is arranged so that water may be pumped into the tank from accessible wells, ponds, or streams, and solution pumped from the tank and not discharged by the nozzle returns either to the tank or into the pump suction. A large, strong air-chamber is necessary in order to avoid sharp shocks to the pump and also to equalize the pressure. Batteries should be placed where there is as little jarring as possible, away from the heat of the engine, and where water will not reach them. One of our machines has been fitted with a magneto with excellent results. Engines and motors of the two and four cycle types have been used and both water and air cooled engines have been tested. Until recently only gas engines of the stationary type were used, but last summer the two-cylinder marine motor, water cooled, gave excellent results, and a four-cylinder engine of this class will perhaps be still more satisfactory.

The agitation of the solution is accomplished by a shaft fitted with 2 or 3 two-bladed propellers, which passes through the lower part of the tank. It is operated by the engine so that the poison is thoroughly mixed. One-and-one-fourth-inch hose has been used for spraying with these machines, but at the present time 1-inch hose is coming into favor. The nozzle is of much the same type as that used on fire hose, being fitted for interchangeable tips, varying from $\frac{1}{8}$-inch to $\frac{1}{4}$-inch aperture.

The machinery is mounted on the back part of a wagon truck, the front part being occupied by a 400-gallon to 500-gallon U-shaped tank. The trucks are as short as possible to accommodate the tank and necessary machinery and are provided with stout springs and brake. They are also built so that the front wheels will cut under the tank, as this is of advantage in turning around in narrow streets.

ONE OF THE TEN HIGH-POWER SPRAYING OUTFITS USED IN THE GIPSY MOTH WORK OF THE BUREAU OF ENTOMOLOGY. (ORIGINAL.)

HIGH-POWER SPRAYING OUTFIT IN USE IN TREATING ROADSIDE TREES. (ORIGINAL.)

When a machine of this type (Pl. X) is used and a pressure held at from 200 to 250 pounds, trees from 60 to 75 feet high can be thoroughly sprayed from the ground. It is necessary in spraying the woodland areas to use long lines of hose, and this requires the use of a considerable number of men to move the hose about rapidly, so that the spray material can be well distributed by the man holding the nozzle. In the work along roadsides this system was used in 1907 with satisfactory results, but the time required for moving the hose greatly increased the cost of treatment. In order to diminish the cost of applying poison to the roadside areas, and also to enable the workmen to treat a greater mileage in a given length of time, a special arrangement was devised by Mr. Rogers which is known as a "water tower." This is set up on top of the tank and is mounted on a mast 6½ feet high made of 2½-inch piping which is provided with braces to hold it in perpendicular position. It is attached to the top of the tank with bolts so that it can be laid down when not in use. At the top of the mast is a threaded street L made on free to the mast and a T is made onto the L in such a manner as to provide what is practically a universal joint. Through the T a length of 1¼-inch, 16-gauge steel tubing is placed, which is fitted with collars to hold it firmly in position. The tube is about 20 feet long; at the outer end the nozzle is attached, while to the other, which extends only about 4 feet from the point of attachment to the mast, is coupled the hose carrying the solution.

The tube near the end where the hose enters is reenforced by a quantity of lead which makes it nearly balanced on the mast. The nozzle is raised by lowering the reenforced end of the tube, and when the sprayer is in operation the nozzle is about 25 feet from the ground. With this arrangement, if the pressure is maintained at 200 pounds and a ¼-inch nozzle used, trees 80 to 90 feet in height can be readily sprayed. If the wind is light or favorable, a strip along one side of the road 100 feet deep, or more, can be treated. It is impossible to use this arrangement with satisfactory results if the wind is blowing from the strip, but under favorable conditions good work can be done if the sprayer moves along the road while the machine is in operation. (See Pl. XI.) It is more effective to spray these strips twice, as this assures better distribution of the poison. A modification of this system was tried during the past summer and consisted simply of using the tower for elevating the spray and treating the high trees and growth as far back as possible from the roadway, while at the same time another hand nozzle, with smaller tip of the same type as the one on the tower, was operated by a man standing on the top of the tank. The latter nozzle was used for treating the trees close to the road, and by this modification more thorough work was done. (See fig. 18.)

It is obvious that the tower can not be used except for treatment of roadsides, and where woodland areas are to be sprayed it is often necessary to lay long lines of hose from the sprayer, which should be located as near as possible to a supply of water. The State of Massachusetts has conducted large spraying operations over thousands of acres of forests of this character in the North Shore district with excellent results. In some cases a line of hose more than one-fourth of a mile long has been used, and it was possible to maintain sufficient pressure at the nozzle to do satisfactory work. Woodland work of this character is very expensive, owing especially to the amount of labor required to carry the hose. A machine and crew of men can usually cover about 12 acres of woodland per day, the entire cost of treatment averaging about $10 per acre. Roadsides can be

FIG. 18.—Spraying a roadside, using a combination tower and hand nozzle, so as to throw two streams. (Original.)

treated, where the tower is used, for about $2 per acre, and it is possible under favorable conditions to spray 2 miles in a single day.

With the last mentioned outfit it is necessary to employ two men to operate the nozzles, an engineer to look after the machine, and a team and driver. A driver with a horse and wagon accompanies each sprayer with a supply of poison, gasoline, extra hose, etc. The driver of the supply wagon is required to post warning notices in the treated strips, which indicate that spraying has been done, so that owners of cows and other animals will not permit them to feed on the sprayed foliage or grass.

Under favorable circumstances from 4,000 to 5,000 gallons is sprayed out in 8 hours, but this amount is sometimes reduced by each machine, owing to pump or engine troubles.

COST OF METHODS EMPLOYED.

In the gipsy moth work it is very necessary to know the approximate cost of cleaning up or caring for any given infested area. The treatment work attempted by the Bureau has been principally along the line of caring for trees growing near wooded roadsides, while that of the States has covered infested areas of all kinds. In the latter work, especially in woodland areas, much money has been expended in thinning out the trees and putting the forests in the best possible condition, so that the moth can be successfully treated. Special attention has been paid to leaving trees which would be the most profitable, and also those which are to some extent immune from the feeding of the insect.

Mr. L. H. Worthley, assistant forester in charge of moth work for the State of Massachusetts, who has had wide experience in cutting-out operations, states that woodland can be properly thinned (not pruned) and put in condition for treatment measures against the gipsy moth at a cost ranging from $15 to $35 an acre. This variation depends on the character and size of the trees to be cut. The first roadside work done by this office where considerable heavy timber was cut cost about $40 an acre for thinning, burning, pruning, and creosoting egg clusters. As the force of men became more experienced in the work it has been possible to reduce the expense of cutting out these roadside strips. The average cost of work on over 30 miles of strips last fall amounted to $27.50 an acre. It may seem at first glance as though this method required an excessive expenditure of money; nevertheless it should be stated that the gipsy moth can not be successfully controlled unless the woodland is properly thinned and dead wood removed. In addition to this, if hollow trees are allowed to remain it is almost impossible to keep the insect in subjection. Another feature which should be pointed out is that although the first expense of cutting is large, the cost of caring for the area in future years is greatly reduced. Our data show that as a result of putting the roadsides in good condition for future treatment it has been possible to reduce the amount each year which must be expended for destroying the caterpillars and egg clusters.

Many experiments have been carried on for the purpose of decreasing the cost of spraying work. The adoption of the water tower on the tanks has materially assisted in this direction. A careful record of the spraying this year shows that over 360 miles of roadway were sprayed on both sides. By taking into account the entire cost, including labor, poison, supplies, fuel, and a liberal allowance for depreciation on the outfits used, it should be possible to spray roadsides for about $2 an acre.

If spraying could be relied on to control the gipsy moth, the problem would be greatly simplified, but unfortunately it is impossible to destroy all the caterpillars by spraying, and it is usually necessary to supplement the work either with burlap or tanglefoot, and to creosote all of the egg clusters that can be located during the winter. The cost of these methods is difficult to determine, as there is much variation in expense owing to the character of the infestation, the size of trees, and the locality in which the work is to be done. In general it may be said that woodland can be pruned, egg clusters creosoted, and brush cut and burned for $25 to $30 an acre; tanglefoot applied and tended for the season for $5 to $6; sprayed for $2 to $10; creosoted the following winter for $5, and should be kept free from injury by the gipsy moth for $2 an acre for each year thereafter.

VALUE OF NATURAL ENEMIES IN CONTROLLING GIPSY AND BROWN-TAIL MOTHS.

The influence exerted by native birds and insect enemies of the gipsy and brown-tail moths in this country has already been mentioned. As soon as the work was resumed by the State of Massachusetts, it was found that in some sections of the territory infested by the brown-tail moth large numbers of caterpillars were dying from a fungous disease. The matter was investigated by assistants employed by Mr. Kirkland in 1906, and specimens of the disease-bearing caterpillars were referred to Dr. Geo. E. Stone, botanist of the Massachusetts agricultural college, who stated that the cause of the death of the caterpillars was a fungus known as *Empusa aulicæ* Reichardt. This disease destroyed millions of caterpillars during the spring and early summer of 1906, and it has been found quite frequently since that time in Massachusetts, New Hampshire, and Maine. It works on both small caterpillars in the webs and the larger ones which feed during the early summer. This has assisted in checking the increase of the insect, especially in the sections of Massachusetts where it first became seriously injurious. The development of this fungus is influenced largely by weather conditions and during some years it has not greatly reduced the number of caterpillars.

During the past two or three years large numbers of caterpillars of the gipsy moth have died from a disease which is popularly known as the "wilt" or caterpillar cholera. This has been prevalent particularly in badly infested areas, especially in woodland, where many of the trees have been nearly defoliated. It seems to develop more rapidly on caterpillars which have not had sufficient nourishment, although in some places it was present where a considerable amount of foliage remained. The caterpillars attacked by this trouble become sluggish and soon die, the inside of the body becoming semiliquid and putrid. When the cholera is prevalent, the trunks of trees below tanglefoot or burlap bands, where the caterpillars congregate, are sometimes completely covered with dead or dying larvæ. Isolated cases of caterpillars that had died from this disease were observed previous to the year 1900, but at that time the insects killed by it were relatively few. This trouble, which is supposed to be a disease known as "flacherie," was recognized as fatal to the silkworm many years ago.

Both of the diseases above mentioned are being carefully investigated by specialists of Harvard University in cooperation with the office of the Massachusetts state forester.

THE INTRODUCTION OF PARASITES AND NATURAL ENEMIES OF THE GIPSY AND BROWN-TAIL MOTHS.

Although the work of introducing parasites and natural enemies of the gipsy and brown-tail moths is entirely separate from the field work which is being carried on for the control of the insects mentioned, a brief statement is made concerning it, as it has an enormous practical bearing on the problem at hand.

It is evident that if the natural enemies of these insects can be introduced into the infested district in large numbers and be able to survive our climatic conditions and reproduce in the same ratio that they do in their native homes, it should be possible by this means to largely curtail the destruction that is now prevalent in New England. An effort in this direction has been carried on for the past four years by the Bureau of Entomology in cooperation with the State of Massachusetts, and Dr. L. O. Howard, Chief of the Bureau, has had the matter in charge.

A considerable number of parasites and natural enemies have been received and liberated, and conditions at the present time seem to warrant the hope that eventually much good will result from this work. It should be borne in mind, however, by some of those who are overenthusiastic as to the possibilities of controlling the insect pests by means of their parasites or natural enemies, that few cases are on record where work of this sort has been entirely effectual. Furthermore, it should be pointed out that the gipsy moth was liberated in this country nearly twenty years before it became such a serious pest as to cause widespread notice and the adoption of active measures for its suppression. This being the case, it will undoubtedly be several years before it will be possible to notice definite results from the reproduction of parasites in the field, and until it has been demonstrated that natural enemies can control the situation it is folly to curtail the amount of hand work which is being employed for the destruction of these pests.

VALUE OF THE WORK OF SUPPRESSION TO THE FARMER AND FRUIT GROWER.

From what has been already mentioned in this report it must be apparent that the strenuous effort being made to control the spread of the gipsy and brown-tail moths is of great value to farmers and fruit growers, especially to those who live outside the infested district. Should these insects spread over the United States and cover the same range which they now occupy in foreign countries the cost of controlling them and the damage which would result to orchards and to forest and shade trees would be enormous. The more progressive citizens throughout the country who understand the situation must appreciate the danger of the spread of these pests and are undoubtedly in sympathy with the work which is being carried on to restrict their increase. The residents of the infested district who have seen the devastation caused understand the necessity for thorough and persistent work if the trees are to be preserved. (See Pl. XII.) This is especially true in cities and towns where most of the shade trees have a desperate struggle to maintain an existence and where, owing to unfavorable conditions for tree growth, it is difficult to replace trees which have died from any cause. The hand methods of suppression which are being used are the best that have been devised and new or more effective methods are eagerly sought for by all who have a hand in managing the work.

The introduction of parasites and natural enemies, and the study and attempt to make use of the diseases of the insect which are known to exist, are being pushed as rapidly as possible. Both branches of the work are being conducted for the ultimate benefit of the property owners in the infested district and for the protection of all those who are fortunate enough to reside beyond its limits. The cost of protecting trees from such well-known insects as the San Jose scale, the codling moth, the elm leaf-beetle, and many other insects which prey upon them in more or less restricted localities throughout the United States, represents an enormous annual expenditure of money. This cost is ultimately met by the consumer of the products, and in the moth-infested district (fig. 19) by the tenant who lives on the property where treatment is applied.

SUGGESTIONS TO THE OWNERS OF PRIVATE PROPERTY IN THE INFESTED DISTRICTS.

It is evident that little progress can be made in controlling such insects as the gipsy and brown-tail moths without the hearty cooperation and intelligent interest of owners of private property in the infested districts. As a rule, owners have shown great appreciation of the work which is being carried on and many have expended large sums of money in caring for the trees on their own property. In sec-

VIEW SHOWING CONTRAST BETWEEN TREES PROTECTED FROM THE GIPSY AND BROWN-TAIL MOTHS AND THOSE UNPROTECTED. (ORIGINAL.)

[The tree at the left is an oak defoliated by brown-tail caterpillars and containing many of their webs at tips of branches.]

tions which are now only slightly infested less interest is taken in the matter because of the fact that few of the citizens thoroughly understand the damage which these pests are capable of inflicting.

Owners of orchards are advised that if modern methods of horticultural practice are adopted it is possible to put their trees on a paying commercial basis in spite of the presence of these insects.

Too many New England orchards yield no great revenue at the present time because of neglect, which is either due to lack of interest in caring for the trees or to ignorance of the possibility of making them sources of revenue. (See fig. 20.) Few intelligent farmers expect to harvest a profitable crop of potatoes without giving the land proper culture and treating the vines to protect them from the ravages of the potato beetle, and if the owner of fruit trees expects an income from this source he must give his orchards the best of care and protect the trees and fruit from the many insect enemies which prey upon them. The orchards of New England should be thoroughly pruned and trees which do not yield good varieties of fruit or which are in poor condition should be cut down and burned. Those remaining should be sprayed to destroy the insect pests which already attack them, and if the gipsy and brown-tail moths are present the additional expense of fighting them will not prevent the growing of a profitable crop.

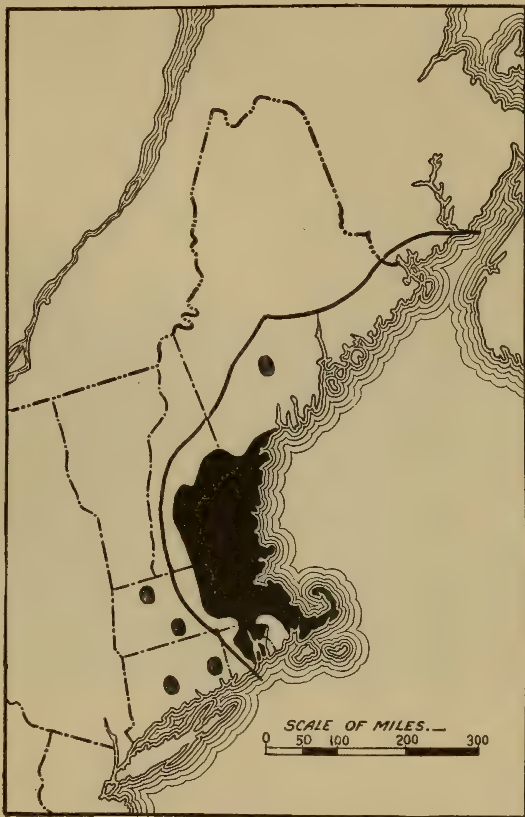


FIG. 19.—Map of New England, showing present area infested with the gipsy moth and the brown-tail moth. The black area is that infested with the gipsy moth; the brown-tail moth occupies all of the area to the right of the black line. (Original.)

Owners of woodland on which the trees are of marketable size should cut the timber if the gipsy moth is prevalent in the region. Care should be taken in doing this work to cut out all poor and worthless trees, and if possible to leave for reforesting purposes vigorous specimens of ash, maple, pine, or coniferous trees of which the insect is not especially fond and which can be protected with the least possible expense. (See fig. 21.)

The planting or preservation of ash and hickory is recommended as the wood is of high value and these trees are not subject to attack by the brown-tail moth. Planting pine or other coniferous trees for reforesting purposes is also advisable, as the region is suited to their growth and these can be protected from moth injury at slight expense.

It is probable that many of the forests containing oak or other trees which are preferred by these insects must in time give way to species less subject to attack. In the meantime the owner should take advantage of the opportunity to harvest his merchant-

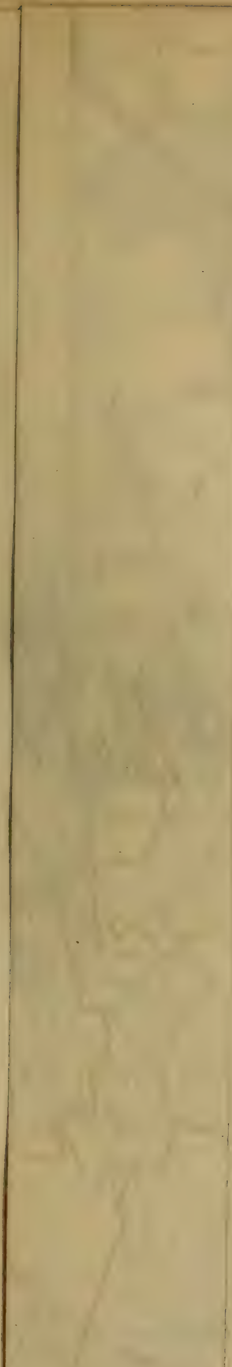
FIG. 20.—Neglected apple orchard in which the trees have been killed by the gipsy moth. (Original.)

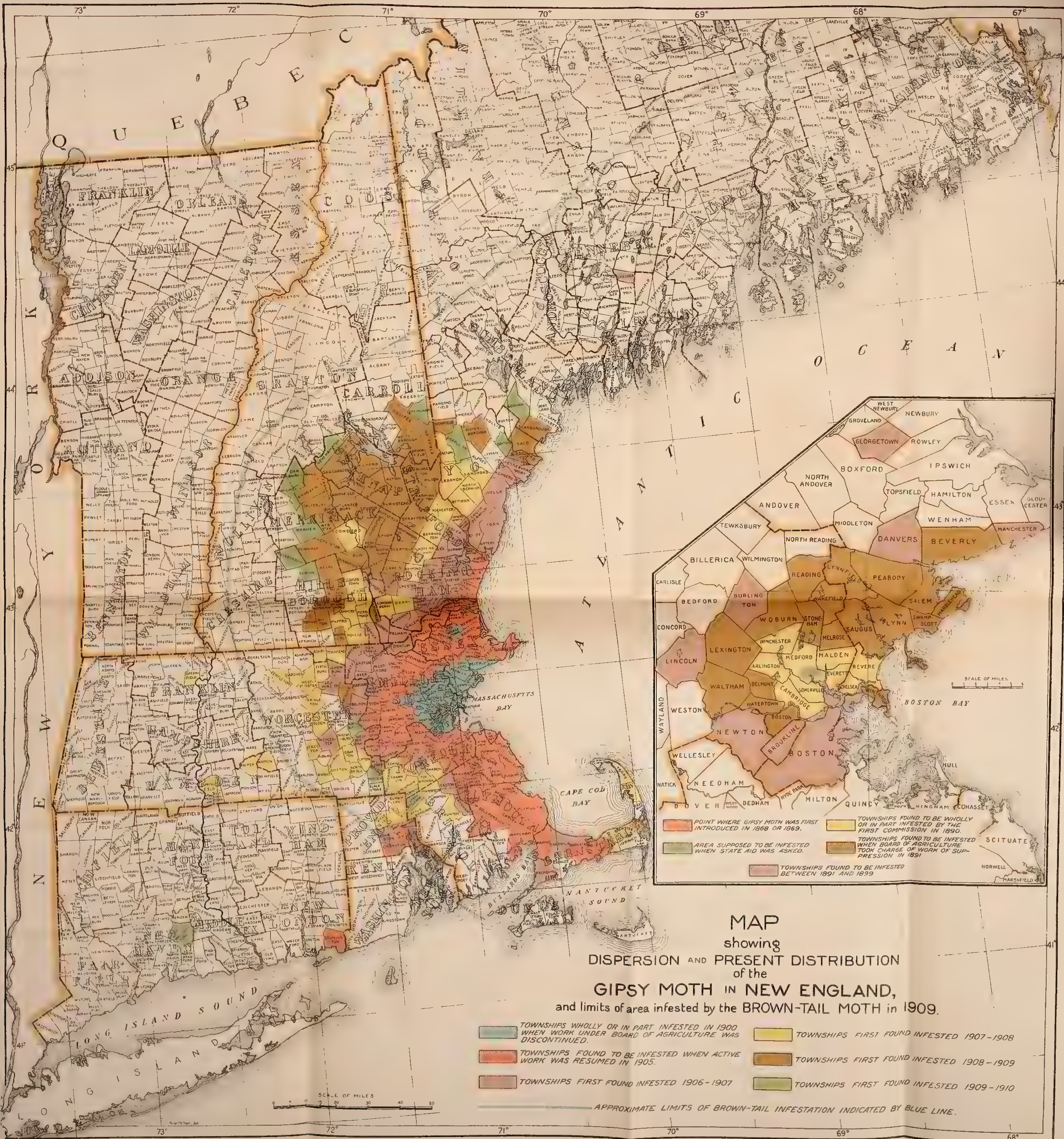
able trees that are susceptible to attack and foster the growth of other species that will not be destroyed.

In cities and towns much progress can be made by cutting out neglected areas of worthless trees and in some sections the number of trees on the streets or on private property can be reduced and still provide as much shade as is desirable. If this work is intelligently done no injury will result to the property; in fact, a direct benefit will accrue and the cost of future work required to hold the moths within reasonable bounds will be greatly decreased.

THE OUTLOOK.

At the time the work on the gipsy moth was abandoned by the State of Massachusetts in 1900, over $1,000,000 had been spent in an attempt to exterminate the pest. Since the work was resumed in 1905 nearly $4,000,000 has been expended by the different States in


70°


MAP
showing
DISPERSION AND PRESENT DISTRIBUTION
of the
GIPSY MOTH IN NEW ENGLAND,
and limits of area infested by the BROWN-TAIL MOTH in 1909.
TOWNSHIPS WHOLLY OR IN PART INFESTED IN 1900 WHEN WORK UNDER BOARD OF AGRICULTURE WAS DISCONTINUED.
TOWNSHIPS FOUND TO BE INFESTED WHEN ACTIVE WORK WAS RESUMED IN 1905.
TOWNSHIPS FIRST FOUND INFESTED 1906-1907
TOWNSHIPS FIRST FOUND INFESTED 1907-1908
TOWNSHIPS FIRST FOUND INFESTED 1908-1909
TOWNSHIPS FIRST FOUND INFESTED 1909-1910
APPROXIMATE LIMITS OF BROWN-TAIL INFESTATION INDICATED BY BLUE LINE.
POINT WHERE GIPSY MOTH WAS FIRST INTRODUCED IN 1868 OR 1869.
AREA SUPPOSED TO BE INFESTED WHEN STATE AID WAS ASKED.
TOWNSHIPS FOUND TO BE WHOLLY OR IN PART INFESTED BY THE FIRST COMMISSION IN 1890.
TOWNSHIPS FOUND TO BE INFESTED WHEN BOARD OF AGRICULTURE TOOK CHARGE OF WORK OF SUPPRESSION IN 1891
TOWNSHIPS FOUND TO BE INFESTED BETWEEN 1891 AND 1899
SCALE OF MILES
QUEBEC
NEW YORK
ATLANTIC OCEAN
LONG ISLAND SOUND
LONG ISLAND
MASSACHUSETTS BAY
CAPE COD BAY
NANTUCKET SOUND
BOSTON BAY

New England, which are infested with the gipsy or brown-tail moths, by private property owners, and by the United States Government, in an attempt to suppress them and to prevent their further dissemination. Every known means which promised good results in accomplishing this end has been tried in the field. The best methods of hand suppression have been carried on extensively and foreign countries have been literally ransacked for parasitic and predaceous enemies of the moths in the hope that they may in due time develop into a most important factor in checking the ravages of these insects. Owing to the ability of both sexes of the brown-tail moth to fly considerable distances, it has been impossible to prevent its rapid spread to new localities (see fig. 22), but the methods employed in the worst

FIG. 21.--View of a hill where all the timber was cut to prevent its destruction by the gipsy moth; pile of logs in the foreground. (Original.)

infested sections have afforded a large amount of relief from the injury which this insect causes.

Each year more or less territory has been found infested by the gipsy moth where the pest was not previously known to exist, so that the territory now known to be infested covers in the aggregate about 7,900 square miles. (See Pl. XIII.) At a conservative estimate three-fourths of this area consists of wooded land, while the balance is made up of residential sections, orchards, and farm lands. While the States in the infested section and the United States Government have done much work in the residential sections and along some of the principal roadways, it has been impossible to inspect the large forest area so as to determine the present state of infestation. So long as some of these areas remain badly infested it is difficult to prevent further dissemination of the gipsy moth. The methods adopted of keeping roadways clear has undoubtedly been a factor in preventing many colonies from becoming established at distant points, but although nearly 250 miles of roadways have been treated in this manner in Massachusetts, there is still a very large mileage of trunk roads which can not be given proper attention with the funds at hand. The need of more work in the infested area is very urgent, as this is the only possible way to prevent the continued spread of the insect

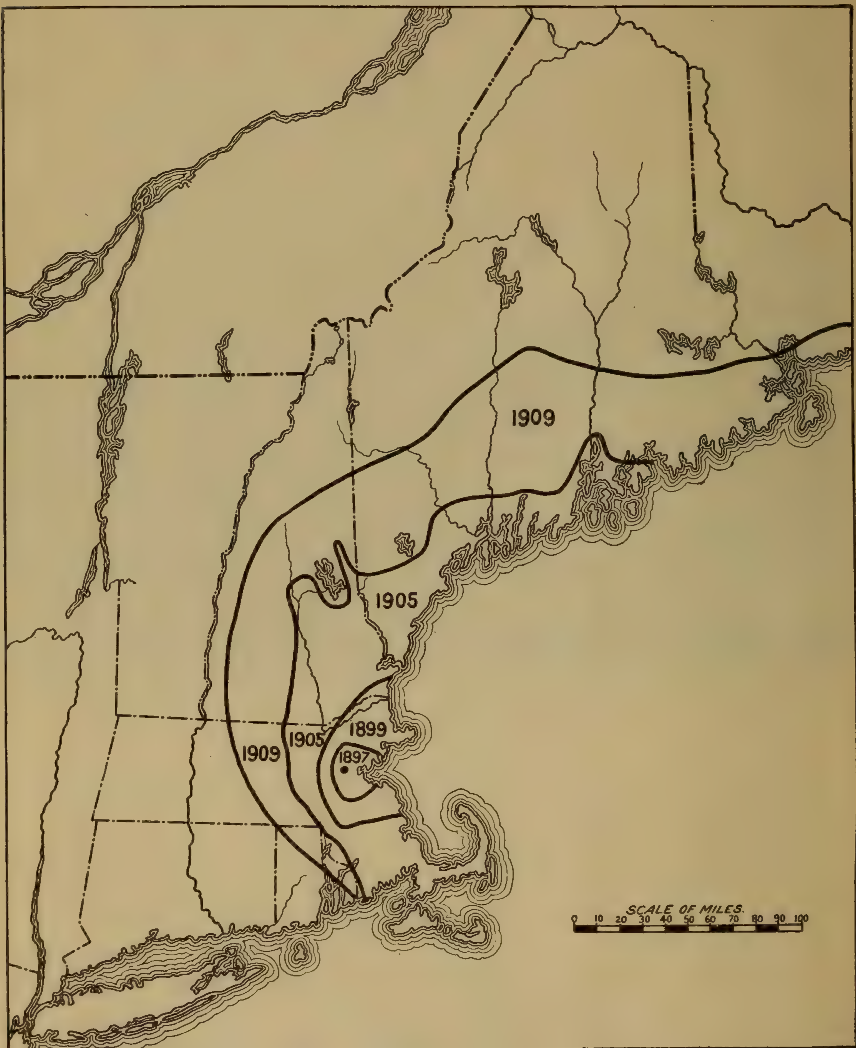


FIG. 22.—Map of New England, showing areas infested by the brown-tail moth from 1897 to 1909. (Original.)

until the parasites and natural enemies which are being introduced have an opportunity to show their capacity for reducing the pest. The importance of the work against this insect extends beyond state lines or sectional lines and should receive the cordial support of all who are interested in agriculture, horticulture, or forestry.

THE MORE IMPORTANT AMERICAN PUBLICATIONS ON THE GIPSY AND BROWN-TAIL MOTHS.

1889. Fernald, C. H.—Ocneria dispar, Notes.<Spec. Bul. Mass. Agr. Coll. Hatch Exp. Sta., pp. 3–8, figs. 4, November.

1892. Forbush, E. H., and Fernald, C. H.—Special report of the state board of agriculture on the work of extermination of the *Ocneria dispar* or gypsy moth. <39th Ann. Rep. Sec. Mass. State Bd. Agr., 1891, pp. 287–312, pls. 5. Boston.

1892. Fernald, C. H.—Report on insects. The gypsy moth (*Ocneria dispar*, L.). <Bul. 19, Mass. Agr. Coll. Hatch Exp. Sta., pp. 109–116. (Illustrated.)

1893. Forbush, E. H., and Fernald, C. H.—Report of the state board of agriculture on the work of extermination of the gypsy moth.<40th Ann. Rep. Sec. Mass. State Bd. Agr., 1892, pp. 259–297. (Illustrated.) Boston.

1894. Forbush, E. H., and Fernald, C. H.—Report of the state board of agriculture on the work of extermination of the gypsy moth.<41st Ann. Rep. Sec. Mass. State Bd. Agr., 1893, pp. 263–302, pls. 6, map. Boston.

1895. Forbush, E. H., and Fernald, C. H.—Report of the state board of agriculture on the work of extermination of the gypsy moth.<42d Ann. Rep. Sec. Mass. State Bd. Agr., 1894, pp. 235–270, pls. 5. Boston.

1896. Forbush, E. H., and Fernald, C. H.—The gypsy moth. *Porthetria dispar* (Linn.). Published under direction of the Massachusetts state board of agriculture. Boston. pp. 495 and appendices pp. i–c, pls. 66, maps 5, figs.

1896. Forbush, E. H., and Fernald, C. H.—Report of the state board of agriculture on the work of extermination of the gypsy moth.<43d Ann. Rep. Sec. Mass. State Bd. Agr., 1895, pp. 199–237, pls. 3. Boston.

1897. Fernald, C. H., and Forbush, E. H.—Report of the state board of agriculture on the work of extermination of the gypsy moth.<44th Ann. Rep. Sec. Mass. State Bd. Agr., 1896, pp. 349–433. (Illustrated.) Boston.

1897. Howard, L. O.—The gipsy moth in America.<Bul. 11, new series, Div. Ent., U. S. Dept. Agr., pp. 39, figs. 8.

1897. Fernald, C. H., and Kirkland, A. H.—The brown-tail moth.<Spec. Bul. Mass. Agr. Coll. Hatch Exp. Sta., pp. 15, fig. 1, pls. 4.

1898. Fernald, C. H., and Forbush, E. H.—Report of the state board of agriculture on the work of extermination of the gypsy moth.<45th Ann. Rep. Sec. Mass. State Bd. Agr., 1897, pp. 305–439. (Illustrated.) Boston.

1899. Fernald, C. H., and Forbush, E. H.—Report of the state board of agriculture on the work of exterminating the gypsy moth.<46th Ann. Rep. Sec. Mass. State Bd. Agr., 1898, pp. 409–481, figs. 2, pls. 11. Boston.

1900. Fernald, C. H., and Kirkland, A. H.—Report of the state board of agriculture on the work of exterminating the gypsy moth.<47th Ann. Rep. Sec. Mass. State Bd. Agr., 1899, pp. 339–388, pls. 7. Boston.

1901. Report of the state board of agriculture on the work of extermination of the gypsy moth.<48th Ann. Rep. Sec. Mass. State Bd. Agr., 1900, pp. 353–369. Boston.

1902. Report of committee on gypsy moth, insects and birds.<49th Ann. Rep. Sec. Mass. State Bd. Agr., pp. 313–319. Boston.

1903. Report of committee on gypsy moth, insects and birds.<50th Ann. Rep. Sec. Mass. State Bd. Agr., 1902, pp. 265–271, pl. 1. Boston.

1903. Fernald, C. H., and Kirkland, A. H.—The brown-tail moth (*Euproctis chrysorrhœa* L.) Published by Massachusetts state board of agriculture. Boston. pp. 73, pls. 14.

1905. Marlatt, C. L.—Report on the gypsy moth and the brown-tail moth, July, 1904.<Cir. 58, Bur. Ent., U. S. Dept. Agr., pp. 12, pl. 1, map 1.

1905. SANDERSON, E. D.—The gypsy moth in New Hampshire.<Bul. 121, N. H. Coll. Agr. Exp. Sta., pp. 81–104, figs. 11, December.

1905. HITCHINGS, E. F.—The brown-tail moth in Maine.<Quart. Bul. Maine Dept. Agr., vol. 4, No. 4, pp. 101–127, December. (Illustrated.)

1906. BRITTON, W. E.—The gypsy moth in Connecticut.<5th Rep. State Ent. Conn. f. 1905, pp. 246–252, figs. 2–6.

1906. KIRKLAND, A. H.—First annual report of the Massachusetts superintendent for suppressing the gypsy and brown-tail moths. Public Document No. 73, January, 1906. Boston. pp. 161.

1906. HITCHINGS, E. F.—First annual report of the state entomologist on the brown-tail moth and other insect pests of the State of Maine, 1905, pp. 21. (Illustrated.)

1906. FELT, E. P.—The gypsy and brown-tail moths.<Bul. 103, N. Y. State Mus., pp. 20, pls. 10.

1907. KIRKLAND, A. H.—Second annual report of the Massachusetts superintendent for suppressing the gypsy and brown-tail moths. Public Document No. 73, January, 1907. Boston. pp. 170. (Illustrated.)

1907. HITCHINGS, E. F.—The gypsy moth in Maine.<2d Ann. Rep. State Ent. on the gypsy and brown-tail moths and other insect pests of the State of Maine, 1906, pp. 9–20, pl. 1, figs.

1907. HITCHINGS, E. F.—The brown-tail moth (*Euproctis chrisorrhoea*).<2d Ann. Rep. State Ent. on the gypsy and brown-tail moths and other insects pests of the State of Maine, pp. 21–26, fig. 6.

1907. STENE, A. E.—Report of the Rhode Island commissioner for the suppression of the gypsy and brown-tail moths for the year 1906. Providence. pp. 80, pls. 28.

1907. BRITTON, W. E.—Gypsy moth work in Connecticut.<6th Rep. State Ent. Conn. f. 1906, pp. 235–260, map, figs. 2–7, pls 3–10.

1908. HITCHINGS, E. F.—Brown-tail and gypsy moths.<3d Ann. Rep. State Ent. on the gypsy and brown-tail moths and other insect pests of the State of Maine, 1907, pp. 14–56, figs. 8–14, pls. 1, 6–20.

1908. STENE, A. E.—Report of the Rhode Island superintendent for the suppression of the gypsy and brown-tail moths for the year 1907. Providence. pp. 52, figs. 2, pls. 10.

1908. BRITTON, W. E.—Progress of the work of controlling the gypsy moth in Connecticut. 7th Rep. State Ent. Conn. f. 1907, pp. 300–312, pls. 7–13.

1908. BRITTON, W. E.—The brown-tail moth (*Euproctis chrysorrhaea* Linn.).<7th Rep. State Ent. Conn. f. 1907, pp. 313–318, figs. 1–4, pl. 14.

1908. SANDERSON, E. D.—The gipsy and brown tail moths in New Hampshire.<Bul. 136, N. H. Agr. Exp. Sta., pp. 156, figs. 34, February.

1908. KIRKLAND, A. H.—Third annual report of the Massachusetts superintendent for suppressing the gypsy and brown-tail moths. Public Document No. 73, January, 1908. Boston. pp. 228. (Illustrated.)

1909. BRITTON, W. E.—Account of progress in suppressing the gypsy moth in Connecticut.<8th Rep. State Ent. Conn. f. 1908, pp. 772–777, pls. 42, 43.

1909. WORTHLEY, L. H.—Fourth annual report of the Massachusetts superintendent for suppressing the gypsy and brown-tail moths. Public Document No. 73, January, 1909. Boston. pp. 75. (Illustrated.)

INDEX.

Page.

Apple, preferred food plant of gipsy moth 14, 74
Arsenate of lead against elm leaf-beetle 65
    gipsy moth 17, 40–41, 64–69
Ash for reforesting purposes in district infested by gipsy moth 64
    practically immune from attack by gipsy moth 14, 74
Bands, sticky, against the gipsy moth 18
Birds, enemies of gipsy moth and brown-tail moth 26, 27
Brown-tail hairs, poisoning effect 24, 26
    moth, adults, description and life history 23, 24
        and gipsy moth field work by State of Massachusetts 47–49
            cost of methods employed 69–70
            experiments 60–62
            inspection of lumber and forest products 57–60
            in the State of Connecticut 56–57
                Maine 50–52
                New Hampshire 53–54
                Rhode Island 54–56
            introduction to report 9
            suggestions to owners of private property in infested districts 72–74
            value to farmer and fruit grower 72
        danger of introduction from foreign countries 60–62
        discovery in America 20
        eggs, description and life history 21
        European history 21
        experimental work in control 62–63
        flight 23–24
        larvæ, description and life history 21–22
        life history 21–24
        Massachusetts Act for suppressing it 31–35
        National work against it begun 37–47
        natural enemies native to America 26–27
            value 70–71
        outlook for control 74–76
        parasites and natural enemies, introduction 71
        publications in America treating of it 77–78
        pupæ, description and life history 22–23
        winter webs 22
"Brown-tail rash" 24–26
Burlapping against the gipsy moth 17–18
Burning and cutting against the gipsy moth 18

Page.
Carabidæ, enemies of gipsy moth and brown-tail moth.......... 27
Cedar, red, practically immune from attack by gipsy moth.......... 14
"Cholera" of gipsy-moth caterpillars.......... 70–71
Conifers, food plants of gipsy moth.......... 14
Corn, food plant of gipsy moth.......... 14
Creosote against gipsy moth egg-masses.......... 19–20, 41, 43
Crow, factor in dissemination of gipsy moth.......... 27
Cutting and burning against gipsy moth.......... 18
Dipterous parasites of gipsy moth and brown-tail moth.......... 27
Elm leaf-beetle, arsenate of lead as remedy.......... 65
Empusa aulicæ, fungus enemy of brown-tail caterpillars.......... 70
Euproctis chrysorrhœa. (*See* Brown-tail moth.)
"Flacherie" affecting larvæ of gipsy moth.......... 70–71
Forest products and lumber, inspection against gipsy moth and brown-tail moth.......... 57–60
Fungous disease of brown-tail caterpillars.......... 70
Galerucella luteola. (*See* Elm leaf-beetle.)
Garden crops, sometimes eaten by gipsy moth caterpillars.......... 14
Gipsy moth, adults, description and life history.......... 16
and brown-tail moth field work by State of Massachusetts.......... 47–49
cost of methods employed.......... 69–70
experiments.......... 60–62
inspection of lumber and forest products.......... 57–60
in the State of Connecticut.......... 56–57
Maine.......... 50–52
New Hampshire.......... 53–54
Rhode Island.......... 54–56
introduction to report.......... 9
suggestions to owners of private property in infested districts.......... 72–74
value to farmer and fruit grower. 72
conditions in infested territory at close of Massachusetts state work, 1900.......... 29
danger of introduction from foreign countries.......... 60–62
egg clusters, method of destruction.......... 19
eggs, description and life history.......... 12
experimental work in control.......... 62–63
importance as an insect pest in this country.......... 9–10
introduction and spread in this country.......... 9–10
larvæ, description and life history.......... 13–15
in younger stages can not eat pine.......... 62–63
life history.......... 12–16
Massachusetts Act for suppressing it.......... 31–35
methods formerly employed in work against it.......... 16–20
now used in fighting it.......... 63–70
National work against it begun.......... 37–47
natural enemies native to America.......... 26–27
value.......... 70–71
outlook for control.......... 74–76
parasites and natural enemies, introduction.......... 71
publications in America treating of it.......... 77–78
pupæ, description and life history.......... 15

	Page.
Gipsy moth, record of it in its native home	11–12
state work against it in Massachusetts, 1890–1900	11
discontinuance	28–29
discontinuance, results	30–31
funds expended	29
progress made	27–28
resumption	31–37
Grass, sometimes eaten by gipsy moth caterpillars	14
Hemlock, food plant of gipsy moth	15
Hickory for reforesting purposes in district infested by gipsy moth	74
Hymenopterous parasites of gipsy moth and brown-tail moth	27
Insect enemies of gipsy moth and brown-tail moth native to America	26–27
Juniper, practically immune from attack by gipsy moth	14
Lumber and forest products, inspection against gipsy moth and brown-tail moth	57–60
Maple for reforesting purposes in district infested by gipsy moth	74
not a preferred food plant of gipsy moth	14, 74
Oak, preferred food plant of gipsy moth	14
Ocneria dispar. (*See* Gipsy moth.)	
Orchards, proper treatment in districts infested by gipsy moth and brown-tail moth	73
Pentatomidæ, enemies of gipsy moth and brown-tail moth	27
Pine for reforesting purposes in districts infested by gipsy moth	74
not eaten by small gipsy moth caterpillars	62–63, 74
white, food plant of gipsy moth	14–15
Porthetria dispar. (*See* Gipsy moth.)	
Pruning against gipsy moth	19
Scouting against gipsy moth	16–17
Sparrow, English, enemy of brown-tail moth	24
Spraying against gipsy moth	17
improvements in machinery	63
outfits now used	65–68
Spruce, food plant of gipsy moth	15
Tanglefoot, use against gipsy moth	39–40, 63–64
Toad, enemy of gipsy moth and brown-tail moth	27
Willows, preferred food plants of gipsy moth	14
"Wilt," disease of gipsy moth caterpillars	70-71

O

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN NO. 88.

L. O. HOWARD, Entomologist and Chief of Bureau.

PREVENTIVE AND REMEDIAL WORK AGAINST MOSQUITOES.

BY

L. O. HOWARD, Ph. D.,

Chief of Bureau.

Issued June 20, 1910.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1910.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN NO. 88.

L. O. HOWARD, Entomologist and Chief of Bureau.

PREVENTIVE AND REMEDIAL WORK AGAINST MOSQUITOES.

BY

L. O. HOWARD, Ph. D.,

Chief of Bureau.

Issued June 20, 1910.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1910.

BUREAU OF ENTOMOLOGY.

L. O. HOWARD, *Entomologist and Chief of Bureau.*
C. L. MARLATT, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. CLIFTON, *Executive Assistant.*
W. F. TASTET, *Chief Clerk.*

F. H. CHITTENDEN, *in charge of truck crop and stored product insect investigations.*
A. D. HOPKINS, *in charge of forest insect investigations.*
W. D. HUNTER, *in charge of southern field crop insect investigations.*
F. M. WEBSTER, *in charge of cereal and forage insect investigations.*
A. L. QUAINTANCE, *in charge of deciduous fruit insect investigations.*
E. F. PHILLIPS, *in charge of bee culture.*
D. M. ROGERS, *in charge of preventing spread of moths, field work.*
ROLLA P. CURRIE, *in charge of editorial work.*
MABEL COLCORD, *librarian.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., March 29, 1910.

Sir: I have the honor to transmit herewith the manuscript of a bulletin on preventive and remedial work against mosquitoes.

It is my hope, with your approval, to follow this with four other bulletins and a circular, all relating to mosquitoes, and to prepare the series in such a way as to bring about a measurably complete consideration of these annoying and dangerous insects for North America.

I respectfully recommend that this manuscript be published as Bulletin No. 88 of this Bureau.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

	Page.
Introduction	7
Protection from bites	12
Protective liquids	12
Screens and canopies	14
Screening breeding places	18
Abolition of breeding places	19
Deterrent trees and plants	22
Eucalyptus	22
Castor-oil plant	23
Chinaberry trees	25
Other plants	25
Peat	27
Water plants	27
Smudges and fumigants	30
Pyrethrum or chrysanthemum	30
Mimms Culicide	33
Pyrofume	34
Sulphur dioxid	35
Other fumigants	37
Mercuric chlorid	39
Apparatus for catching adult mosquitoes	40
Remedies for mosquito bites	41
Drainage measures	42
The California work	44
The New Jersey work	47
The value of reclaimed lands	53
General reclamation work	53
Salt-marsh lands in New Jersey	59
The practical use of natural enemies of mosquitoes	62
Salamanders, dragonflies, predaceous mosquitoes, and fish	62
Fish introduced into Hawaii to abate mosquitoes	68
Fish in the West Indies	69
Fish in German East Africa	70
A Brazilian fish	71
Mr. Thibault's observations	72
Destruction of larvæ	72
Organization for community work	80
The importance of interesting children	86
Recent work in Germany	87
Work along river fronts in Egypt	88
Examples of mosquito exterminative measures in different parts of the world and of the sanitary results following them	89
Federated Malay States	89
The work in Habana during the American occupation, 1901–2	92

	Page.
Examples of mosquito exterminative measures, etc.—Continued.	
Work at the Isthmus of Panama	93
Work in Rio de Janeiro	95
Work in Algeria	98
Work in Ismailia	100
Work in Veracruz	100
Work in Japan	102
Antimosquito work in other parts of the world	104
Conclusion	114
Index	117

PREVENTIVE AND REMEDIAL WORK AGAINST MOSQUITOES.

INTRODUCTION.

For many centuries humanity has endured the annoyance of mosquitoes without making any intelligent effort to prevent it except in the use of smudges, preparations applied to the skin, and in removal from localities of abundance. And it is only within comparatively recent years that widespread community work against mosquitoes has been undertaken, this having resulted almost directly from the discoveries concerning the carriage of disease by these insects.

As obvious a procedure as it might seem to be, the abolition of mosquito-breeding places is a comparatively new idea. The treatment of breeding places with oil to destroy the larval forms is, however, by no means recent. As early as 1812 the writer of a work published in London entitled "Omniana or Horæ Otiosiores" suggested that by pouring oil upon water the number of mosquitoes may be diminished. It is stated that in the middle of the nineteenth century kerosene was used in France in this way, while in the French quarter in New Orleans oil was placed in water tanks before the civil war, the idea having possibly come from France to New Orleans or vice versa.

Another early recommendation of the use of oil was given by an anonymous writer in the Magazin Pittoresque,[a] in an article on the "Mosquito and Its Metamorphoses." The phraseology translated into English is as follows:

> When one has recognized that the ponds or ditches existing close to houses are swarming with the larvæ of mosquitoes, one can immediately destroy this dangerous race by spreading on the surface a little oil, which extends in a very thin film and prevents the little insects from coming up to breathe. This proceeding is especially easy to put into practice upon the irrigating tanks in gardens, since it is in such places that the greatest number of mosquitoes develop.

Again, quite recently, Mr. John P. Fort, of Athens, Ga., has communicated to the writer that about the year 1854, while his father, Dr. Thomlinson Fort, was physician to the penitentiary at Milledgeville, Ga., a place of about 2,000 people, the institution had become so infested with mosquitoes as to cause much complaint. Doctor

[a] Vol. 15, pp. 178–182, 1846.

Fort had the matter investigated, and it was found that the mosquitoes originated in the tan vats of a tanyard in the penitentiary and in a large cistern attached to the livery stable in the city. He ordered oil to be put upon the water in the tan vats and the mosquitoes were destroyed.

In 1892 some exact experimentation was undertaken by the writer in Green County, N. Y., which indicated the amount of kerosene necessary for a given water surface, and the duration of efficiency. These experiments also showed that adult mosquitoes are captured by a kerosene film—that is to say, adult females alighting on the surface of the water for the purpose of depositing eggs or for drinking are destroyed by the kerosene before the eggs are laid. The account of these experiments, published in Insect Life,[a] attracted much attention by persons interested and received extended newspaper notices, from which it resulted that practical work on a larger or smaller scale was carried on with success by H. E. Weed, at the Mississippi Agricultural College; by Dr. John B. Smith, on Long Island; by Prof. V. L. Kellogg, on the campus of the Stanford University of California; by Rev. John D. Long, at Oak Island Beach, Long Island Sound; by Mr. W. R. Hopson, near Stratford, Conn.; by Mr. R. M. Reese, in Baltimore; by Mr. W. C. Kerr, on Staten Island; by Mr. M. J. Wightman, at an Atlantic coast resort; and by Dr. St. George Gray, in the British West Indies. The publication of the extensive mosquito article in the bulletin on household insects[b] by the writer and Mr. Marlatt intensified this interest, and was productive of other successful work.

With the discovery of the disease-bearing relation of mosquitoes, first with malaria and next with yellow fever, public interest in their destruction became intensified, and large-scale remedial work was done at many points. Bulletin No. 25,[c] by the writer, devoted considerable space to the subject of remedies, and indicated in the main those remedies which are of use to-day and are to be recommended upon a sound basis of practical experimentation. It is probably unfortunate that the writer in this bulletin laid so much stress upon the use of petroleum as to obscure in a way the much more vital measures of thorough drainage and the complete abolition of breeding places; but the idea that was prominent in his mind at the time the bulletin was written was "Let us stop mosquito breeding at once in an economical way, and then let us take our time in more expensive, more elaborate, and more radical measures." The same criticism can be made and the same partial, though by no means

[a] Vol. 5, No. 1, pp. 12–14, September, 1892.
[b] Bul. 4, n. s., Div. Ent., U. S. Dept. Agr., 1896.
[c] Bul. 25, n. s., Div. Ent., U. S. Dept. Agr., 1900.

satisfactory, explanation in the case of a book entitled "Mosquitoes,"[a] published in the spring of 1901; but both bulletin and book served a good purpose, and together undoubtedly helped to start, to a great measure, the antimosquito work which has since been carried on in the United States.

Practically beginning with 1901, there has been a rather rapid increase in antimosquito work by individuals and communities, but this work has not progressed with anything like the rapidity demanded by the distressing conditions of many localities and in fact of great areas. Yet it is probably accurate to state that more effective work of this kind has been done in the United States than in any other country. This is probably due to the greater prevalence of mosquitoes in the United States than in any other highly civilized country, but the well-known practical character of the American people is also an element.

During the summer of 1900 Mr. W. J. Matheson carried on some admirable antimosquito work at his large place at Lloyds Neck, Long Island, N. Y. This work was thoroughly done and was most successful, no mosquitoes breeding where they had previously swarmed to such an extent as to render the localities uninhabitable. In the autumn of 1900 there was a migration of salt-marsh mosquitoes to Lloyds Neck from salt marshes bordering on Center Island. Mr. Matheson induced the practical residents of Center Island to take up extensive work during the summer of 1901, and this work was carried through in a very perfect manner by Mr. H. C. Weeks, engineer in charge, and was described in the Century Magazine for July, 1902. In the summer of 1901 was also begun by far the largest piece of work as yet undertaken. It originated on the "Northern Shore" of Long Island, in the regions between Hempstead Harbor and Cold Spring Harbor, and was carried on under the auspices of the North Shore Improvement Association, a group of wealthy and prominent residents of this part of the island. The work during the summer of 1901 included an almost microscopic survey of the region and the preparation of a map showing the breeding places of the several kinds of mosquitoes. It included also the preparation of reports by entomological experts, a report by Professor Shaler, of Harvard University, on marsh areas and related subjects; an account of the work done on Center Island during 1901; and engineering reports, including recommendations for treatment, by Mr. H. C. Weeks. A volume was published in the spring of 1902 entitled "Reports on Mosquitoes, with Map,"[b] which forms a very sound basis for thorough ocean-shore community work for some time to come. Following the survey of the work by the North Shore Improvement Association in 1901 there were carried on by private individuals and by the association in 1902

---

[a] "Mosquitoes." By L. O. Howard. 1901.

[b] New York, 1902.

certain remedial and preventive operations. One of the most interesting of this series was performed on the estate of Mr. W. D. Guthrie. By means of a dike and a sluice gate a large marsh area was drained, and the breeding of the salt-marsh mosquitoes was stopped. A stretch of 75 acres of land was reclaimed and the soil was disintegrated and properly treated, with the result that cabbages, turnips, and celery were grown at the close of the summer of 1902.

The year of 1902 was also marked by the first effort to secure anti-mosquito legislation from one of the United States. The state entomologist of New Jersey, Dr. John B. Smith, backed by an intelligent public sentiment, tried to secure the passage of a bill by the state legislature during the winter of 1901–2, appropriating $10,000 for the purpose of investigating the possibilities of the wholesale destruction of the salt-marsh mosquito and other kinds of mosquitoes. The bill passed one branch of the legislature, but failed in the other branch. The governor of the State, however, was able in other ways to provide Doctor Smith with a limited sum to carry on researches. In this work he discovered a number of most interesting and vitally important facts concerning breeding habits of the salt-marsh mosquitoes, indicating that the breeding places of these species are more or less circumscribed, and that the matter of control is by no means as expensive as it appears at first sight, and it was these discoveries that eventually led to the passage of the law which will be mentioned later.

Admirable community work was taken up during 1901–2 by certain New Jersey towns, notably South Orange, Elizabeth, Montclair, Monmouth Beach, and Summit. Independent work was begun in Greater New York under Doctor Lederle, and the mapping of mosquito breeding places within city limits was begun. Independently, the health officers of Brooklyn, Jamaica, and Bronx Borough began efficient work, while the summer resorts of Arverne and Woodmere reduced the mosquito supply by intelligent operations. At Willets Point intelligent and efficient work was carried out on a small scale. In Massachusetts interesting and important work was done at Brookline and at Worcester. In Brookline the board of health first considered the work in August, 1901, and in September all the breeding places of the malaria mosquito and of the other mosquitoes were treated. In 1902 all pools, ponds, ditches, and other breeding places, including catch-basins, were located on the town map. The approximate areas were determined and the number of catch-basins ascertained. Breeding places of Culex and Anopheles, respectively, were determined, and also the places where both the species were breeding—this being done in order to ascertain the proper intervals for treatment; that is, whether every two weeks or every three weeks. Public dumps and other places where accidental receptacles of water might be found were also located on the maps. Light fuel oil was used on all breeding places. The public dumps were found to be very important in the work, since many accidental receptacles, like bottles, cans, wooden and tin boxes, and the like, were to be found. Where these were breakable, they were simply broken; when not, they were carried and dumped into pools to assist in filling these.

This Brookline work was so thorough that the community was greatly relieved from the mosquito pest, although in the autumn some low meadows near the town, where drainage work had been postponed, were found to be breeding mosquitoes in great numbers.

At Worcester the work was of the most interesting kind. Dr. William McKibben and Dr. C. F. Hodge started the crusade. Breeding places were mapped and photographed and public lectures were given. The school children of the several grades were interested and were organized into searching parties. Many breeding places were filled, and others were treated with kerosene. A strong point was made in Worcester, by those engaged in the crusade, by the prevalence of malaria in many places in the city. The relation between the mosquito-breeding places and the houses where there were malaria patients was effectively pointed out, and a map was prepared showing the exact distribution of malaria in the city, and photographs were made showing the character of the breeding places of the malaria mosquito. It is probable that these Worcester efforts to interest the school children were the first made in this direction, although the idea was carried out to a much greater extent later in San Antonio, Tex., under Doctor Lankford, as will be pointed out on subsequent pages. Other work during the summer was carried on at Pine Orchard and Ansonia, Conn., at Old Orchard Beach, in Maine, and on the campus of the Michigan Agricultural College, in Michigan. Strong efforts were made during the summer to start work at Baltimore, but for a time the city council refused to make appropriations. At Atlanta, Ga., the sanitary department used a large amount of kerosene in the stagnant pools and swampy places around the city, and warned the citizens to watch their rain barrels and keep their gutters open. A great many pools of water were drained, and in the negro quarters of the city the sanitary inspectors were constantly on the lookout for standing water in buckets and other chance receptacles. The matter was taken up with the county commissioners, and the area of preventive measures was extended toward the close of the season. In Savannah some work was done, and the number of mosquitoes reduced very considerably. Oil was used diligently by the sewer-cleaning forces, and was placed in the catch-basins. So great was the relief that many people in Savannah for the first time used no mosquito bars. At Talladega, Ala., under the direction of Dr. B. B. Simms, antimosquito work was commenced early in the season, and was carried out systematically and thoroughly. No place that could possibly prove a breeding place was overlooked. The application of kerosene was repeated several times during the year. St. Louis took up the work early in July, and the municipal assembly made an appropriation for supplies. The health department, however, was hampered for lack of men, and little work was done.

Such were the early steps in the mosquito crusade in this country. Many other communities have taken up the work since 1902. Some, through inefficient work, have allowed their efforts to lapse, and have become more or less indifferent. Others have gone ahead and have spent considerable sums of money in their mosquito fight.

In the early days of mosquito warfare there was great indifference combined with incredulity as to the danger from mosquitoes, even among the medical profession, and particularly in the South. This indifference and incredulity, however, have now, for the most part, passed away. Boards of health very generally appreciate the desirability of antimosquito work, and as rapidly as town councils can be induced to appropriate the necessary funds the work is going ahead.

Excellent antimosquito work has been carried on during the past few years in Honolulu, backed by rather modest funds, under the direction of the then entomologist of the Hawaiian Agricultural Experiment Station, Dr. D. L. Van Dine. In Porto Rico some work is being done, as well as in the Philippines, under the United States Government. In Cuba and in Panama the work has been of a standard character and the operations at these points will be more fully mentioned in subsequent paragraphs.

In other parts of the world many striking examples of the value of antimosquito work have been shown comparatively recently, and several of these will be detailed later.

PROTECTION FROM BITES.

PROTECTIVE LIQUIDS.

A number of different substances have been in use to rub upon the skin or to put near the bed as a protection from mosquitoes. Spirits of camphor rubbed upon the face and hands, or a few drops on the pillow at night, will keep away mosquitoes for a time, and this is also a well-known property of oil of pennyroyal. Oil of peppermint, lemon juice, and vinegar have all been recommended for use as protectors against mosquitoes, while oil of tar has been used in bad mosquito localities. A mixture recommended by Mr. E. H. Gane, of New York, is the following:

Castor oil	ounce	1
Alcohol	do	1
Oil of lavender	do	1

The oil of citronella has come into very general use in the United States in the past few years. The odor is objectionable to some people, but not to many, and it is efficient in keeping away mosquitoes for several hours. A mixture recommended by Mr. C. A. Nash, of New York, composed of 1 ounce oil of citronella, 1 ounce spirits of camphor, and one-half ounce oil of cedar, has been the most efficacious mixture tried by the writer. Ordinarily a few drops on a bath towel hung over the head of the bed will keep *Culex pipiens* away for a whole night. Where mosquitoes are very persistent, however, a few drops rubbed on the face and hands will suffice. This mixture, in the experience of the writer, has been effective against all mosquitoes except *Aëdes* (*Stegomyia*) *calopus*, the yellow-fever mosquito. This mosquito begins to trouble the sleeper at daybreak, and by that time the potency of the mixture has largely passed, and one is apt to be in his soundest sleep. If, however, one could arrange to be awakened just before daybreak and apply the mixture, returning for the last nap, it is probable that it would be efficacious.

Fishermen and hunters in the north woods will find that a good mixture against mosquitoes and black flies can be made as follows: Take 2½ pounds of mutton tallow and strain it. While still hot add one-half pound black tar (Canadian tar), stir thoroughly, and pour into the receptacle in which it is to be contained. When nearly cool stir in 3 ounces of oil of citronella and 1½ ounces of pennyroyal.

Oscar Samostz, of Austin, Tex., recommends the following formula:

Oil of citronella .... ounce..	1
Liquid vaseline .... ounces..	4

Apply freely to exposed parts.

Doctor Durham, of the English Yellow Fever Commission, Rio de Janeiro, told the writer that he and the late Doctor Myers found that a 5 per cent solution of sulphate of potash prevented mosquitoes from biting, and that they were obliged to use this mixture while at work in their laboratory in Brazil to prevent themselves from being badly bitten.

An anonymous correspondent of American Medicine, who signs himself F. A. H., says:

> I would advise the use of the oil of cassia, for the odor is not offensive to human beings and it is an irritant poison to all kinds of insects. Besides, its power remains for a long time after it has dried.

Pure kerosene has been used for this same purpose. An excellent example of its practical use came to the writer in a letter from Dr. W. H. Dade, an army surgeon, writing from the Philippine Islands under date of November 15, 1901.

He stated that during November, 1900, while traveling up the Cagayan River on the steamer *Raleigh*, they were bothered greatly by mosquitoes both during the day and night, Culex and Anopheles both being present and breeding in fire buckets along the sides of the vessel. The buckets were teeming with larvæ. They did not seem to have thought of putting kerosene on the buckets in order to stop the breeding, but at the suggestion of Doctor Dade a rag was saturated with kerosene, the face, hands, and feet were smeared with it, and the rag was put where it could be conveniently reached. When aroused from sleep by mosquitoes another application was made. "Those who had not used these means before seemed perfectly surprised at the splendid immunity gained. The odor and the greasy feeling imparted were the only drawbacks to its use." Doctor Dade continued to experiment with this remedy after his return from an unsuccessful attempt to capture General Aguinaldo, and found that the addition of 1 part oil of bergamot to 16 of kerosene imparted an odor scarcely objectionable, and at the same time added sufficient body to the kerosene to prevent evaporation in less than six to eight hours. After that, when the soldiers had to leave the post, and after it became impracticable to carry cans with them in the field for a long or protracted march, this mixture was used, with the result that the list of malarial patients was noticeably shortened. The oil of bergamot was hard to obtain and is too expensive to be used wholesale, but the soldiers rarely objected to the odor of kerosene and the bergamot was not continued.

In moist tropical regions where one perspires profusely, the oily mixtures considered under this heading applied to the skin are transient in their effects. Under these circumstances they should be applied rather liberally to the clothing, particularly about the neck and wrists.

SCREENS AND CANOPIES.

Such obvious measures as the screening of houses, the use of netting for beds, and the wearing of veils and gloves after nightfall in badly infested regions, need no consideration in detail. But even in such an apparently simple matter as house screening certain points must be taken into consideration. It may be incidentally stated that with proper treatment of breeding places screening is unnecessary. The expense to which the people of the United States go for screens against mosquitoes and flies is enormous, and has been estimated at $10,000,000 annually. If this expense were at all necessary it should surely be thoroughly done.

In screening a house, as Dr. John B. Smith has pointed out in his Bulletin No. 216 of the New Jersey Agricultural Experiment Station, the attempts frequently fall far short of protection:

> Adjustable, folding, or sliding screens are never tight, and when the insects really want to get indoors they work their way patiently between the two parts of the screen or between its frames and the window. But even a well-fitted screen either sets tightly into the frame or, running like a sash, may offer leaks when a window is only partly

opened. * * * There is abundant opportunity for the insect to get in between the net and lower cross bar; in fact, there is no real protection at all. Where the netting is fixed to the outside of its frame, so that there is no space between it and the lower part of the sash, the insects nevertheless find their way in between the window sashes. * * * It has been already said that the mosquitoes will, in certain seasons, attempt to make their way through the screens, and they have less trouble with wire netting than with any other because the meshes are even in size and the strands smooth. Some of the fabrics used for nettings, especially of the cheaper grades, have the threads so fuzzy that it is simply impossible for the mosquitoes to make their way through, and they rarely even try it except where there is a tear, or where the threads have been spread apart leaving an unusually large opening. Where an onslaught is made on wire netting it can be checked by painting lightly with kerosene or oil of citronella. I have tried both and found them successful.

In addition to these mechanical difficulties it often happens that the cellar and attic windows of houses are not screened. This is a great mistake, since mosquitoes will enter these windows and pass the winter in both cellars and attics.

With regard to bed canopies there is reason for the greatest care. There should be ample material to admit of a perfect folding of the canopy under the mattress, and the greatest care should be taken to keep the fabric well mended. It often happens in mosquito regions that little care is taken of the bed nettings in the poorer hotels, and it is necessary for perfect protection that a traveler in the Southern States should carry with him a pocket housewife and should carefully examine his bed netting every night, prepared to mend all tears and expanded meshes.

Veils and nettings for camping in the Tropics are absolute necessaries. Light frames are made to fit helmetlike over the head and are covered with mosquito netting. Similar frames readily folded into a compact form are made to form a bed covering at night, and every camping outfit for work in tropical or malarial regions should possess such framework and plenty of mosquito netting as an essential part of the outfit.

An illustrated advertisement in Ross's admirable Mosquito Brigades shows a folding-hood mosquito net especially for the use of travelers when taking rest. This is 6½ feet long, 4 feet wide, and 2 feet high. It is a frame arrangement which can be opened by the traveler so as to envelop himself when he is lying down. The frame is easily carried in the hand, being only 40 inches long by 4 inches in diameter when folded. There is also given an illustration of a small, compact mosquito house for use by travelers while writing, reading, or taking their meals. It is large enough to contain two persons seated, and is constructed with a frame which is easily portable. The frames are manufactured by a firm of surgical-instrument makers in Liverpool. No doubt other apparatus of the same kind is manufactured and to be purchased at large outfitting establishments, such as the army and navy stores in London.

Some attention has been paid to the subject of the size of the mesh of screens with especial reference to the yellow-fever mosquito. Working party No. 2 of the Public Health and Marine-Hospital Service, at Veracruz, conducted a few experiments to determine the question of the size of the mesh. Their experiments were conducted by placing screens with a varying number of meshes to the inch over breeding jars and putting bananas, sirup, and other food on the other side so as to tempt the hungry mosquitoes to pass through. The fruit and other food was placed in a jar which was inverted over the mosquito-breeding jar, and a piece of gauze or netting was inserted between the two jars so that the mosquitoes would have to pass through the meshes in order to appear in the upper jar. As a result it was found that both males and females passed through a netting containing 16 strands or 15 meshes to the inch, but could not pass 20 strands or 19 meshes to the inch. It therefore became evident to these observers that the large-meshed mosquito bars ordinarily used in Veracruz would not offer proper protection and that window screening must also be of a finer wire than is sometimes employed.

Goeldi refers to this screen question, both in regard to the yellow-fever mosquito and to the common rain-water-barrel mosquito, in connection with some very interesting observations about the range of variation in the size of the individuals of the same species, a fact which is frequently noticed with other insects but to which special attention has not been called elsewhere with mosquitoes.

Frequently I have observed, both in *Stegomyia fasciata* and in *Culex fatigans*, alongside of individuals of normal stature individuals very much smaller—veritable dwarfs. This observation may be made on specimens captured in freedom as well as on those in captivity, in this last case the phenomenon repeating itself rather frequently. There are sometimes born individuals, both males and females, so small that they easily pass through the mesh of wire gauze much closer than the mesh of "Grassi's gauze" which to-day is produced on a large scale in Italy with a view to the prophylaxis against the Anopheles and malaria (Grassi, himself, recommends a gauze that shall not have less than nine meshes in 1½ centimeters of distance, which corresponds to little linear squares 1.7 mm. to the side). The government of the State of Para imported for my experiments from Italy under this name a gauze which had but six threads to 1½ centimeters of linear extension, corresponding to squares of 2½ mm. along one side. I refer particularly to this last brand, which I consider sufficient as a rule for application to hospitals to impede the invasion of mosquitoes from the outside, but which I found, nevertheless, insufficient for the walls of my cages destined for experiments on mosquitoes like *Stegomyia fasciata* and *Culex fatigans* in captivity.

In general, the phenomena of *macrosomia* and *microsomia* in plants and animals are related directly with greater or less abundant nutrition, and I do not believe that the quoted *dwarf race* of Stegomyia and Culex is to be explained in any other way than by a sparse alimentation and a delayed development in the larval stage. On this point I have at hand experiments in proof: Larvæ reared in clear water—that is to say, relatively poor in assimilable substances—gave me imagos of small stature. Furthermore, it is yet to be shown that I am deceived in my opinion that the frequency of dwarf individuals captured in freedom is not notably greater at certain periods, assuming almost the character of a rule. Thus this year [1905], in the last weeks of October and November, before we entered fully upon the rainy season, I got the impression that the females of dwarf dimensions were particularly numerous. I doubt that this is the work of a mere accident; it is very possible that the frequency of dwarf individuals, normally possible during the whole year, may be periodic and represent a case, somewhat diminished, of what is called in entomology "*dimorphism of seasons.*" Theoretically there can be no serious obstacle in accepting the argument that in the height of the dry season, with the growing lack of water, the conditions of life for the larvæ become more difficult, thus favoring the generation of mosquitoes below the normal dimensions. Impoverished water and reduced food may really, as we have seen above, oblige the larva to take two or three times the period normally necessary for its development and to acquire the necessary growth for its metamorphosis. I have the feeling that hibernation, in the sense in which this word is accepted in zoologic literature, may well for the tropical and equatorial Culicidæ find its expression in two ways: (1) Delayed development of the larvæ; (2) dwarfed stature of the imagos.

[*Note by translator.*—Doctor Goeldi enters into long explanation as to hibernation, evidently for the benefit of equatorial readers who might accuse him of the mal-use of technical terms. He refers to the phenomenon of "seasonal lethargy" and endeavors to trace a connection between the circumstances favoring the development of the perfect insects in parallelism with the "periodicity of yellow fever." His final paragraph is as follows:]

It would be a mistake to believe that these dwarf individuals of Stegomyia are less aggressive and sanguinary than those of normal stature. They behave in a precisely similar manner; their bites are not less painful, as I have had frequent occasion to prove.

A study of the question of mosquito bars or canopies, both for indoors and out-of-doors, has been made by Dr. F. Arnold, the district medical officer of health, northern Transvaal, and he has published an interesting article on the subject in the Transvaal Agricultural Journal for October, 1907, pages 13–15. He illustrates the mesh of different nettings purchased in Pretoria, labeling a netting with a mesh 1 mm. in width as good, one of 2 mm. as doubtful, and one of 3 mm. as bad. These nettings were tested by stretching them over the mouths of three large pill boxes, and in each pill box was put a known number of live, uninjured mosquitoes. The boxes were placed on a chair alongside his bed, where they remained all night, with the idea that by placing the mosquitoes near a sleeper they would be anxious to get at him, and the natural conditions existing in a bedroom would be imitated; that is, there would be a mosquito and a sleeper separated by a net. The conclusions were those above indicated. Doctor Arnold continues his directions in the following words:

In this country the bell-shaped bedroom mosquito net is almost always used; box-shaped nets are rarely seen. In Eastern countries the box-shaped net is generally used fixed on to a large four-posted bed; such an arrangement has the great advantage that the net can be drawn tight and there is within it so large a space for the sleeper that his limbs, if uncovered, are not likely to come in contact with the net.

Frequently the bell net has too small a ring at the top and the netting is not sewn on to the calico which closes the ring, but is gathered up above it by a running thread; such an arrangement causes folds to be formed in the net above the ring, and through the grooves of these folds mosquitoes enter freely. Again, the net is often allowed to hang loose on the bed or it is drawn over the whole bedstead on to the ground. When hanging loose it affords very little protection, for it will, during the night, certainly come in contact with the face, arms, etc., which will be bitten through the net. If placed right over the bedstead, then its lower margin must be heavily weighted with a long and continuous sand bag, and every care must be taken to drive away mosquitoes which may be sleeping on the dark underside of the mattress; in outlying districts white ants would, in one night, make short work of net and sand bag if lying on a mud floor. How, then, should a net be made and arranged?

Proceed as follows: Obtain a ring of wood or iron, in diameter two and a half to three feet; close it with a piece of stout calico; on this calico, around the circumference of the ring, sew the mosquito net very carefully, using netting of the mesh shown as No. 1. Suspend the net to the ceiling in the usual way. Next arrange the bedding as is done on board ship; that is to say, take the upper sheet, blanket, and counterpane and fold the margins inwards at the sides and at the foot; all of the bedding which will cover the sleeper will then lie on the top of the under sheet. Now tuck the mosquito net under the mattress all around, drawing it tight. On going to bed draw out the net at one side, creep in under it, and carefully tuck it back under the mattress. The sleeper is now in a cage; it does not matter how much he kicks about the net will remain true, and, provided that a fair-sized bed is used, there is not much risk of an unclothed part of the body touching the net. For use on the veldt many kinds of stretchers, etc., have been devised. The writer has used a folding stretcher which carries four thin upright rods. Through eyes in the upper ends of these rods runs a cord, and over the whole structure is placed a box-shaped net. The net sold with the stretcher has its lower margin weighted; it is intended that this lower margin should lie on the ground. But this is a theoretical arrangement. First, one rarely gets a flat piece of ground free of grass and stones whereon to place the stretcher; secondly, a sudden gust of wind causes the hanging net to "ride-up" on the feet of the stretchers; and lastly, a stone or grass lifts up the lower margin of the net.

The net, etc., should be arranged as follows: Take a large, long blanket, 7 feet by 5 feet, fold it lengthwise, and lay it on the stretcher to serve as a mattress. Arrange the blankets which will cover you just as the top bedding is arranged for an indoor bed. Tuck in the net carefully all around under the blanket mattress, taking special care to cross the folds of the net around the upright rods. Crawl in under the net and close it in the usual way. The stretcher used by the writer, when opened for use, measures 6½ by 2½ feet, and stands 15 inches above the ground. The whole outfit (stretcher, rods, and net) weighs 26 pounds and can be packed into a canvas sack measuring 3 feet by 13 inches.

SCREENING BREEDING PLACES.

What we have said in regard to the size and mesh to be used in window screens and canopies applies equally well to screens over possible breeding places to prevent the breeding of mosquitoes or the issuing of mosquitoes which have bred therein. In cities in the Gulf States, where the rain-water supply is conserved in large tanks, screening is necessary and is now enforced, Galveston and New Orleans perhaps being the first to make this an important health measure. But rain-water barrels everywhere must also be screened in the same way, except where fish are used to kill the early stages of mosquitoes. In out-of-the-way places, however, where it is difficult to get good screens or where the expense of screening is seriously to be considered, a cheap cover may be made for well-mouths or water barrels, such as described by Dutton in his Report of the Malaria Expedition to the Gambia, and which he states was devised by Doctor Forde.

This cover consists of a large iron hoop obtained from discarded barrels, to which is fastened all around a piece of stout calico or sacking free from holes in such a manner that a good deal of sag is left in the material. After water is obtained from the well the hoop is thrown over the mouth, and the calico catching on the rim of the well completely closes the entrance and is kept taut by the weight of the iron hoop. This cover is so simple, and, however carelessly applied, must so effectually close the entrance of the tub against mosquitoes that I think it is well worthy of extensive use in the town. Dr. Forde has lately informed me that these covers are now being made in Bathurst, and are sold to the natives for the sum of four pence.[a]

ABOLITION OF BREEDING PLACES.

In considering this general question just as in considering so many questions relating to mosquitoes, a complication arises from the enormous mass of facts concerning the life histories of the different species of mosquitoes; facts discovered, for the most part, in the past three or four years. At the time of the publication of Bulletin 25, new series, of this Bureau, the specific habits of but a few mosquitoes were known and the generalizations drawn from the knowledge of these few species were altogether too broad and must now be greatly modified. There is much diversity in the breeding places of different species. Those of the two commonest household mosquitoes, namely, *Culex pipiens* in the North and *C. quinquefasciatus* and *Aedes* (*Stegomyia*) *calopus* in the South, correspond well to generalizations formerly named, breeding as these species do in every chance receptacle of water about residences, and their destruction means the abolition of all such receptacles. Where the rain-water barrel or the rain-water tank are necessary they should be screened. In New Orleans and other southern cities the boards of health are now enforcing such screening. This should be done with extreme care, a fine mesh wire being used and the fitting being made very perfect.

About a given house the waste places in the immediate vicinity should be carefully searched for tin cans, bottles, and wooden or tin boxes in which water can accumulate, and all such receptacles should be destroyed or carted away. The roof gutters of the building should be carefully examined to make sure that they are not clogged so as to allow water to accumulate. The chicken pans in the poultry yard, the water troughs for domestic animals, the water cup of the grindstone, are all places in which mosquitoes will breed and in them

[a] 8 cents.

water should not be allowed to stand for more than a day or so at a time. In the South the water accumulating under water tanks should be treated or drained away. The urns in the cemeteries at New Orleans have been found to breed mosquitoes abundantly. The holy water fonts in Roman Catholic churches, especially in the South, have commonly been found to breed mosquitoes; in some places sponges have been substituted for standing water, and other churches have adopted a closed font, which allows the holy water to issue through a small spigot. In still other churches salt has been put in the water to prevent the breeding of mosquitoes. In slightly marshy ground a favorite breeding place is in the footprints of cattle and horses. In one country village, which contained many small vegetable gardens in a clay soil, during the rainy season mosquitoes were found breeding abundantly in the water accumulating in the furrows in the gardens.

Even in the house mosquitoes breed in many places where they may be overlooked. Where the water in flower vases is not frequently changed mosquitoes will breed. They will breed in water pitchers in unused guest rooms. They will breed in the tanks in water-closets when these are not frequently in use. They will breed in pipes and under stationary washstands where these are not frequently in use, and they will issue from the sewer traps in back yards in city houses during dry spells in the summer time when sewers have not recently been flushed by heavy rains. In warehouses and on docks they breed abundantly in the fire buckets and water barrels.

In country houses in the South where ants are troublesome and where it is the custom to insulate the legs of the tables with small cups of water, mosquitoes will breed in these cups unless a small quantity of kerosene is poured in. Where broken bottles are placed upon a stone wall to form a cheval-de-frise, water accumulates in the bottle fragments after rains and mosquitoes will breed there. Old disused wells in gardens are frequent sources of mosquito supply, even where apparently carefully covered, and here the nuisance is easily abated by the occasional application of kerosene. The same thing may be said of cesspools. Cesspools are frequently covered with stone and cement, but the slightest break in the cement, the slightest crack, will allow the entrance of these minute insects and unlimited breeding often goes on in these pools without a suspicion of the cause of the abundance of mosquitoes in the neighborhood. The writer remembers, for example, on one occasion walking through a New Jersey garden and noticing a covered cesspool with a slight crack in the cement. He remarked upon the danger to the proprietor of the estate, who replied that mosquitoes could not possibly gain entrance to the water. Later in the evening, about dusk, the same spot was passed again and a cloud of mosquitoes was seen issuing from the crack so abundantly that at a little distance it seemed like a stream of smoke. A little kerosene put a stop to this.

Fountains and ornamental ponds are frequent breeding places, and here the introduction of fish, as indicated in another place, is usually all-sufficient. It frequently happens, however, that the grass is allowed to grow down into the edges of ornamental ponds and mosquito larvæ find refuge among the vegetation and so escape the fish. Broad-leaved water plants are also often grown in such ponds, and where these broad leaves lie flat upon the surface of the water, as they frequently do, one portion of a given leaf may be submerged so that mosquito larvæ may breed freely in the water over the submerged portion of the leaf, protected from fish by the leaf itself, the fish rising from below. It is necessary, therefore, to keep the edges of such ornamental ponds free from vegetation and to choose aquatic plants whose growth will not permit of mosquito-larvæ protection. In many small country towns, even where there is a water supply, tanks are to be found under the roofs to supply bathrooms. Such tanks should be screened, since mosquitoes gain entrance to the tank-room either through dormer windows or by flying up through the house from below in search of ovipositing places. About a large old house there are so many of these chance-breeding places that only the most careful and long-continued search will find them all. Frequent change of water or the use of kerosene will render them all harmless.

In community work in cities all of the points mentioned must be borne in mind, and in the portions of the community where the residences are for the most part detached villas, in the absence of swampy suburbs the householders are in the main responsible for their own mosquitoes. There are, however, breeding places for which the municipality may be said to be responsible and these entirely aside from public fountains, reservoirs, or marshes. It seems unlikely that in any general sewerage system mosquitoes may breed in the sewers proper. That they do breed in the catch-basins is well known. The purpose of the catch-basin is to catch and retain by sedimentation sand and refuse which would otherwise enter the sewer and deposit in it. It is intended to be watertight and to hold a considerable body of water which stands in it up to the level of the outlet pipe. Such catch-basins are very commonly used in back yards and at the crossings of streets. The water is removed only by rain or when street or yard surfaces are washed. In dry seasons the period of stagnation may last several weeks, certainly long enough for mosquito breeding. As a matter of fact, mosquitoes in midsummer do breed in such basin traps or catch-basins by millions. In the work against mosquitoes in Brookline, Mass., in 1901 and 1902, previously referred to, *Culex pipiens* was found breeding abundantly in them, and more than 1,000 such basins were regularly treated with petroleum. It is a matter of common observation in the city of Washington that during the usually dry period of late July, August, and September mosquitoes are rather numerous in the northwest quarter of the city where there are no possible breeding places other than these catch-basins, and it is urged that under such circumstances residents make an effort to have such basins frequently treated with kerosene.

The suggestion has been made that in cities it may, under certain circumstances, be possible for mosquitoes to breed in water accumulating in the troughs of underground-conduit electric railways, but so far as known to the writer no exact affirmative observations have been made. That there is abundant opportunity for water to accumulate in these troughs and that it does so accumulate there can be no doubt. It is true that such water will immediately become very dirty, since dirt of all kinds falls into the slot, and it would also be more or less oily. There remains a chance that mosquitoes may breed in this manner, although Gen. George H. Harries, vice-president of the Washington Railway and Electric Company, of the city of Washington, informs the writer that in his opinion this chance is very slight.

DETERRENT TREES AND PLANTS.

There are many references in descriptive literature to certain trees and plants in the neighborhood of which mosquitoes are never found. Notable among these are the eucalyptus trees and the castor-oil plant. Of recent years there have been many newspaper notes about other plants and in southern States the chinaberry tree is said to be distasteful.

EUCALYPTUS.

The statement has often been made that the planting of eucalyptus trees in malarial regions will drive away malaria. This idea had become rather firmly grounded before the discovery of the carriage of malaria by mosquitoes. It has been said, for example, that the planting of eucalyptus trees in the Roman Campagna was followed by a notable improvement in the malarial conditions. Eucalyptus oil has been used to keep mosquitoes from biting. Mr. Alvah A. Eaton, of California, wrote to the Bureau of Entomology, in 1893, that in his opinion where the blue gum grows no other remedy against mosquitoes need be sought for. He further stated that, no matter how plentiful mosquitoes may be, a few twigs or leaves laid on the pillow at night will secure immunity. Another correspondent of the Bureau, Mr. W. A. Saunders, wrote from California that he had planted eucalyptus trees about his house nineteen years previously and that they had reached a height of 140 feet. According to his statement, an irrigating ditch ran through the grove, but there was never a single mosquito larva in the grove, although on both sides of the grove larvæ were plentiful. On the other hand, the late Dr. A. Dugés, of Guanajuato, Mexico, wrote the Chief of the Bureau, on September 8, 1900:

> I have received your very interesting study of the mosquitoes of the United States and thank you greatly for it. At the end of the book you speak of the utility of eucalyptus for driving away insects. I have had some experience with these trees. The fresh leaves placed upon the pillow will attract mosquitoes. Thinking that the mosquitoes loved this plant I had placed the branches farther away, but without result. I have burned the leaves in my chamber, and the cursed beasts have resisted the smoke.

Eucalyptus trees of many species are now grown generally all through California, and the idea that they drive away mosquitoes must be abandoned. Mr. H. J. Quayle, in Bulletin 178 of the California Agricultural Experiment Station, states that in the Burlingame section not far from San Francisco, all of the avenues are lined with eucalyptus trees and mosquitoes are most numerous where these trees are most abundant. In 1901 he captured a pint cup of mosquitoes immediately under eucalyptus trees. Coyote Point is covered with eucalyptus trees, yet the construction of a hotel on the point was abandoned on account of the abundance of mosquitoes.

Edmond and Etienne Sergent, in their antimalarial work in Algeria, had occasion to study the question of eucalyptus and published their results, together with the results of their observations and experiments upon certain other plants supposed to be deterrent to mosquitoes, in the Comptes Rendus des Séances de la Société de Biologie, November 14, 1903. With regard to eucalyptus they show that the railway station of Ouled-Rahmoun, formerly greatly troubled by mosquitoes, was visited by them much less frequently after the cutting down of great eucalyptus trees which surrounded it. The station of Ighzer-Amokran, which is isolated in the middle of a desert plain, is surrounded by a little grove of eucalyptus. Before the windows and doors were screened the rooms were visited every evening by quantities of Anopheles. The traveling Kabyles who stopped at this station would never sleep at midday under the foliage of the eucalyptus, for they said mosquitoes always came down on them. They went under the olives, where they were never bitten.

CASTOR-OIL PLANT.

During the winter of 1901 a great deal was said in the newspapers about the planting of the castor-oil plants (*Ricinus communis*) to prevent mosquitoes. These notes at that time were mainly based upon a consular report from Capt. E. H. Plumacher, United States consul at Maracaibo, Venezuela. In this report Captain Plumacher stated that his residence is surrounded by plantain and banana trees and that he had been troubled in the past by a great number of mosquitoes which gathered in these trees. Following the example of old settlers, he planted castor seeds, which grew up in profusion, with the result that no mosquitoes were to be found among the trees, although he kept the ground well irrigated. Captain Plumacher came to Washington the following year and called on the writer April 18, 1901, bringing with him the seed of the particular variety of the castor-oil plant with which he had noted the result above stated. The seeds were planted upon the department grounds and observations indicated that mosquitoes were not at all deterred by the plants. In a report sent in from Progreso, Yucatan, September 17, 1903, United States Consul Thompson makes the following statement:

> The belief is current among the natives of Yucatan that a few castor-oil plants growing in or near a dwelling will protect the inmates from mosquitoes and certain other noxious insects peculiar to Yucatan. This belief has been to a certain extent confirmed upon experiment by me personally. My dwelling at one time seemed to be peculiarly acceptable to mosquitoes. I planted a row of castor-oil plants around the courtyard and in a short time the mosquito was as rare as he was formerly a frequent visitor. My plants were destroyed by the cyclone and now the mosquitoes are as abundant as formerly.

Some of the Venezuela seeds brought by Captain Plumacher were sent to Mr. J. Turner Brakeley, of Bordentown, N. J. He planted them in the early summer of 1901, and later in the summer observations were made with the result that mosquitoes were found both on the Venezuela plants and on other castor-oil plants. Mr. Brakeley wrote:

> The castor-oil plant is no good as a "skeetonal" protection in New Jersey. It may be a protection against the Venezuela mosquito, but it is no good where the blood pirates of New Jersey are concerned.

Giles publishes a letter sent to the Pioneer, an Indian journal, in 1901, in which the correspondent stated that he had seen a recommendation of the castor-oil plant as a deterrent for mosquitoes, and in consequence had six plants placed in pots in his room. The result was that the plants were thickly covered by the insects, which seemed "to be actually invigorated by the apparently stimulating effect of their new quarters."

The Sergents in Algeria experimented both with the castor-oil plant and with pawpaw (*Carica papaya*), on account of the reputation that these plants had as deterrents against mosquitoes. A pawpaw about 90 centimeters (3 feet) high and in good condition was inclosed in a mosquito bar of tulle, oblong in form, with its axis directed perpendicularly to the window from which the light came. In the end of the bar nearest the window they suspended a raisin grape, for food of the mosquitoes, and a little vessel of water. Then at the opposite end of the bar they put in four females of *Anopheles maculipennis* and four females of *Culex pipiens*. They wished to see if the instinct which attracts the mosquitoes toward the light and toward an apparent way of escaping, and on the other hand the need of nourishment and water, would induce the mosquitoes to pass the middle portion of the bar which was entirely filled with large leaves of the pawpaw. At the end of four minutes one Anopheles and one Culex had passed from one end of the bar to the other; at the end of ten minutes another Anopheles and two Culex were seen to place themselves upon the pawpaw leaves and they remained there for hours. The mosquito bar was left intact for eight days. During this period the mosquitoes went everywhere and rested sometimes several hours upon the leaves and upon the branches.

An experiment exactly similar was carried on at the same time with *Ricinus communis*, with precisely similar results. When these experiments concluded at the end of eight days one Anopheles and one Culex were found dead in the pawpaw mosquito bar, and in the Ricinus bar also one Anopheles and one Culex. But in similar cages in another room during the same time six Anopheles out of twenty had died and nine Culex out of twenty-eight, in the absence of the Carica and Ricinus plants. The authors concluded that pawpaw, castor-oil plant, and eucalyptus are powerless in their effect on mosquitoes.

CHINABERRY TREES.

In spite of the statement that chinaberry trees will protect against mosquitoes, observations have failed to show the truth of the statement, and in mosquito regions people are quite as liable to be bitten while sitting under a chinaberry tree as under any other tree. Nevertheless there is an observation upon record which suggests that further experiments will be interesting. In the Public Health Reports, Vol. 21, No. 44, November 1, 1901, Dr. G. M. Corput, assistant surgeon, U. S. Marine-Hospital Service, gave the results of certain experiments conducted by hanging cans of water in the branches of different trees, including oak, pine, cherry, and palmetto. He found that in the can hung in the chinaberry bushes there were no mosquito larvæ at any time, although larvæ were found in all of the other cans.

OTHER PLANTS.

A number of plants credited with being deterrent to mosquitoes have been mentioned from time to time in the newspapers, some of the accounts being of a sensational character. The New York papers, for example, in the summer of 1906 contained numerous notices of the so-called "phu-lo" plant introduced from the Tonkin country in French Indo-China by Baron de Taillac. This plant was said to be valuable as a fodder for cattle, and to drive away mosquitoes. An effort was made to determine the plant, and Mr. W. E. Safford searched the literature of oriental economic botany without finding anything corresponding to it. He found that in the East Indies there is a Verbascum or mullein called "phul," the seeds of which are supposed to be narcotic, and the leaves used like those of tobacco. The leaves of this plant, although not good for general forage, are eaten by camels and goats. Assuming that this is the plant mentioned by the newspapers, there is nothing in the economic literature concerning its use as a mosquito deterrent.

Another plant which is said to act as a deterrent is a lavender known as *Ocimum viride,* a perennial which grows from 3 to 6 feet in height and occurs from Senegambia southward to Angola. Mr. A. E. Shipley [a] states that Major Burdon, resident of the Nupe Province, northern Nigeria, had given him the following account of the plant:

> A fragment of what turned out to be *Ocimum viride* was given me in August last at Lokoja, northern Nigeria, by Capt. H. D. Larymore, C. M. G., R. A., resident of the Kabba Province. Capt. Larymore's notice had been drawn to the plant by a native living in a low-lying part of the native town at Lokoja, who had told him that the natives suffered very little from the swarms of mosquitoes which existed in that part, as they protected themselves from them by the use of this plant.
>
> Capt. Larymore made inquiries and obtained a few specimens of the plant, which grows wild, though not very abundantly, in the neighborhood of Lokoja. These specimens he planted in pots and boxes and kept in and about his house. The specimens I saw were about the size of a geranium.
>
> He informed me that the presence of one of these plants in a room undoubtedly drove the mosquitoes out, and that by placing three or four of the plants around his bed at night he was able to sleep unmolested without using a mosquito net. This is very strong testimony to the efficacy of the plant, for the house in which Capt. Larymore was living is, as I had cause to know well in former years, infested with mosquitoes.

Mr. Shipley further states that E. M. Holmes in "Notes on the Medicinal Plants of Liberia" records that when chewed or rubbed the leaves of *O. viride* give off a strong odor of lemon thyme, and mentions that Doctor Roberts, of Liberia, entirely substituted the use of the plant for that of quinine in cases of fever of all kinds, giving it in the form of an infusion.

Goeldi, in Brazil, has experimented with *Ocimum minimum* without the slightest beneficial result. He also tested *Carica papaya,* a plant which has a similar reputation, but also without beneficial result. An account of the Sergents' experiments with the latter plant has just been given under the heading of the castor-oil plant.

Mr. Shipley's article in the Tropical Agriculturist was reprinted in the British Medical Journal and was quoted in many other periodicals, and in consequence many requests for seeds of *Ocimum viride* were received at the Royal Botanical Gardens at Kew from many parts of the world. About this time a report was received from Dr. W. T.

[a] The Tropical Agriculturist, February 2, 1903, pp. 555-556.

Prout at Freetown, Sierra Leone, and was published by Sir William Thistleton-Dyer in the London Times for July 27, 1903, and in Nature, July 30, 1903. Doctor Prout's report included an account of experiments made with the "basil" plant in relation to its effect upon mosquitoes, and he concludes that his observations "appear to dispose conclusively of the plants possessing any real protective value." He showed that growing plants have little or no effect in driving away mosquitoes, and are not to be relied upon as a substitute for the mosquito net. He showed, further, that fresh "basil" leaves have no prejudicial effect upon mosquitoes when placed in close contact with them, and, further, that while the fumes of burnt "basil" leaves have a stupefying and eventually a destructive effect on mosquitoes, it is necessary, in order to produce this effect, to bring about a saturation of the air which renders it impossible for individuals to remain in the room. He thinks that cones made of powdered "basil" would, when burned, have the effect of driving mosquitoes away, and that the plant to that extent might be found useful.

PEAT.

An article in the London Times in 1908, written by an anonymous correspondent, refers to the absence of mosquitoes in swamps and marshes with peat. The writer says: "Given marshy lands and no peat, mosquitoes abound; given marshy land and peat, there are none." This article was answered by Mr. F. V. Theobald in Nature, October 15, 1908, pages 607–608. Mr. Theobald showed that he had found *Anopheles nigripes* and *Anopheles bifurcatus* breeding in the water of peat cuttings in Wales and Somerset and on the far-famed Wicken Fen numbers of *Aëdes cantans*. He stated that mosquitoes are often very abundant in the fens, even where the peat is dug. Besides the species above mentioned he has found *Anopheles maculipennis* and *Culiseta annulata* in peaty water and near peat piles in northern Wales.

WATER PLANTS.

Ordinary pools of stagnant water give birth to thousands of mosquitoes, the larvæ breeding with the greatest facility in such water. The presence of algæ and certain low forms of aquatic vegetation is evidence of the stagnation of the water, and an algal scum is frequently associated with the idea of mosquitoes in one's mind. But it is perfectly plain that where the water covering of aquatic vegetation becomes extremely dense mosquitoes can not breed, since there is no opportunity for the larvæ to come to the surface to breathe. Access to air is shut off by the dense covering of vegetation. It has often been a matter of surprise that mosquitoes are not more numerous in Holland, where the country is traversed by canals and dikes.

Mosquitoes breed there in ponds and in chance receptacles of water, but the water in the large canals is so constantly agitated by the passage of boats and by the wind that mosquitoes can not breed, and in the smaller ditches and canals the surface of the water becomes so completely covered with a continuous layer of minute aquatic vegetation (often of considerable thickness) early in the summer that there is no opportunity for the extensive breeding of mosquitoes.

Quite recently this idea has been taken up with practical ends in view in regard to antimosquito work in German colonies in Africa. It is stated in a dispatch from Consul-General Richard Guenther, of Frankfort,[a] that the director of fisheries at Biebrich, Mr. Bartmann, had found a duckweed of the genus Azolla to be especially well adapted to this use; and it was at his instance that experiments were made at the malaria station at Wilhelmshaven. It was found that the growth of the plant covered the experimental waters in a short time with a layer of about 6 centimeters, which suffocated all the mosquito larvæ below and prevented the living insects from depositing eggs in the water. Consul-General Guenther states that several years ago Director Bartmann communicated this method to the mosquito-destroying commission at Eltville on the Rhine, which has used it repeatedly with good success.

So positive were the statements published in the United States as to the results of Mr. Bartmann's work with Azolla plants that one species has been imported from Europe into the United States and will be experimented upon by the United States Department of Agriculture and by Doctor Smith, of Rutgers College. The prospects of success, however, are by no means great. One of the German officials who took part in the question of mosquito extermination in the German-African colonies is far from enthusiastic regarding the practical use of this plant, although it has been advertised on all sides in Europe and in this country. In his opinion it may possibly be of some use in special places, but so far as experiments have gone, down to the present day, the plants will not grow in dense or even moderate shade, and therefore they are of no use in the tropical forests where there are large and small pools of water—the very places where it is most needed. Moreover, the Azolla plants do not stand any great cold, nor do they stand short seasons, for which reasons their use is excluded from highland and northern regions. Further, they will not grow in brackish water and can not be utilized along seacoasts, and, still further, in case of drought they all perish and thus necessitate the restocking of dried pools and swamps.

A short statement regarding the practical use of water plants occurs on pages 1 and 2 of the fourth volume of Theobald's "Mono-

---

[a] Monthly Consular and Trade Reports, Bur. Manufactures, U. S. Dept. Commerce and Labor, March, 1909.

graph of the Culicidæ of the World." This statement may well be quoted:

Major Adie, I. M. S. (Ind. Med. Gaz., xxxix, June, No. 6, 1904), brings considerable evidence to bear on the benefit of *Lemna minor* as a means of keeping mosquitoes from laying their eggs on water. He shows that tanks covered with this green flat weed never contain larvæ of Culicidæ, whilst others at the same time of year are full of them.

As a test he "cleared certain areas near the banks of all *Lemna* and enclosed them with light floating structures, which were fixed enough to resist the winds—in fact, made experimental pools. I was pleased," he says, "to find in due time plenty of *Anopheles* larvæ in these pools. This seemed to prove that *Lemna* acts as a mechanical obstruction to the process of egg-laying, and a very obvious method of prevention occurred to me. Why not deliberately promote the growth of *Lemna minor* in all unavoidable collections of water to prevent the propagation of mosquitoes?"

This same green plant grows freely in England, and I have noticed a similar occurrence here. A pond close to my house was frequented by numbers of the larvæ of *Anopheles bifurcatus* and *A. maculipennis* every year. Two years ago its surface became smothered with *Lemna minor*, Linn., and *Lemna arrhiza*, Linn.; no *Anopheline* larvæ could then be found. As this was the only breeding ground near, both species have practically died out.

This small yet widely distributed genus of floating plants evidently has a very marked effect upon the frequence of culicid larvæ in natural and artificial collections of water.

The little *Lemna arrhiza*, or the rootless duckweed, occurs in Asia, Africa, South America, and Europe, and apparently has the same effect as the larger *L. minor*.

An early suggestion as to the practical use of water plants occurs in Mr. William Beutenmüller's essay on the "Destruction of the mosquito and house fly," published in Dragon-Flies *v.* Mosquitoes, The Lamborn Prize Essays, New York, 1890. Mr. Beutenmüller states that Mr. L. P. Gratacap, of the American Museum of Natural History, suggests the increase of fresh-water algæ as deterring the progress of mosquito larvæ in the water and as affecting their destruction before they can rise to the surface of the water to breathe. Mr. Beutenmüller, considering the suggestion important, stated that he believed that the vast number of fronds of Oscillatoria in the Central Park lakes, in New York City, have had a deterrent effect on the propagation of mosquitoes in the lakes. A largely disseminated mass of algæ floating through the water by its intermixed and diffused stipes he thought would seriously embarrass the development and movements of the mosquito larvæ.

The duckweeds were considered by Dr. H. P. Johnson in an appendix to Smith's New Jersey Report for 1902,[a] and by virtue of the actual small-scale experiment tried, these observations are printed in full.

While most forms of aquatic vegetation promote the breeding of mosquitoes, the Lemnaceæ, or duckweeds, are unfavorable, and in many waters almost or even wholly prevent it. These tiny plants consist merely of a floating frond, resembling a miniature lily-pad. It is circular or more frequently lobated and three to six millimeters

[a] Rep. Ent. Dept. N. J. Agr. Coll. Exp. Sta. f. 1902, pp. 565–566.

in diameter. From the under surface hang one or more roots, which never fasten in the soil, but derive their nourishment from the water. Its reproduction, mainly by division of the frond, is so rapid that in a short time (usually before July 1) it completely mantles quiet waters, notably sheltered ponds and ditches without perceptible flow. Its extraordinary abundance, often covering whole acres of shallow water, makes it an efficient protection from mosquito breeding. Wherever this plant forms a complete covering no larvæ have been found. Such places should never be treated with oil, for nature has provided a far more lasting and equally effective protection. It is probably impossible for a mosquito to lay her eggs on lemna-covered water. Even should larvæ wander in from adjacent waters, they would be unable to reach the surface for air, and would thus soon become asphyxiated. Larvæ of *Culex pungens*, injected by means of a pipette beneath the lemna in the jar * * * died in less than an hour. Where the lemna mantle is not complete, but presents interspaces of open water, larvæ of both Culex and Anopheles will usually be found in small numbers only, for lemna waters are apt to harbor the various predaceous water-bugs in great numbers.

In considering these duckweeds it should be pointed out that mosquito larvæ other than Anopheles are often found in waters well covered by them. Both Dr. H. G. Dyar and Mr. Frederick Knab have made this observation.

SMUDGES AND FUMIGANTS.

Hunters and campers have been in the habit of using almost anything that will make a dense smoke as a smudge to drive away mosquitoes. In Bermuda, fresh cascarilla bark is burned for this purpose, and elsewhere other green bark and vegetation. For household use, however, a number of different substances have been tried.

PYRETHRUM OR CHRYSANTHEMUM.

For many years finely ground powders known as Pyrethrum powder, Chrysanthemum powder, Persian insect powder, or Dalmatian insect powder have been used to kill insects. They became famous for their insecticidal effects long before their composition was known. Their use seems to have originated in Asiatic countries beyond the Caucasus Mountains. The powder was sold at high price by the inhabitants and was brought by merchants to Russia and western European countries. The nature of the powder was kept a secret until the beginning of the last century, when an Armenian merchant, Mr. Jumtikoff, learned that the powder was obtained from the dried flowerheads of certain species of composite plants of the genus Pyrethrum growing abundantly in the region now known as "Transcaucasia." The son of Mr. Jumtikoff began to manufacture the article on a large scale in 1828, and since then the pyrethrum industry has steadily grown and now the export in dried flowerheads in that part of the country is very important.

The species grown commercially in the Transcaucasian region is *Pyrethrum roseum.* The species grown in Dalmatia is *P. cinerariæ-*

folium, and the crop in Dalmatia is comparatively as valuable as the other. Thirty years ago it was considered the most valuable export in Dalmatia. The best powders are made from the dried flowerheads of these plants, and the essential principle seems to be a volatile oil that disappears with age and with exposure. Powders imported from Europe are apparently not so strong as powders made in this country from imported dried flowerheads brought over in bulk. For this reason it was, many years ago, deemed very desirable to establish a Pyrethrum-growing industry in the United States, and in 1881 the United States Entomological Commission imported and distributed the seeds of the two species above mentioned to a number of correspondents in different parts of the country. The total success was inconsiderable. Further experiments another year met with comparative failure. About this time more extensive plantations were made in California and an insect powder was made by the Buhach Producing and Manufacturing Company, of Stockton, Cal., which, being American grown and freshly ground, came into use, and is still being produced and sold under the proprietary name of "buhach," the word being supposedly derived from a slavonic word "buha," meaning flea. An article by Mr. D. W. Coquillett on the production and manufacture of this powder will be found in a bulletin[a] of this Bureau.

Most of the insect powders sold in the shops in this country have Pyrethrum powder as a basis. It is difficult to get a pure and thoroughly efficient powder. There is often adulteration. Frequently the powder made from the dried flowerheads is adulterated with powder made from the stems, or with other adulterants. Pyrethrum powders are usually used dry and are puffed or blown into crevices frequented by insects, or puffed or blown into the air of a room in which there are mosquitoes or flies. The burning of the powder in a room at night is a common practice. The powder is heaped up in a little pyramid which is lighted at the top and burns slowly, giving off a dense and pungent smoke with an odor very much like that of the Chinese punk used to light firecrackers. Often the powder is moistened and molded roughly into small cones, and after drying it burns readily and perhaps with less waste than does the dry powder. Of late years in mosquito-infested countries a number of mosquito pastilles have been sold, and many of these are molded from powders that contain more or less Pyrethrum. The efficacy of the burning pyrethrum in a close room is almost perfect. It will not actually kill all the mosquitoes, but will stupefy them and cause them to fall to the floor where they may be swept up and burned. With the windows open, however, and the constant currents of fresh air blowing through the room, this fumigation is not especially effective, and it is necessary for protection to sit in the cloud of smoke.

[a] Bul. 12, old series, Div. Ent., U. S. Dept. Agr., pp. 7–16, 1886.

The pungent odor of burning pyrethrum is not disagreeable to most people, but to some it is disagreeable, and with certain susceptible individuals it produces headache. It is apparently possible, however, to volatilize the oil without producing the actual smoke. Mr. H. W. Henshaw, of the Bureau of Biological Survey, United States Department of Agriculture, informs the writer that a few years ago a man in Hawaii patented an appliance for producing this volatilization which is all that can be wished for. The powder is placed on a brass or other metal screen above the chimney of a kerosene lamp, the idea being to dissipate the vapor of the volatile oil. According to Mr. Henshaw the effect of this method is most remarkable. "Besides being very economical in powder there is only a very slight odor perceptible and that is not at all unpleasant. The effect on the mosquitoes is immediate and all that can be wished for. They simply clear out." Another method of burning the powder that has often been employed by the writer consists in puffing it from an insufflator into a burning gas jet. This is a simple method where gas is used for illuminating purposes and produces a vapor that suffocates all mosquitoes and other insects that may be in the room.

While pyrethrum has been mainly used as a means of clearing living rooms of mosquitoes, and has ordinarily been burned in the rooms while they were occupied, it has also come into use in the extensive fumigation of houses in cases of epidemics of yellow fever, in the effort to rid houses of malarial mosquitoes, and to destroy all mosquitoes hibernating in cellars, attics, or disused rooms of residences, as well as similar hibernating mosquitoes in barns and outhouses. While reasonably effective for such purposes, it does not seem to be as effective as some of the other substances to be mentioned later and at the same time it is more expensive.

As to the quantity to be used, the regulations of the board of health of New Orleans, adopted May 25, 1903, specify the burning of 4 ounces of pyrethrum powder to 1,000 cubic feet of space; but the president of the board, Dr. Edmond Souchon, a little less than a year later wrote to the United States Marine-Hospital Service that this quantity was found insufficient for thorough work, and that 1 pound of the powder to every 1,000 cubic feet of space is necessary. As a matter of fact, however, the New Orleans board of health abandoned pyrethrum about that time, on account of the fact that the fumes do not kill mosquitoes but simply stupefy them, so that they have to be brushed up and burned. Not willing to run the slightest chance of having mosquitoes survive by escaping destruction after being stupefied, the board decided to use sulphur fumes in preference.

Nevertheless, on account of the fact that the fumes are not noxious to human beings, there still remains a decided use for pyrethrum in everyday work in mosquito-inhabited regions.

MIMMS CULICIDE.

During the yellow-fever outbreak in New Orleans in the summer of 1905 a Mr. Mimms, a chemist of New Orleans, invented a mosquito fumigant which was experimented with rather extensively and found to give good results. It was made of equal parts, by weight, of carbolic-acid crystals and gum camphor. The acid crystals were melted over a gentle heat and poured slowly over the gum, resulting in the absorption of the camphor and a final clear, somewhat volatile, liquid with rather an agreeable odor. This liquid is permanent and may be kept for some time in tight jars. In fumigation work 3 ounces of this mixture is volatilized over a lamp of some kind for every 1,000 cubic feet of space. A special apparatus for the purpose has been perfected by Dr. H. A. Veazie, of New Orleans, but a simple apparatus may be made from a section of a stovepipe, cut so as to have three legs and outlets for draft, an alcohol lamp placed beneath and a flat-bottomed basin on top. The substance is inflammable, but the vapor is not explosive. The vapor is not dangerous to human life except when very dense, but it produces a headache if too freely breathed. The writer, on the 8th of November of the epidemic year (1905), took part in the fumigation of a room containing about 1,200 feet of space in New Orleans in company with Dr. J. H. White, in charge of the public health and marine-hospital service operations in the city during the epidemic, Dr. Rupert Blue, Doctor Richardson, Dr. H. A. Veazie, and several other assistant surgeons in the service. A number of specimens of *Culex quinquefasciatus* were flying about the room. There were two boxes each about 1 foot long, with gauze slides containing one-half dozen or more mosquitoes each and a large tube of 2 inches diameter and possibly 1½ feet in length, the mouth of which was covered with mosquito bar and which lay on its side on the mantelpiece and contained several specimens of the Culex. About 6 ounces of the mixture were volatilized and the room was kept closed, without any effort to artificially stop cracks, for exactly one hour. Upon re-entering and airing the room, all mosquitoes were found to be dead and a cockroach was also found dead on the floor, having come up from between the cracks. The vapor is lighter than air, and the mosquitoes in the room unnoticed on entrance soon after fumigation sought the lower air strata of the room, gradually descending toward the floor and toward the windows, which were on one side of the room only. Sheets of manila paper had been spread before each window, and on these sheets at the end of the hour were all of the mosquitoes to be found in the room.

An account of experiments with this mixture, containing details of apparatus, etc., by Passed Assistant Surgeon Berry, of the United

States Public Health and Marine-Hospital Service, has been published.[a] The conclusions reached by Doctor Berry are as follows:

1. Culicide, in the proportion of 4 ounces per 1,000 cubic feet, used for two hours with apparatus similar to that used by us, kills *Culex pungens*, *Stegomyia*, and *Anopheles maculipennis* and temporarily stuns the house fly.

2. In the proportion of 3 ounces to 1,000 cubic feet it does not always kill the *Anopheles maculipennis*.

3. Culicide takes fire spontaneously if heated sufficiently. It is therefore necessary to keep the liquid at a certain distance from the flame; it is also better to have more than one basin in a large space, and about 8 ounces is the maximum quantity to use in one pan. All large cracks must be pasted up—the doors and windows, if loose fitting. Gummed paper spread under a window left light would be of great benefit. (I concur with Passed Assistant Surgeon Goldberger as to the closing up of large cracks, but more for preventing weakening of the strength of the gas in the room by diffusion than from any belief that insects might escape from the room.)

4. In the minds of intelligent operators, and used according to the methods employed by us, it ranks next to sulphur as an insecticide in practical fumigation.

5. Culicide vaporizes and later cools, condensing on exposed surfaces again as it cools. Whether in this way it injures articles of gilt and the like was not investigated. In practical work the only articles removed from rooms were foodstuffs and animal pets, and no complaint of injury was received. It gradually evaporates, leaving a persistent, though not disagreeable, odor.

As to the cost, with the present high prices of the ingredients of Culicide the cost of fumigating a room with 4 ounces to 1,000 cubic feet is 16 cents per 1,000 cubic feet, as compared with sulphur at 7 cents and pyrethrum at 50 cents, using 2 pounds of each of the latter per 1,000 cubic feet. The estimate does not take into consideration the alcohol used to evaporate the Culicide, but this is not much more, if any, than that used to ignite pyrethrum or sulphur pots. A further saving in favor of Culicide is that the apparatus can be easily carried in the hands from place to place. Had sulphur been used in the instances cited a wagon would have been necessary to transport the materials, which were, in the case of Culicide, conveyed in street cars. The gang would have had to be larger to move the many articles from a house necessary to be removed in sulphur fumigation, to say nothing of the larger amount of pasting to be done. Likewise, at the end of the fumigation the time required to remove the apparatus from the room is much less. For this and other reasons, if the cost of the labor is counted, I do not believe Culicide is much more expensive than sulphur, and if the cost of the articles damaged by sulphur is considered, the difference would be in favor of Culicide.

PYROFUME.

Dr. J. H. McCormack, of Mobile, Ala., has discovered that pyrofume, derived by a fractional distillation from pine wood, as a by-product in the manufacture of turpentine, is a valuable and good fumigant for mosquitoes. It is a clear liquid of a straw color; has a pungent taste, and the odor of pine woods. It is said to be harmless to mucous membranes, skin, fabrics, colors, polished metal, and painted woodwork. A report of the experiments with this substance by Passed Assistant Surgeon Francis of the United States Public Health and Marine-Hospital Service, has been published.[b]

---

[a] Public Health Reports for February 2, 1906, vol. 21, No. 5, pages 83–89.

[b] Public Health Reports, June 29, 1906, vol. 21, No. 26, pp. 711–712.

A summary of Doctor Francis's experimental work follows:

1. As compared with sulphur, pyrofume stands on an equal footing in price.
2. Whereas the federal regulations require two hours' exposure to sulphur, pyrofume is efficient against mosquitoes in one hour.
3. While sulphur is injurious to metals, fabrics, paint, and colors, pyrofume leaves them unchanged.
4. Pyrofume is suitable for fumigating the engine rooms and cabins of ships, and for cars and fine residences.
5. In amounts necessary to kill mosquitoes it does not injure bananas.
6. A person can walk about in a room full of fumes and can sleep without discomfort in a room two hours after fumigation.
7. It requires only five minutes to fumigate a large room of 5,000 cubic feet.
8. The fumes are generated outside the room and conducted into it.

These conclusions were favorable, but the substance has not been taken up in the practical work of the Public Health Service on account of the fact that special contrivances necessary for the best application of the substance have not yet been perfected.

SULPHUR DIOXID.

The damage done by sulphur dioxid to household goods is the principal objection to its use as a fumigant, but in the case of yellow fever epidemics where absolutely thorough fumigation is necessary it is the most reliable of all substances to use. It was used practically exclusively in the antimosquito work during the yellow-fever outbreak of 1905 in the city of New Orleans. Suspected houses were fumigated in the most thorough way. Every effort was made to close all crevices in the rooms fumigated. Heavy paper was pasted over all apertures, including cracks. This gas is obtained by burning flowers of sulphur or lump sulphur in a small pot, fire being started with alcohol. It should be used on a bright day, and pots and polished metal and delicate things should be removed. It has been found that 2 pounds of sulphur for each 1,000 cubic feet of space will be perfectly efficient against mosquitoes and other insects. Sulphur candles may be used where available.[a]

Writing of sulphur, Giles objects to pure sulphur fumigation on account of the difficulty of burning it, and suggests a mixture of 1 part of niter and charcoal to 8 of sulphur, the mixture being made up in pastilles weighing 4 ounces each, by means of a little gum water, dried in the sun. In India he burned one of these pastilles for every 1,000 cubic feet of space and found that the effect was admirable, and that even in thatched buildings hardly a mosquito escaped. After fumigating, the floor of a bathroom in which hardly any mosquitoes could be found was covered with dead mosquitoes, which indicates not only

---

[a] For an excellent account of certain careful experimentation with sulphur, see an article by Passed Assistant Surgeon Francis, of the United States Public Health and Marine-Hospital Service, published in Public Health Reports, March 29, 1907, vol. 22, No. 13, pp. 346-348.

the efficacy of the fumigant, but also the effectual ways in which the Indian mosquitoes hide. He suggests that the fumigating should be done toward the end of the hibernating season, and during the heat of the day, when practically all of the mosquitoes are under shelter. He urges the adoption of this method of fumigation in all government barracks, showing that each pastille costs no more than one Lee-Medford cartridge, and that the annual bill for invaliding men who have been educated to use the latter is so heavy that it would be well to adopt any measure likely to diminish it.

In the course of the admirable work carried on during the last six years in Rio de Janeiro and which has achieved such brilliant results, it has been found that sulphur dioxid has given the best results in the disinfection of houses. Cruz has given the following account of the methods used:

The house to be disinfected was completely closed. Every opening or orifice where gas might escape was sealed with gummed paper. The furniture, too, after being thoroughly cleansed, is tightly closed. Metallic or gilded objects are protected with a covering of vaseline. After the roof is covered over with canvas the garrets are opened for the free access of sulphur gas. The canvas is fastened to the walls with lath. Then sulphur is burned in proportion of 10 to 20 grams per cubic meter, being deposited in several receptacles distributed about the house and kept clear of the floor. Each receptacle should not contain more than 1 kilogram [2.2 pounds] in order to insure complete combustion. In the vacant spaces under the roof the burning sulphur should be placed in receptacles set into others containing water to avoid danger of fire. After all the receptacles are placed, the workmen close up the only exit left open and keep the house thus sealed for not less than 2 hours. The heated air and that displaced by the sulphur gas escapes through the crevices of the roof, but the mosquitoes are kept in by the canvas covering.

In the admirable fight against the yellow-fever mosquito in New Orleans in the summer of 1905, the following directions for fumigating with sulphur dioxid were given out by the health authorities:

Remove all ornaments of metal, such as brass, copper, silver, and gilt from the room that is to be fumigated. All objects of a metallic nature which can not be removed can be protected by covering the objects tightly with paper, or with a thin coating of vaseline applied with a brush.

Remove from the room to be fumigated all fabric material after thoroughly shaking. Open all drawers and doors of furniture and closets.

The room should be closed and made as tight as possible by stopping all openings in chimney, floor, walls, keyholes, and cracks near windows and doors.

Crevices can be closed by pasting strips of paper (old newspapers) over them with a paste made of flour.

The sulphur should be placed in an iron pot, flat skillet preferred, and this placed on bricks in a tub or other convenient water receptacle with about an inch of water in the bottom. This is a precaution which must be taken to guard against accidents, as the sulphur is liable to boil over and set fire to the house.

The sulphur is readily ignited by sprinkling alcohol over it and lighting it.

The apartment should be kept closed for two hours, and then opened up and well ventilated.

NOTE.—To find the cubic contents of the room, multiply the length of the room by the width, and this total by the height, and to find the amount of sulphur necessary to fumigate the room divide the cubic contents by 500, and the result will be the amount of sulphur required in pounds.

Take, for example, a room 15 feet long, 10 feet wide, and 10 feet high, we would multiply 15 x 10 x 10, equals 1,500 cubic feet. Divide this by 500 and you will have the amount of sulphur required, viz, 3 pounds.

After a rigid series of experimental tests, Rosenau, of the U. S. Public Health and Marine-Hospital Service, concludes that sulphur dioxid is unexcelled as an insecticide. He shows that very dilute atmospheres of the gas will quickly kill mosquitoes, and that it is quite as efficacious when dry as when moist. He shows that it has surprising power of penetrating through clothing and fabrics, and that it will kill mosquitoes even when hidden under four layers of toweling in one hour's time and with very dilute proportions. He states that although this substance has long been disparaged as a disinfectant, because it fails to kill spores, it must now be considered as holding the first rank in disinfection against yellow fever, malaria, filariasis, and other insect-borne diseases.

OTHER FUMIGANTS.

In the early antimosquito work in European cities different substances were experimented with. Fermi and Lumbao in their outlined experiments recommend chlorin gas. These writers advise that 4 or 5 spoonfuls of chlorid of lime be placed in a dinner plate and that from 5 to 10 cubic centimeters of crude sulphuric acid be poured upon it. This liberates the chlorin gas, which kills the mosquitoes. The same writers claim that the vapors of chloral act rapidly, killing mosquitoes in a few seconds. Celli and Casagrande in their early experiments in Italy recommend a substance called larycith III, which is probably a misprint for larvacide. This is dinitrocresol, a yellow aniline color, which kills adult mosquitoes when burned in small quantities. Formaldehyde gas was recommended in 1890, but has been found to have almost no insecticidal value.

Dr. John B. Smith[a] found that the powdered "jimson" weed (*Datura stramonium*) can be burned to advantage in houses. He recommends 8 ounces to fumigate 1,000 cubic feet of space. He states that it should be made up by the druggist into an amount with niter or saltpeter 1 part to 3 parts of Datura, so as to burn more freely. He states that the fumes are not poisonous to human beings, are not injurious to fabrics or to metals, and can be used with entire safety. He suggests that it be burned in a tin pan or on a shovel.

A long list of fumigants is given by Celli in his work entitled "Malaria According to the New Researches," and this list has received a critical review, which carries at the same time the results of certain experimental work by Arthur J. Kendall, in Bulletin No. 1 of the

[a] Bul. 216, N. J. Agr. Exp. Sta., p. 12, November 24, 1908.

laboratory of the board of health, Isthmian Canal Commission, Panama, 1906. Bulletin No. 2 of the same service (1906) contains an account of experiments in practical culicidal fumigation, also by Doctor Kendall.

The burning of dried orange peel has been recommended as a deterrent against mosquitoes, but there seem to be no records of conclusive experiments, although the writer has been assured of its efficacy by a Japanese physician visiting the United States.

In the course of his experiments with different disinfectants against mosquitoes, Rosenau, of the U. S. Public Health and Marine-Hospital Service,[a] did his principal work with formaldehyde and sulphur dioxid. We have mentioned his conclusions with regard to the latter substance in a previous paragraph. Formaldehyde gas, on account of its germicidal use, was early suggested against mosquitoes when their importance in the rôle of carriers of disease was ascertained, so that exact experimentation was necessary. Rosenau's results were as follows:

> Formaldehyde gas is a feeble insecticide. Mosquitoes may live in a very weak atmosphere of the gas overnight. It will kill them, however, if it is brought in direct contact in the strength and time prescribed for bacterial disinfection. For this purpose any of the accepted methods for evolving the gas is applicable, but the methods which liberate a large volume in a short time are more certain than the slower ones.
>
> Direct contact between the insects and the gas is much more difficult to obtain in ordinary room disinfection against mosquitoes than against germs, because the sense of self-protection helps the former to escape from the effects of the irritating gas. They hide in the folds of towels, bedding, clothing, hangings, fabrics, and out of the way places, where the formaldehyde gas does not penetrate in sufficient strength to kill them. The gas is polymerized and deposited as paraform in the meshes of fabrics, which prevents its penetration, and large quantities are lost by being absorbed by the organic matter of fabrics, especially woolens. In our tests whenever the insects were given favorable hiding places, such as in crumpled paper or in toweling, they quickly took advantage of the best place for themselves and thus escaped destruction.
>
> There is a striking analogy between the strength of the gas and the time of exposure necessary to penetrate the fabrics in order to kill mosquitoes and the strength and time necessary to penetrate in order to kill the spores of bacteria.
>
> Mosquitoes have a lively instinct in finding cracks or chinks where fresh air may be entering the room, or where the gas is so diluted that they escape destruction. They are able to escape through incredibly small openings. Some of the smaller varieties, such as the *Stegomyia fasciata* can get through a wire screen having 12 meshes to the inch. Therefore, formaldehyde gas can not be trusted to kill all the mosquitoes in a room which can not be tightly sealed.
>
> It was concluded that to succeed in killing all the mosquitoes in a closed space with formaldehyde gas the following definite requirements are essential: A very large volume of the gas must be liberated quickly, so that it may diffuse to all portions of the space in sufficient concentration. The room must have all the cracks and chinks where the insects may breathe the fresh air carefully sealed by pasting strips of paper over them. The room must not contain heavy folds of drapery, clothing, bedding, or fabrics in heaps or so disposed that the insects may hide away from the full effects of this gas.

---

[a] Bul. No. 6 of the Hygienic Laboratory, September, 1901.

MERCURIC CHLORID.

Surg. G. M. Guiteras,[a] of the United States Public Health and Marine-Hospital Service, has recounted a series of experiments with mercuric chlorid, the use of which was first suggested to him by G. F. Matzke, steward on the American steamer *Beecham,* who told Doctor Guiteras that he had used it in the cabin of his vessel with success. Doctor Guiteras carried out a series of five experiments in a room 12 feet high by 15 feet by 13¼ feet, having a capacity of 2,385 cubic feet, sublimating the mercuric chlorid in a porcelain evaporating dish over an alcohol lamp. Mosquitoes in cages approximately containing a cubic foot of space, covered with wire gauze, were exposed at varying elevations in the room, and from 30 to 60 grams of mercuric chlorid were sublimated at exposures varying from two to three hours, at temperatures of from 77° to 88° F. Mosquitoes in the upper part of the room were invariably killed, while some of those very near the floor escaped, most of the latter, however, being killed, and the remainder never recovering perfectly except in one experiment where the temperature was only 77° F. Twenty-five grams of mercuric chlorid were found to be sufficient for 1,000 cubic feet of space. He showed that about twenty minutes are consumed in sublimating 60 grams of the chlorid; that brass work is not tarnished, and that nickel-plated work and instruments are not tarnished when wiped off immediately after fumigation. He further showed that painted surfaces are unaffected unless the chlorid is sublimated close to them and they are not immediately wiped off. Moreover, it does not affect colored silk, cotton, or woolen goods. The poisonous qualities of the substance, in Guiteras's opinion, do not constitute a real danger. When the room was opened after the experiments, he found it filled with a thick mist, but the room was entered without any especial precaution and the windows were opened. In a few minutes the vapor was carried away, leaving a slight deposit on the surfaces within the room. This was allowed to remain for two or three days, and the room was used in the meantime without any bad results. The deposit, however, should have been removed with a damp cloth, and with this ordinary care, the experimenter believes, there will be no danger in the use of the substance.

The advantages he considers to be the facility of obtaining mercuric chlorid, the small quantity necessary, and the simplicity of its use; a good alcohol lamp and a porcelain evaporating dish constitute all the machinery necessary, and its use is certainly much more convenient than sulphur, where the operators have to carry about heavy iron pots and barrels of sulphur. As to expense, he shows that at $1 per pound the 25 grams used per 1,000 feet cost somewhat less than

[a] Public Health Reports, vol. 26, No. 50, pp. 1859–1861, December 10, 1909.

half a cent, whereas 2 pounds of sulphur per 1,000 cubic feet would cost 6 cents. Moreover, it is pointed out that in practical work on a large scale the expense and trouble of hauling the disinfecting equipment from one place to another would be greatly diminished. He concludes that while mercuric chlorid can not altogether take the place of sulphur, it has a hitherto unrecognized effect, especially with reference to flies and mosquitoes.

APPARATUS FOR CATCHING ADULT MOSQUITOES.

In his important paper entitled "A Preliminary Account of the Biting Flies of India,"[a] Mr. H. Maxwell-Lefroy, imperial entomologist, describes an interesting apparatus which he used to catch mosquitoes in his bungalow. In an account published in the United States Daily Consular and Trade Reports,[b] Consul-General William H. Michael, of Calcutta, mentions this apparatus, stating it to be an invention of Mr. Lefroy. In his own account, however, Mr. Lefroy does not claim it as his invention.

He used a wooden box, lined with dark green baize and having a hinged door; the trap was 12 inches long, 12 inches broad, and 9 inches deep; a small hole, covered by a revolving piece of wood or metal, was prepared in the top of the box, and tin was placed on the floor inside. Owing to the habits of mosquitoes to seek a cool, shady place in which to rest, such as a dark corner of the room, or bookshelf, or something of the sort, they will enter this trap, which is put in the part of the room most frequented by mosquitoes, all other dark places being rendered uninhabitable, so far as possible. Mr. Lefroy writes:

> My room being open to the veranda, hordes of mosquitoes come in, and as the room is lined with bookshelves there are many desirable sleeping places. The trap stands in a shady corner, and a large number of mosquitoes enter it when they come home in the morning; the rest are usually driven out of the bookshelves either with a duster or a little tobacco smoke. Finding this desirable sleeping place untouched, they go in; the door is then slammed and fastened. At the top of the box is a small hole with a movable plate to close it; through this a teaspoonful or less of benzene is introduced and the plate put back. After a little time all the mosquitoes are dead. The box is taken to the veranda and opened there till the fumes of benzene escape.

In this way in thirty days Mr. Lefroy caught 2,336 mosquitoes—a daily average of 83.75; daily average of females, 22.68. At the same time 23 of the biting sand flies of the genus Ceratopogon were caught. He further states that whereas the inmates were before disturbed with mosquitoes and sand flies, which especially attacked the baby, the pest practically entirely ceased. All of the mosquitoes were not exterminated, but so large a portion was

---

[a] Bul. No. 7, Agricultural Research Institute, Pusa, India, pp. 12–14, 1907.
[b] Dept. Commerce and Labor, Bureau of Manufactures, p. 10, March 3, 1909.

destroyed that the inmates of the house suffered no more. Mr. Lefroy goes on to say:

> I am not prepared to recommend this as a universal remedy. It must be sensibly used; a small amount of personal effort in teaching a servant is necessary at first. But where mosquitoes are a plague, especially to little children, the housekeeper's thirst for the blood of the mosquitoes may rise to so great a pitch that she will welcome this device and take a delight (as we do) in counting the corpses daily.

An interesting homemade apparatus in common use in many parts of the United States is very convenient and effective. It consists of a tin cup or of a can cover nailed to the end of a long stick in such a way that a spoonful or so of kerosene can be placed in the cup, which may then, by means of the stick, be pressed up to the ceiling so as to inclose one mosquito after another. When pressed up in this way the captured mosquito will attempt to fly and be caught in the kerosene. By this method perhaps the majority of the mosquitoes in a given bedroom—certainly all those resting on the ceiling—can be caught before one goes to bed.

REMEDIES FOR MOSQUITO BITES.

It must have been the experience of most people that ordinarily little swelling and irritation result from the puncture of a mosquito where there has been no scratching or rubbing of the part. But individuals vary greatly in this respect, and it is undoubtedly true that not only do different species of mosquitoes vary in their effect, but that different individuals of the same species may also vary. The application of household ammonia has been found by many to give relief, and alcohol is also said to stop the irritation. Dr. E. O. Peck, of Morristown, N. J., finds glycerin a sovereign remedy. Touch the bite with glycerin and in a few minutes the pain is gone. Dr. Charles A. Nash, of New York City, marks the puncture with a lump of indigo and states that this instantly stops the irritation, no matter whether the application is made immediately or after the lapse of a day or so. The most satisfactory remedy known to the writer from his own personal experience has been moist soap. Wet the end of a piece of ordinary toilet soap and rub it gently on the puncture and speedily the irritation will pass away. Mr. Charles Stevenson, of Montreal, writing to the Canadian Entomologist in September, 1901, stated that he had found naphthaline moth balls to afford immediate relief from the bites of dangerous Diptera, including mosquitoes, and that a friend of his had used it successfully on flea-bites. He advises rubbing the moth ball on the affected part for a few minutes. Napththaline is also recommended by Professor Boges, director of the national board of health at Buenos Aires.

Iodin is frequently recommended for this purpose, and a note in a recent number of the Journal of Tropical Medicine and Hygiene recommends a modification in the shape of 30 to 40 grains of iodin to the ounce of saponated petroleum, stating, "A few drops rubbed in a mosquito bite or wasp sting allay the pain instantaneously."

Rev. R. W. Anderson, rector of St. Thomas and St. Dennis, wrote us from Wando, S. C., some years ago, that he has often found that by holding his hand to a hot lamp chimney the irritation of mosquito punctures would be instantly relieved.

DRAINAGE MEASURES.

The drainage of swamp areas for agricultural or other industrial reasons needs no argument nor treatment here. The value of reclaimed swamp land for various purposes is treated somewhat in extenso in a later section, "Value of reclaimed land." The drainage of swamp areas, primarily in order to improve sanitary conditions and to reduce the annoying scourge of mosquitoes, which in itself frequently prevents the proper development of neighboring regions, is in operation and needs no argument; but it is, nevertheless, of recent undertaking. Thus, in drainage a number of things are accomplished, and where drainage is accompanied by filling, still other results are to be reached. Drainage on a small scale for the purpose of doing away with mosquitoes has been practiced for a long time. In "Mosquitoes," page 198, the writer shows how, by an expenditure of $40 for drainage in the summer of 1900 in a Maryland village, malaria practically ceased to exist, although the previous summer there had been one or more cases in every family in the district.

One of the editors of the Scientific American, Mr. Frederick K. Beech, is quoted (loc. cit., pp. 208–209) as follows:

> In the town of Stratford, Conn., where I have resided for the past forty-five years, we have been greatly plagued by swarms of mosquitoes, so great, in fact, that the "Stratford mosquito" became a well-known characteristic of Stratford. We have in the southern part of our town, bordering on the sound, several acres of marsh land or meadow, which would become periodically overflowed with water in the summer and a tremendous breeding ground for mosquitoes, and this plague to the town continued until about 1890–91, when a party from Bridgeport, Conn., purchased a large section of the meadows and began to protect them by a dike, both on the north and south ends, which shut out the water. In addition to this, numerous drain ditches were made which helped to carry the water away. The result of this work made the land perfectly dry and spongy, so that after a rain no pools collected on the surface of the meadow and the creation of the mosquitoes was prevented. The transformation was so remarkable that people outside the town would hardly believe that it had been effected, and a year or two later the town voted a special appropriation of $2,000 to the party who undertook to build the dike and render the meadows mosquito-proof. It had also the effect of placing on the market a large tract of land elevated from the sound, for residences, and as many as twenty-five summer residences have been built upon this land bordering on the sound, and the number is increasing each year. They are free from mosquitoes, so that the operation shows the economy and the benefit that will result by using some means for eliminating the mosquito-breeding pools.

A great deal of valuable drainage work has been done in the past few years in the salt marshes of the North Atlantic coast, and there is one instance of this on the Pacific coast, with the direct idea of doing away with the salt-marsh mosquitoes, several species of which occur in such localities, all having unusual power of flight and being able to proceed inland for many miles, thus annoying the inhabitants of a large extent of country. One of the first operations of this kind was conducted by the wealthy owners of Center Island, off the north coast of Long Island, in Long Island Sound. This work led to the somewhat elaborate work under the organization known as the North Shore Improvement Association, referred to elsewhere, which included simple operations over a considerable distance along the north shore of Long Island and in the vicinity of Oyster Bay. These operations took place in 1902 and 1903. Later some excellent work was done at Lawrence, Long Island, and the following account, taken from the "Report of the New York State Entomologist," Dr. E. P. Felt, for 1905, gives an excellent idea of methods and results:

A most striking illustration of this work is that given by Lawrence, L. I., which has amply demonstrated the feasibility of controlling the salt-marsh mosquitoes by relatively simple and comparatively inexpensive ditching operations. The annual expense is only about $1,000 and the total expenditure on these operations during the past four years does not exceed $10,000, in spite of the fact that the village is situated upon a narrow neck of land with the extensive salt-marsh areas of Jamaica Bay to the north and west and large marshes south and east, all producing in former days millions of mosquitoes, which invaded the village in swarms with every favorable breeze. Some of these marshes extend almost to the center of the village, which is so completely surrounded that a journey of 2½ miles in almost any direction will bring one to a salt marsh. More unfavorable conditions for mosquito control could hardly be found, and before this work was attempted mosquitoes swarmed in the village in May and remained in numbers most of the season. The second year swarms did not invade this territory till June, and last year it was the first of July before they appeared. Our investigations at the end of last July showed that there were practically no mosquitoes in the center of the village. It was our privilege to sit on a piazza one evening when conditions were most favorable for mosquito activity. Though it was cloudy with only a little breeze, and rather warm, not one appeared. Previous to this antimosquito work it was said that one could not sit on this piazza without being covered with netting, and the owner even went to the trouble of making a framework to hold netting to suspend over individual chairs, so that his family and guests could sit in comfort.

This very desirable result has been brought about by a draining system so planned that the entire length of all the ditches will be flushed by every tide. The general practice is to run these ditches within about 200 feet of firm ground and sometimes closer, making them 18 to 24 inches in width, from 2 to 3 feet deep, with main ditches here and there to tidal channels. A few headland ditches are run into the more dangerous swampy areas in baylike extensions of the marsh. Such ditches require no surveying and cost only 1½ cents a running foot. A little experience enables one to lay them out properly and the tides make the determining of levels extremely easy. It was very interesting to compare the conditions between ditched areas and undrained marshes. The former were so free from mosquitoes that one could tramp upon them with practical immunity from bites, though occasionally a few mosquitoes were seen on one's person. No larvæ were found, and in fact there were very few places where breeding was possible. Undrained marshes presented a very different condition. Mosquitoes swarming in adjacent woodlands made driving very uncomfortable, and when on the marshes one was attended by considerable swarms of vicious biters, even in midday. Here and there breeding pools were literally black with young wrigglers. This contrast between drained and undrained areas would doubtless have been much greater were it not for the fact that our inspection was made during such a dry time that even undrained marshes presented comparatively few favorable breeding places.

Experience at Lawrence has shown that deep ditches with perpendicular sides are far more permanent than shallow ones with sloping sides. The attempt to slope the bottom of the ditch so that all the water will drain out invariably results in depressions which may become dangerous breeding places and the drainage value of the ditch is much lessened. Sloping sides afford opportunity for the growth of grass and sedges with the result that the ditch soon becomes choked with vegetation. The deep perpendicular ditches described above remain entirely free from vegetable growth, and with a little care in removing sods and drifting matter will last for years. Some dug four years ago were in perfect condition last July, though the grass growing along the sides overhung and almost hid the ditch from view in places. An area of 25 feet on each side is easily drained by such a ditch. The village now has 40 miles of marsh drains, which require more or less attention from three men during most of the open season. They keep the ditches clear, supplementing their work by judicious oiling here and there wherever mosquito larvæ are abundant, and then have considerable time available for perfecting the system and ditching more distant marshes. Experience showed that a considerable number of salt-marsh mosquitoes bred on that portion of Jamaica Bay northwest of the village were brought in by southwest followed by northeast winds. This led to the extension of ditching operations some 2 miles beyond the village limits. The work in the immediate vicinity of Lawrence was done partly at public expense assisted by contributions from owners benefited, though it was impossible to secure the cooperation of persons owning the distant marshes, which latter were drained entirely at village expense. The existence of such breeding areas is an imposition upon adjacent communities, and it is only a question of time before public opinion will demand a law either compelling owners to abate such nuisances or else provide for their suppression at public expense. The money invested by Lawrence in this work, a total of less than $10,000, has amply justified itself in vastly improved conditions. The village and its vicinity have been entirely freed from breeding places, although it is subject to late summer invasions by hordes of mosquitoes when favorable winds bring them from undrained marshes. Even this will be obviated when the value of the work becomes more generally appreciated, and then the cost of the operations will be amply returned in increased land values, to say nothing of the satisfaction accruing from the absence of these dangerous and annoying pests.

On the north shore of Long Island, in Connecticut, and especially in the vicinity of New Haven, certain simple ditching operations have been carried on which have resulted, at a comparative inexpense, in a very considerable reduction of the mosquito supply.

THE CALIFORNIA WORK.

In California, in connection with work carried on by the California State Agricultural Experiment Station, in 1905, some excellent work was done under the auspices of the Burlingame Improvement Club, in San Francisco, under the direction of H. J. Quayle, of the California Experiment Station. The territory involved is included in the upper portion of the San Francisco Peninsula, extending from South San

Francisco on the north to San Mateo on the south, a distance of about 10 miles. The salt-marsh area included consisted of a narrow strip along the San Francisco Bay shore, varying from one-half to 2 miles in width and 10 miles long. No part of the area was continually covered with water, and it is all above the lowest high tide. The higher tides, however, particularly those accompanying full moon, almost completely submerge the area. The operations, as described,[a] are quoted as follows:

What was done on the marsh.—The actual work of control was commenced February 27, when a gang of men was started to work at ditching on the salt marsh. This work was started near the Blackhawk dairy, where the marshes begin north of Burlingame, it being the intention to work northward toward San Bruno, and make the work permanent as far as we would be able to go in a single season. However, the work went rapidly and the troublesome areas north of Millbrae were not so numerous as was figured, and consequently practically the whole area was covered during the past season.

The ditching in the Blackhawk area consisted in connecting the pools and areas of standing water with the tidal creeks in order that they might drain more rapidly and before a brood of mosquitoes would have time to develop. The largest of these ditches were 12 inches wide and about 15 inches deep, and these served as main channels into which smaller laterals were cut. These laterals, and, indeed, the greater part of all of the ditches, were but one spade wide, and one or two spades deep, according to the depth of the pool to be drained. Only where the pools were very large and a great quantity of water to run off in a short time was it necessary to make larger ditches. By "a spade" here is meant the common California spade, which is about 6 inches wide and 10 inches high. The eastern drain spade has not yet found its way to California; undoubtedly it would be preferable for the deeper ditches in this kind of work. In addition to the well-defined pools, there was a considerable area in the Blackhawk region which was covered with but a few inches of water for a considerable time after each high tide, and before the rains ceased in the spring water stood over this area almost continuously. Such areas had to be treated by making a number of parallel ditches from 50 to 75 feet apart, in order to permit of sufficiently rapid drainage. Rather extensive ditching was done here to make the area safe while the rains were still continuing, while later in the season, when the rains ceased, it would have been safe with much less ditching. Small pools that were far from tidal creeks were made safe by filling in rather than draining. The size of the pool, and the length of ditch necessary to drain, will determine which of the methods is to be followed. In this way the marsh area was gone over, doing away with all the places where larvæ were found or were likely to be found for a distance of about a mile along the bay northward, where the diked area was met with.

This part of the marsh presented a more difficult problem. The dike, having been neglected for ten or twelve years, was in poor condition, and there were several breaks in the upper end near Millbrae. The gates were not in working order, and their floors were too high to drain the area enclosed.

The breaks in the dike at the upper end permitted the water to back up at the opposite side, and this, together with the fresh water from the hills, kept the water level, at almost high tide, over a large part of the area. To make matters worse, the dike, just after it was built, was in effective operation just long enough to thoroughly dry the ground and cause it to crack. These cracks, which are 4 or 5 inches wide and 2 or 3 feet deep, still exist, forming a complete network over most of the area. Mosquitoes were found breeding in this area, and it was next to impossible to get over the ground,

[a] Bul. 178, Univ. of Cal. Exp. Sta., pp. 15–21, 1906.

even with waders. A considerable part of the area was submerged to the depth of a foot or more, thus concealing from view the cracks and tidal creeks, which one was likely to fall into at every step, and which made any attempt at rapid progress somewhat discouraging.

It was at once evident, under these conditions, that if the area was to be controlled, the dike must be either cut through in a number of places in order to allow a freer circulation of water, or the breaks must be repaired and the gates put in operation, and the water kept out. The latter scheme was the one followed, because it would be possible to make the area thoroughly dry, and thus the results would be more certain. In attempting to operate the gates we were made to appreciate the effect of a ten or twelve years' coating of rust on the large screws by which the gates were manipulated. After the gates were put in operation the breaks in the dike were repaired and the weak places strengthened. The largest break repaired was immediately joining the upper gate. This was 30 feet wide, and by the action of the water had worn down so that at high tide there was a depth of 10 feet of water. A double wall of sheet piling about 6 feet apart was sunk here and the space between filled in with earth. The other breaks were repaired by sinking a single wall of sheet piling in the center and filling in on both sides with dirt.

After these repairs were completed the gates were operated, opened at low tide and closed at high tide, for a week, but at the end of this time there was still much water in the area, because the gate floors were not low enough to lower the water level sufficiently. This made it necessary to lower the gate floors and add an extension to the gates to reach the lower level. This being done the gates were again operated for several days, but it was found that, due to seepage of water through the dike in many places, hand operating would have to be kept up almost indefinitely. It was therefore necessary to replace these old-style gates, operated by hand, by automatic ones, and these were, consequently, put in at both the upper and lower gates, and the floors lowered 32 and 20 inches, respectively. These gates were made to swing on an axle at the top, the lower end being free and easily moved by the pressure of the water, so that at low tide it was opened by the pressure of water on the inside, and closed as the water from the high tide rose on the outside.

This tidal creek, which served as an outlet for the lower gate, had become filled in to a depth of 2 or 3 feet during the period the gate was closed, and this was cleaned out for 300 or 400 yards toward the bay in order to drain out the area enclosed by the dike.

With this work done upon the dike the area enclosed by it was treated in much the same way as that outside, except that the network of cracks, already mentioned, had to be filled in in many places, and several of the tidal creeks deepened. The reward for all this work came later in the season when the area was changed from a veritable breeding ground to the safest portion of the marsh. Indeed, this area was the key to the situation, and the excessive abundance of mosquitoes in this particular territory was without doubt due to this extensive breeding ground.

It is appropriate to mention here the connection of this work with the reclamation of marsh lands. This tract of 500 or 600 acres, which had been useful only for duck hunting, is now thoroughly dry and could be put to agricultural uses at very little additional expense. Such work has already been extensively taken up on the marshes below San Mateo, and it had been found that a good crop of grain can be raised on such land in the second year of its cultivation. It is safe to predict that all the marsh land involved in the present campaign will be under cultivation before many years, and because of its proximity to the metropolis of the coast should be very valuable.

Besides the marshes already mentioned, permanent control work was done on the marsh about Millbrae and northward to San Bruno, and also some drainage work at Coyote Point, opposite San Mateo. The work at these places was much the same as that already described, and further details are unnecessary.

In addition to this permanent work, there was some oiling done on the marsh where the ditching and filling work were not rapid enough to keep ahead of a developing brood. The total amount of oil applied, however, did not exceed 400 gallons, and most of this was applied to the large tidal creeks in the reclaimed land opposite San Mateo. The remainder was applied to pools where wrigglers appeared after a high tide, and, the brood being checked, we had until the next high tide in which to make the pools permanently safe.

During 1908, 200 acres of salt-meadow land on the shore of Little Neck Bay, between Bay City and Douglaston, Long Island, were drained by simple ditching measures. This work was done at the instigation of the Bay Side Park Association and the Douglaston Civic Association, both associations forming a joint committee to exterminate mosquitoes. They went to the board of health of Flushing and enlisted its aid under a new law which permits the board of health to enforce the drainage of mosquito-breeding places. The board of health issued its orders to the owners of the meadow lands, commanding them to drain their properties within ten days. The movement was most successful, and by October 24, 1908, 75 miles of ditches had been dug on the Flushing meadows, and the work was still going on.

As early as 1900 excellent antimosquito work was done on Staten Island, New York, by the Richmond County Club, under the leadership of Mr. W. C. Kerr, in the course of which considerable drainage of fresh-water swamps above the seacoast places was carried on with great success and at a minimum of expense. This work, accompanied with the use of kerosene on the larger ditches, resulted in complete relief from the attacks of the fresh-water mosquitoes, which during the early summer had previously been always numerous and ferocious. But, down the bluffs, below the cliffs, there was a large area of salt marsh, and in the higher portions of this marsh land the salt-marsh mosquitoes bred abundantly and flew up the bluff in swarms to take the place of the fresh-water mosquitoes. An attempt was made, by members of the club, to buy this land and drain it, but they were unsuccessful. A few years later the meadow was taken up by Doctor Doty, the health officer of New York, who eventually began drainage measures, which have been carried out with persistence and effect. Some of the most effective of any drainage work has been done in the course of these operations.

THE NEW JERSEY WORK.

The most interesting and probably the most important work of this character that has been done anywhere in the world was perhaps that undertaken by the State of New Jersey. The writer, in an address on "The Recent Progress and Present Conditions of Economic

Entomology," delivered before the Seventh International Zoological Congress, Boston, August, 1907, made the following statement:

But the work done by Smith, in New Jersey, and that which he has under way in his large-scale campaign against the mosquitoes of that State, are of such a unique character that they force special mention. The mosquito destruction measures carried on by English workers, and especially by those connected with the Liverpool School of Tropical Medicine, in different parts of the Tropics controlled by England, have been large-scale work of great value. That done by the army of occupation in Cuba was of enormous value, so far as the city of Havana was concerned, and an assistant just returned from the Isthmian Canal Zone assures me that it is possible to now sit out-of-doors of an evening upon an unprotected veranda anywhere in the Zone without being annoyed by mosquitoes, and without danger of contracting malaria or yellow fever.

These are all great pieces of work, but when we consider the condition that exists in the State of New Jersey, and the indefatigable and successful work of Smith in the handling of the most difficult problem of the species that breed in the salt marshes, and of his persistent and finally successful efforts to induce the state legislature of that wealthy but extremely economical State to appropriate a large sum of money to relieve New Jersey from its characteristically traditional pest—we must hold up our hands in admiration.

Chapter 134, of the Laws of 1906 for New Jersey, which went into effect on November 1, 1906, the passage of which was largely due to the efforts of Doctor Smith, is so interesting and important in this connection that it is quoted in full, to wit:

AN ACT to provide for locating and abolishing mosquito-breeding salt-marsh areas within the State, for assistance in dealing with certain inland breeding places, and appropriating money to carry its provisions into effect.

Be it enacted by the senate and general assembly of the State of New Jersey:

1.—It shall be the duty of the director of the state experiment station, by himself or through an executive officer to be appointed by him to carry out the provisions of this act, to survey or cause to be surveyed all the salt-marsh areas within the State, in such order as he may deem desirable, and to such extent as he may deem necessary, and he shall prepare or cause to be prepared a map of each section as surveyed, and shall indicate thereon all the mosquito-breeding places found on every such area, together with a memorandum of the method to be adopted in dealing with such mosquito-breeding places and the probable cost of abolishing the same.

2.—It shall be the further duty of said director, in the manner above described, to survey, at the request of the board of health of any city, town, township, borough, or village within the State, to such extent as may be necessary, any fresh-water swamp or other territory suspected of breeding malarial or other mosquitoes, within the jurisdiction of such board, and he shall prepare a map of such suspected area, locating upon it such mosquito-breeding places as may be discovered, and shall report upon the same as hereinafter provided in section eight of this act. Requests as hereinbefore provided for in this section may be made by any board of health within the State, upon its own motion, and must be made upon the petition, in writing, of ten or more freeholders residing within the jurisdiction of any such board.

3.—Whenever, in the course of a survey made as prescribed in section one of this act, it is found that within the limits of any city, town, borough, or village there exists points or places where salt-marsh mosquitoes breed, it shall be the duty of the director aforesaid, through his executive officer, to notify, in writing, by personal service upon some officer, or member thereof, the board of health within whose jurisdiction such breeding points or places occur, of the extent and location of such breeding places, and such notice shall be accompanied by a copy of the map prepared as prescribed in section one, and of the memorandum stating the character of the work to be done and its probable cost, also therein provided for. It shall thereupon become the duty of the said board, within twenty days from the time at which notice is served as aforesaid, to investigate the ownership, so far as ascertainable, of the territory on which the breeding places occur, and to notify the owner or owners of such lands, if they can be found or ascertained, in such manner as other notices of such boards are served, of the facts set out in the communication from the director, and of the further fact that, under chapter sixty-eight of the laws of one thousand eight hundred and eighty-seven, as amended in chapter one hundred and nineteen of the laws of one thousand nine hundred and four, any water in which mosquito larvæ breed is a nuisance and subject to abatement as such. Said notice shall further contain an order that the nuisance, consisting of mosquito-breeding pools, be abated within a period to be stated, and which shall not be more than sixty days from the date of said notice, failing which the board would proceed to abate, in accordance with the act and its amendments above cited.

4.—In case any owner of salt-marsh lands on which mosquito-breeding places occur and upon whom notice has been served as above set out, fails or neglects to comply with the order of the board within the time limited therein, it shall be the duty of said board to proceed to abate under the powers given in sections thirteen and fourteen of the act and its amendments cited in the preceding section, or, in case this is deemed inexpedient, it shall certify to the common council or other governing body of the city, town, township, borough, or village the facts that such an order has been made and that it has not been complied with, and it shall request such council or other governing body to provide the money necessary to enable the board to abate such nuisance in the manner provided by law. It shall thereupon become the duty of such governing body to act upon such certificate at its next meeting and to consider the appropriation of the money necessary to abate the nuisance so certified. If it be decided that the municipality has no money available for such purpose, such decision shall be transmitted to the board of health making the certificate, which said board shall thereupon communicate such decision forthwith to the director of the agricultural experiment station or his executive officer.

5.—If, in the judgment of the director aforesaid, public interests will be served thereby, he may set aside out of the moneys appropriated by this act such an amount as may be necessary to abate the nuisance found existing and to abolish the mosquito-breeding places found in the municipality which has declared itself without funds available as prescribed in the preceding section. Notice that such an amount has been set aside as above described shall be given to the board of health within whose jurisdiction such mosquito-breeding places are situated, and said board shall thereupon appoint some person designated by said director or his executive officer a special inspector of said board for the sole purpose of acting in its behalf in abating the nuisance found to be existing, and all acts and work done to abate such nuisances and to abolish such breeding places shall be done in the name of and on behalf of such board of health.

6.—If in the proceeding taken under section four of this act the common council or other governing body of any municipality appropriate to the extent of fifty per centum or more of the money required to abate the nuisance and to abolish the mosquito-breeding places within its jurisdiction it shall become the duty of said director of the agricultural experiment station to set aside out of the moneys herein appropriated such sum as may be necessary to complete the work, and in all cases preference shall be given, in the assignment of moneys herein appropriated, to those municipalities that contribute to the work and in order of the percentage which they contribute; those contributing the highest percentage to be in all cases preferred in order.

7.—In all cases where a municipality contributes fifty per centum or more of the estimated cost of abolishing the breeding places for salt-marsh mosquitoes within its jurisdiction, the work may be done by the municipality as other work is done under its direction, and the amount set aside as provided in section six may be paid to the treasurer or other disbursing officer of such municipality for use in completing the work; but no payment shall be made to such treasurer or other disbursing officer until the amount appropriated by the municipality has been actually expended, nor until a certificate has been filed by the director or his executive officer stating the work already done is satisfactory and sufficient to obtain the desired result, and that the arrangements made for its completion are proper and can be carried out for the sum awarded.

8.—In all investigations made under section two of this act the report to be made to the board of health requesting the survey shall state what mosquitoes were found in the territory complained of, whether they are local breeders or migrants from other points, and, in the case of migrants, their probable source, whether the territory in question is dangerous or a nuisance because of mosquito breeding, the character of the work necessary to abate such nuisance and abolish the breeding places, and the probable cost of the work. Said board of health must then proceed to abolish the breeding places found under the general powers of such boards, but if it shall appear that the necessary cost of the work shall equal or exceed the value of the land without increasing its taxable value, such board may apply to the director aforesaid, who may, if he deems the matter of sufficient public interest, contribute to the cost of the necessary work, provided that not more than fifty per centum of the amount shall be contributed in any case, and not more than five hundred dollars in any one municipality.

9.—All moneys contributed or set aside out of the amount appropriated in this act by the director of the agricultural experiment station in accordance with its provisions shall be paid out by the comptroller of the State upon the certificate of said director that all the conditions and requirements of this act have been complied with, and in the case provided for in section five payments shall be made to the contractor upon a statement by the person in charge of the work, as therein prescribed, attested by said director, showing the amount due and that the work has been completed in accordance with the specifications of his contract.

10.—For the purpose of carrying into effect the provisions of this act, the said director of the state agricultural experiment station shall have power to expend such amount of money, annually, as may be appropriated by the legislature; *provided*, that the aggregate sum appropriated for the purpose of this act shall not exceed three hundred and fifty thousand dollars. The comptroller of the State shall draw his warrant in payment of all bills approved by the director of the state experiment station, and the treasurer of the State shall pay all warrants so drawn to the extent of the amount appropriated by the legislature.

11.—This act shall take effect November first, one thousand nine hundred and six.

Approved April 20, 1906.

This law was drafted only after the most careful observations by Doctor Smith and his assistants, and after they had made themselves perfectly familiar with the conditions existing in the salt-marsh area in New Jersey and with the exact life histories of the different species of mosquitoes involved, and also after preliminary drainage work had been undertaken and carried to successful conclusion over part of the area without the assistance of state funds.

Doctor Smith had found that three species, of approximately similar habits, develop in the salt marshes of New Jersey and migrate inland for long distances—up to 40 miles in some instances—thus making local work on the part of inland communities by no means perfectly efficient. Citizens' organizations had, for example, done excellent work in the way of destroying household and other fresh-water breeding mosquitoes, in South Orange, Summit, and other inland towns; but occasional inland migrations of swarms of salt-water species necessitated the retention of house screens and discouraged the community workers. The salt-marsh species Doctor Smith found to be *Aëdes cantator*, *A. sollicitans*, and *A. tæniorhynchus*. The former is the more northern and earliest, forming the bulk of the specimens on the marshes north of the Raritan River. South of that point *cantator* makes an early brood only and *sollicitans* is the abundant species during the rest of the season until late fall, when *cantator* sometimes reappears. He finds that *tæniorhynchus* is never so common as the others and is a midsummer species. It was a most important discovery when Doctor Smith and his assistants found that all of these species laid their eggs in the marsh mud, and that these eggs may retain their vitality for three years, even if repeatedly covered with water. He found that every time a marsh becomes water-covered some eggs hatch, and if the water remains long enough the larvæ reach maturity. On account of the possible long duration of the egg stage the problem seemed to be to permit or even favor the hatching of all of the eggs, and then to provide for the removal of the water so rapidly that none of the larvæ could come to maturity.

To accomplish this end a system has been developed by which the force working under the state entomologist makes deep, narrow ditches in the salt-marshes by means of special machinery. These ditches are 30 inches deep and 10 inches wide, the sides being perpendicular. The upper 12 or 18 inches of the ordinary salt marsh is peat or turf, and the water drains readily from it. Below this peat is sand, mud, or clay; and at 30 inches a depth has been reached which is below high-water mark and below the point at which vegetation is likely to start. The ditches are placed from 50 to 200 feet apart, depending upon the character of the marsh, but more often 200 feet apart than less.

Anticipating the ultimate passage of a state bill, work of this character was begun on the Shrewsbury River in 1902, and at the present time both shores are now drained to the full length of the river. In 1903–1904 the marsh areas belonging to the cities of Elizabeth and Newark were drained at the expense of the cities, and in 1906 systematic drainage work was begun at the Hackensack marshes and continued along the shores of Middlesex and Monmouth counties, along both shores of the Raritan River, and along the numerous small rivers and creeks running into the Newark and Raritan bays and into the Arthur Kill.

During the year 1906, and in the preceding experimental work, 4,900 acres of marsh land were drained and 710,000 feet of ditches were put in. During the season of 1907, 10,951 acres of territory were cleaned up and 1,505,524 feet of ditching were put in. During the season of 1908, 6,669 acres of marsh land were dealt with and 888,650 feet of ditching was made. Out of the 1909 appropriation 2,672 acres of marsh were drained with 329,800 feet of ditching. This gives a grand total of 25,192 acres of marsh land and 3,633,974 feet of ditches.

The area extends from the Hackensack at Secaucus to the mouth of Toms River on Barnegat Bay, a distance of nearly 70 miles of shore line. In addition there are about 10 miles on Long Beach in which experimental work was done among the sand hills, in the pockets where the marsh mosquitoes bred whenever there was a storm or a storm tide to fill them. Here no ditches could be made because the layer of turf was very thin and below it was sand. Nor could outlets be obtained to tidewater without the expenditure of disproportionately large sums.

The smaller depressions were filled with brush held in place by a layer of sand, and this served to gather and hold the blowing sand in high winds, causing a complete filling after a year or two. The larger depressions were drained to a center where a pond varying from 6 to 15 feet square was dug 3 or 4 feet deep and a large barrel sunk into the center. This brought the line down below the level of the bay and kept water permanently present; in fact, there was an appreciable rise and fall of water with the tides, and it gave outlet to all the water that drained naturally to these low points. Ditches were dug along the natural drainage lines to these ponds, and the latter were then stocked with killies (*Fundulus* sp.). Some of these pools are now three years old, and the fish have multiplied. Altogether this plan has worked well and required little looking after.

As to the amount expended, the state appropriations make a total of $58,500. About $10,000 has been spent by various municipalities, and probably $75,000 would cover what has been spent in marsh-mosquito work in New Jersey, counting in the local improvements made. This includes also the cost of administration since 1905.

The total estimated cost of the marsh work in the State is $350,000, and up to date the cost of the work actually done is within the amount estimated for that work.

The work has been entirely original in its character, from the beginning of the observations upon the most unexpected habits of the insects, through the development of special machinery, and the ascertaining of the important fact that this simple and very rapid and economic form of drainage meets the important requirement of stopping the breeding of these extremely annoying migratory forms.

The writer has visited the marshes, has seen the excellent results of the work accomplished, and has watched the active operation of digging the ditches. It is possible to walk with dry feet over the drained marshes, and the crop of hay the first year after ditching doubles in quantity.

A bit of work excellent in its results and very economical in its cost, in the way of the drainage of an upland marsh, is described by Doctor Smith in his report for 1908. A new normal school was about to be constructed on Montclair Heights, and there were swampy areas near by which a committee of the state board of education considered to be dangerous as mosquito-breeding places. Doctor Smith caused an inspection to be made early in April, and found that there was a danger point in which not only the ordinary pool mosquitoes but malarial mosquitoes could develop. At a cost of $250, 3,000 feet of ditching was placed or improved, and all the surface water was drained to a culvert through a railroad embankment. The heavy rains of May gave excellent opportunity for testing the effectiveness of the work, and no mosquito breeding was found there throughout the season.

THE VALUE OF RECLAIMED LANDS.

GENERAL RECLAMATION WORK.

The general value of lands reclaimed from swamps is obvious. Practically all of Holland has been reclaimed from the sea. Large areas of the most valuable farming land in the world have been reclaimed from nonproductive swamps. To the nonproductiveness of swamp land must be added the great danger that exists in its continuance through the invariable presence of disease-bearing mosquitoes. The drainage of swamps not only destroys unlimited breeding places of mosquitoes, but vastly increases the value of the land for farming purposes and for other utilitarian uses. Either reason amply pays for the operation. The late Prof. N. S. Shaler, in his report to the North Shore Improvement Association, showed that fields gained by marsh drainage possess the greatest fertility and their endurance to cropping without manuring exceeds that of any other agricultural land except possibly arid regions which are irrigated. The range of crops is great and includes all ordinary farm and garden crops except in some places Indian corn. Reclaimed swamp lands are especially adapted for truck farming, because it is easy to maintain the level of underground water where the roots of the plants can reach it. Professor Shaler shows that the larger part of the best irrigable land in Holland, and much of that in Belgium, northern Germany, and eastern England has been gained from what was originally tidal fields. He estimates not less than 10,000 square miles in those countries to have been redeemed in this way.

The only large example of diked and improved marshes in the northeastern United States is at Green Harbor, Mass., where 1,200 acres have been won to tillage, about one-half being used for hay fields and the other for different crops. The result obtained in the farming of this land is excellent. Asparagus has produced large crops continuously for more than twenty years without the use of any fertilizer.

Prof. Milton Whitney, Chief of the Bureau of Soils, of the United States Department of Agriculture, some years ago drew up the following statement at the request of the writer, concerning the value of reclaimed swamp land:

Swamp lands, by virtue of their position, become the repository of highly fertile material washed from the uplands by the rains. As a general rule, the immediate surface of any soil is the most fertile portion of that soil, resulting from the fact that this surface material is in physical condition, and most exposed to the action of the weather, the sun, rains, and air. This surface is the first portion removed during rains, and is the portion carried down into the swamps and deposited. When erosion goes on at such a rapid rate that both the surface and the underlying raw soil are washed away, the resulting bottom land deposit is frequently sterile. Witness the mud flats and swamps along the Sacramento River, in California, which have been covered with mud from the hydraulic mines of the Sierra Nevadas. Here large areas have been ruined by the mud, and will not become fertile until the weather has acted upon the material long enough to make the soil an acceptable medium for plant growth. Fortunately, most of our lowlands and swamps receive only the more gentle washing or the most fertile materials from the uplands.

Swamp lands contain an unusual amount of organic matter, and for that reason are easy to maintain in proper tilth, light to work, and warm. From their low position, water is generally abundant, or easy to obtain for irrigation by pumping or diversion from nearby streams.

Swamp lands and tide marshes are considered the most valuable of lands in the world's older countries. Their inherent fertility is recognized, and the ease with which they are cultivated and irrigated is greatly appreciated. In England for two hundred years the tide lands have been under reclamation, and to-day over 1,000,000 acres are in a "matchless state of fertility."

In Holland extensive areas have been reclaimed from the sea. The greater part of the country lies at or below the level of the sea, and is reclaimed from a jungle of swamps and savannas. Holland to-day represents one of the most successful attempts at swamp reclamation. Lakes have been drained by diking and pumping, and plans are now on foot to drain the Zuyder Zee, an arm of the ocean.

In our own country swamp reclamation has been carried out on a large scale in the Middle Western States. Ohio, Indiana, Illinois, Michigan, and Wisconsin have great areas of productive land once swamp but now the most fertile and reliable land in those States. The tide marshes around Puget Sound, in Washington, have been lying untouched until within the last few years, but the recent great influx of Scandinavians has resulted in a movement toward the reclamation of these lands, and excellent farms are being established.

In California one of the greatest areas of swamp peat land in the world lies in the Sacramento-San Joaquin Delta. Over 1,500,000 acres of peat from 6 to 40 feet thick are ready for reduction in productive capacity, and to-day large areas are being reclaimed. Yields of 500 bushels of potatoes, 6,000 pounds of asparagus, 60 bushels of barley and oats have been common, and with proper farming such yields should continue to be common.

Wherever properly reclaimed swamp lands are found their fertility is recognized; almost without exception they are more fertile than surrounding uplands. They are frequently used in special crop production, such as in growing celery, asparagus, cranberries, or onions, but in dairying or general farming they are unexcelled as permanent pasture or hay land. The consensus of opinion in districts where swamps have been reclaimed and farmed for many years is that there is no more valuable portion of the farm than the swamp, properly reclaimed.

There is much swamp land in the United States within easy reach of the best markets. New Orleans is surrounded by swamps, but here the problem of reclamation is rendered exceedingly difficult owing to the vast area involved and the periodic invasion by the Mississippi River in front, and Lakes Borgne and Pontchartrain in the rear. The city of New York is in the immediate neighborhood of vast areas of swamps and marshes, and even the partial drainage of this land is being productive of admirable results. The great value of stable land in the vicinity of New York for manufacturing purposes is uncontested, and even the partial drainage of the breeding places of salt-marsh mosquitoes in portions of New Jersey adjacent to New York has resulted, aside from limiting the mosquito supply, in the increase in value of the lands to the owners. After the first ditching the crop of salt hay nearly doubles. The operations carried on conjointly between the city of Brooklyn and the town of Sheepshead Bay, a few years ago, showed the remunerative results to be obtained by simple and beneficial operations. The contents of the ash barrels of the city of Brooklyn were conveyed out into the salt marshes upon specially constructed trolley tracks and in large metal tanks. The tanks were so made that upon reaching the terminus they were taken up by machinery, carried out by an overhead trolley line, and by machinery dumped at a given spot. In this way some hundreds of acres of salt marsh were covered with a 12-foot layer of the contents of the ash barrels of Brooklyn. The layer was packed down by water and contained so much organic matter that almost immediately grass and sunflowers began to grow. At the end of the second year enough soil had formed so that Italians had begun to plant cabbages and other vegetables.

The Government is taking up the subject of reclamation of swamp lands through its Reclamation Service, and extensive surveys are being made by the United States Geological Survey. Under the United States Department of Agriculture appropriations have been made for some years to enable the Secretary of Agriculture to investigate and report upon the drainage of swamps and other wet lands and to prepare plans for the removal of surplus waters by drainage.

A number of interesting and important publications have already been issued by the United States Department of Agriculture, two of which are of general interest, namely, Circular No. 74, Office of Experiment Stations, Excavating Machinery Used for Digging

Ditches and Building Levees, by J. O. Wright (pp. 40, figs. 16); and Circular No. 76, Office of Experiment Stations, The Swamp and Overflowed Lands of the United States, by J. O. Wright (pp. 23, pl. 1). The first of these publications described the use and construction of different classes of dredges, including dipper, clam-shell, rotary, roller, scraper, elevator, and hydraulic dredges, and drag boats; first cost and cost of operation of dredges; machines for building levees; machine for tile ditching. The second gives an estimate of the area of swamp lands in the different States, its ownership, present value, cost of reclamation, and probable value when reclaimed, and discusses the state laws relating to drainage. It is shown in the latter circular that there are in the United States 119,972 square miles of swamp lands, an area which, collected together, would be as large as England, Ireland, Scotland, and Wales together, or larger than the six New England States, New York, and the northern half of New Jersey. It would make a strip 133 miles wide reaching from New York to Chicago. Not all of this swamp land, however, is suited for agriculture, but from the data collected by the Office of Experiment Stations of the United States Department of Agriculture, it seems certain that in the eastern portion of the United States there are 77,000,000 acres that can be reclaimed and made fit for cultivation by the building of simple engineering structures. It is a noticeable and significant fact that 95 per cent of this entire area is held in private ownership. The following paragraphs taken from this Circular No. 76 express the desirability of such drainage from the monetary point of view in very forcible terms:

There is no question as to the fertility of swamp or overflowed land, and when it is protected by embankments to keep out the overflow and is relieved of the excess of water by proper drainage its productiveness is unexcelled. In nearly every one of the States large areas of similar lands have been reclaimed by draining and embanking and have proven to be the most productive farm lands in the districts in which they are located. Illinois, Indiana, Iowa, and southern Louisiana have taken the lead in work of this kind, and in no other part of the country do we find more profitable or higher-priced farms than in those States. Along the Atlantic coast sufficient work has been done to indicate that the vast extent of salt marsh reaching from Maine to Florida can by proper methods be won to agriculture, and when reclaimed the soils are especially adapted to market gardening.

To ascertain why these lands have been allowed to remain so long in their present state we must look to some cause other than their lack of fertility, as this has been fully established by chemical analyses of the soil and by hundreds of productive farms that have been made from such lands.

In the early settlement of our country the farms were located on what were considered the most desirable tracts, determined by accessibility, natural water supply, and the fertility of the soil. As civilization extended westward the home seeker selected the rolling prairie that needed little or no drainage, so that the swamps and overflowed lands were passed by, and only recently has an imperative demand arisen for their reclamation. The desirable farming land is practically all occupied or held for speculation, and to meet the needs of our steadily increasing population it is necessary for this swamp land to be drained and put to proper use. Its nearness to market and its great fertility make it very desirable for small farms.

Can these lands be drained, what will it cost, and how can the work best be done are questions of vital interest to the American people. After considering what has been done to reclaim the marshes of Holland, two-fifths of which lie below the level of the sea, and the difficulties that have been overcome in draining the fens of England, it would be a reflection on the skill and intelligence of the American engineer to proclaim the drainage of our swamp lands impossible. On the contrary, the engineering problems are simple, as most of these lands are several feet above sea level and have natural creeks or bayous that need only to be improved by straightening, widening, and deepening to afford outlets for complete drainage. In case of some of the river bottoms and the salt marsh along the coast it is necessary to build levees to prevent overflow and to construct internal systems of drainage with sluice gates or pumps to discharge the water from within, and by the use of modern machinery this work is neither difficult nor expensive. Levees can be built and ditches excavated with suitable dredges at a cost ranging from 7 to 16 cents per cubic yard. Large works in swamps where the land is overflowed are readily and cheaply constructed in this manner.

As to the cost of draining these lands, and whether or not it will pay, we have but to refer to the numerous works of this kind that have been completed. In those States where large areas of swamp land have been thoroughly drained by open ditches and tile drains the cost ranges from $6 to $20 per acre, while in places where tile drainage was not required the average cost has not exceeded $4 per acre. Judging from the prices which prevail in a large number of these districts where work of this kind is being carried on, it is safe to estimate that the 77,000,000 acres of swamp can be thoroughly drained and made fit for cultivation at an average cost of $15 per acre. The market value of these lands in their present shape ranges from $2 to $20 per acre, depending upon the location and prospect of immediate drainage, with an average of probably $8 per acre. Similar lands in different sections of the country that have been drained sell readily at $60 to $100 per acre at the completion of the work, and in many instances, when situated near large cities, they have sold as high as $400 per acre. To determine whether or not it will pay to drain these lands we have but to consider the following figures:

Cash value of 77,000,000 acres after thorough drainage, at $60 per acre		$4,620,000,000
Present value of this land, at $8 per acre	$616,000,000	
Cost of drainage, at $15 per acre	1,155,000,000	
Value of land and cost of draining		1,771,000,000
Net increase in value		2,849,000,000

These figures, though large, are not fanciful, but are based on results obtained in actual practice in different sections of the country where work of this kind has been done. An extended investigation shows that in every case where a complete system of drainage has been planned and carried out the land has increased in value many fold. In some instances, however, much time and money have been wasted because the work was undertaken without any well-defined plan or it was not sufficient to afford adequate and complete drainage.

The reclamation of swamp and overflowed lands is no longer an experiment; it has become a highly profitable business when based on correct principles. The methods of drainage practiced in different parts of this country and in some of the foreign countries are being carefully considered, and many experiments are being made to determine the best and most economical methods of draining land, and the information thus collected is being classified and the results compared and general rules deduced which, if followed, will in all cases bring highly beneficial results. The comparative cost of the different methods of doing the work and the most satisfactory way of providing funds are also being duly considered.

Were this 77,000,000 acres of swamp and overflowed land drained and made healthful and fit for agriculture and divided into farms of 40 acres each, it would provide homes for 1,925,000 families. Swamp lands, when drained, are extremely fertile, requiring but little commercial fertilizer, and yield abundant crops. They are adapted to a wide range of products and in most instances are convenient to good markets. While an income of $15 to $20 per acre in the grain-producing States of the Middle West is considered profitable, much of the swamp land in the East and South would, if cultivated in cabbage, onions, celery, tomatoes, and other vegetables, yield a net income of more than $100 per acre.

In addition to the immediate benefits that accrue from the increased productiveness of these lands, a greater and more lasting benefit would follow their reclamation. The taxable value of the Commonwealth would be permanently increased, and healthfulness of the community would be improved, mosquitoes and malaria would be banished, and the construction of good roads made possible. Factories, churches, and schools would open up, and instead of active young farmers from the Mississippi Valley emigrating to Canada to seek cheap lands they could find better homes within our own borders.

Holland, two-fifths of which lies below the level of the sea, has been reclaimed by diking and draining, and now supports a population of 450 per square mile. Her soil is no better than the marshes of this country, and her climate not so good as that of the Southern States, yet we have within our border an undeveloped empire ten times her area.

There is no good reason why this condition should longer continue, and it is to be hoped that the American people will soon take steps to abate this nuisance and make these lands contribute to the support and upbuilding of the nation.

In an important article by Mr. H. C. Weeks, in the Scientific American Supplement for January 5, 1901, on the subject of drainage work, the following interesting statements are made:

Cases exist, however, of persons being unwilling to be convinced, and continuing their opposition even after a successful reclamation, as are seen in the official records of Massachusetts, while examinations by the State have shown a great improvement in the sanitary and agricultural conditions. In the instance of Green Harbor, in that State, it is shown that the death rate of the reclaimed district averages lower than the general death rate of the State; that there is a steady increase in summer visitors, and that many houses are being built. The testimony of persons of wide knowledge and ample experience in the science and art of agriculture is adduced, showing the good results in that field, and yet it fails to silence opposers. Besides mentioning the remarkably heavy crops of hay, much preferred by his horses to the best from the uplands, also the excellent crops of strawberries and vegetables raised in these lands, one such qualified observer gives his experience as to asparagus in such convincing words that they are quoted in full: "While visiting the Marshfield Meadows on April 19, 1897, I found asparagus already up, very nearly high enough to cut. I was surprised at this, for my own asparagus had but just appeared above the surface of the ground, although growing on land so warm that I am usually first to ship native asparagus to Boston market. I was also surprised at the size of the stalks, they being much larger than the first set of stalks that appear on my land. When I consider the fact that the land on which this asparagus was growing has produced large crops every year for twenty years without fertilizers of any kind, and still produces better crops than my land, which has had $600 worth of fertilizers to the acre applied to it during the last twenty years, it convinces me that this land, for garden purposes, surpasses any which I have ever examined * * *."

We realize, in a measure, the great value of the material which nature has for ages been storing up for man's future use, if he be wise enough to avail himself of it.

The drainage work done by other countries has given many practical examples of beneficial results from the mosquito standpoint, and from other points of view as well. The details have very recently become available, through the kindness of the United States consul at Milan, Italy, of very extensive drainage operations carried on near Milan, which involved the reclamation of nearly 80,000 acres of land. These details may be found in the Scientific American Supplement No. 1637, May 18, 1907, pages 26233 to 26235. The work cost $3,200,000, and the annual cost of operation is estimated at $16,000. The beneficial results are summarized as follows:

1. In both Mantua and Reggio this tract, comprising 77,867 acres, cultivable only for a sparse crop of poor hay and, on account of the vapors arising from its stagnant swamps, dangerous for pasturage during practically all the year, has been made cultivable, in one year, for wheat, grapes, fruits, and hay, and rendered good for cutting into farms on which people can erect homes in safety.

2. The market values, not only on the 78,000-acre tract but on all contiguous territory, even to the outer bounds of the affected provinces, have leaped to figures equal to two or three times those prevailing before the opening of the Bonifica, i. e., from $120 to $250 or $300 per acre.

3. Farm labor, which formerly expressly avoided these provinces, and made difficult the harvesting of the extensive crops, has been attracted there by the changed conditions; while on account of the demand created by the active development of the drained tract, wages have not been knocked down by the plentitude of supply.

4. Live-stock maladies are under better control.

5. The public health has been afforded a sure and scientific protection.

SALT-MARSH LANDS IN NEW JERSEY.

So much work has already been done in New Jersey that, as repeatedly pointed out in this work, the value of the operations already carried on in that State is very great, if only as an indication of what can be and should be done elsewhere. The whole question of the New Jersey salt marsh and its improvement has been considered by Dr. John B. Smith in Bulletin No. 207 of the New Jersey Agricultural Experiment Station. In this work he gives a consideration of the location of the salt-marsh area, the kinds of salt marsh, the vegetation on the marshes, the present value of the marshes, their actual value, effect of drainage on crops, the needs of salt grass and black grass, and a general consideration as to how the marshes may be reclaimed and who is to pay the expense.

It appears that the present value of the marshes is very small. As a matter of fact, they are either not taxed at all or at such a low rate as to add little to the income of the taxing body. Some of the owners have never paid any taxes, and in some of the townships there is no record of ownerships in the assessor's hands and therefore no notices can be served. It is pointed out, as an evidence of the recognized worthlessness of such land, that none who work on them consider in the least the results of interference with natural drainage; railroads build embankments across them, and pay no attention to the water courses except large creeks. The result is that the marsh often becomes water-logged, and a good salt-hay meadow is turned into a quagmire, and not even the owner protests. Railroads cut sods from the meadows without inquiry as to the ownership of the land, and holes of all sizes are scattered over the meadow, most of them unconnected with tidewater, leaving stagnant pools in which mosquitoes breed.

He points out that all salt marsh, of what he names the third type, which is that area above mean high tide and more or less completely covered with vegetation, may be made to produce an income of from $10 to $40 per acre annually, and that there are many hundreds of acres that do produce such incomes.

In considering the effect of drainage upon crops he gives a number of interesting instances, three of which are quoted:

The Newark meadow has an area of about 3,500 acres, and hay has been cut on parts of it for many years. Before the 90's it was generally cut by men who wished to use it as food for stock or as bedding, and some ditches were cut by those who noticed that well-drained land produced much better crops than such as were either too dry or water-logged. After the 90's a number of banana houses opened in Newark and created a demand for salt hay to use in layering the ripening fruit. This demand led to the cutting of more territory around the edges of the marsh, and $5 a ton was paid for the crop. With the introduction and increase of the glass industry the demand for hay, to be used as packing, increased steadily, and yet greater areas were cut; and in order to get at these areas the cutting was done in the winter, after the meadow was frozen solid, for at no other time could the product be carted off. And this was the condition of affairs in 1904, when the mosquito drainage was done by the city, but under the supervision of the writer. It might be said here that this drainage work was not looked upon with any favor by owners and haymakers, the latter especially protesting vigorously. One man threatened to smash the ditching machine, and yet another promised to shoot the first man that set a spade into his property. The work went on, nevertheless, and altogether nearly 400,000 feet of ditches went into this 3,500 acres.

The results are as follows: On the Hamburg section, where in 1903, on an area nearly one mile square, about 100 tons of hay were taken off during the winter, 250 tons were carted off in 1904, only one year later. The meadow has hardened up right along, and in 1907 nearly the entire area was cut by machine, and a crop of 800 tons, valued at $7.50 per ton, is harvested. Yet a worse place was the area, about one by three-fourths of a mile, known as the Ebeling tract, little more than a sunken meadow before 1904, from which no more than 30 tons of usable grass were obtained. After the ditching the meadow began to rise and improve, and at present writing is at least seven inches above its 1903 level, and correspondingly improved in texture. The crop has increased from 30 tons to 600 tons, not quite so good as the other, but worth an average of $7 per ton. Other areas which had theretofore produced nothing are now being cut. The total cut in 1903 was between 1,000 and 1,200 tons, the 1907 crop will come close to 3,000. And that is not the limit of productiveness.

Forty years ago the Elizabeth marshes, containing about 2,200 acres, were quite generally cut over and good crops of hay were obtained. There was considerable ditching done, but it was not kept up, and as the marsh was crossed and cut up by the railroads without regard to the drainage system, matters became gradually worse; the meadow rotted, the black and salt grass was replaced by sedges and other useless stuff, and less and less was cut each year until, for a decade past, little or nothing has been cut from the area west of the Central Railroad. Where as much as 5,000 tons had once been harvested, less than a thousand tons were harvested in 1903. In 1906 ditches were cut in the southeastern section of the meadow in the course of the mosquito work, and an area on which hip boots were needed in that year can now be safely traveled dry shod. Where we found sedge and useless grasses over two-thirds of the area in 1905, on that same proportion we now have good salt and black grass. In another year, if the ditches are not interfered with, the sedge will be practically out. The balance of the area was ditched early in 1907, all the work being completed early in July. Shallow depressions that have been water covered and mosquito breeders for twenty years are now dry and covered with the salt-marsh flea-bane. The grass which was ten to twelve inches high last year is now twenty to twenty-eight inches high and much more dense. For the first time in nearly twenty years hay is being again cut in areas west of the railroad and in the area between Great Island, Elizabethport and the Central Railroad.

In draining the Shrewsbury River marshes in 1904, the same sort of opposition from hay producers was encountered that we met on the Newark marshes, and it was objected that the ditches cut up the land and made work harder. Nevertheless, the work was done and the result is a crop just double—mostly from longer, thicker grass. Before 1904, two tons per acre was considered a good crop; now, good and bad together, it averages four tons, and local conditions furnish a market that pays $10 per ton.

In his annual report for the year 1908, Doctor Smith states that his investigations showed that a very small part of the salt-marsh area produces as great a crop as it should, and that what is produced does not bring as good a price as it should. The market for salt hay is slight, due in part to the character of the crop and partly to the uses to which it is put. Since the crop is not certain it can not be relied upon, and the price varies with the size of the harvest. Salt hay is used largely for packing, and the amount demanded depends upon business conditions. In 1907 there was a very large crop of hay, but there was a business depression at the same time which brought about so low a price as to scarcely repay harvesting. He shows that salt hay is altogether too valuable to be used for packing material alone, and that if an annual crop could be expected it could be used to supplement upland hay in feeding horses and cattle. The drainage work done by Doctor Smith under the state mosquito law will put the meadows into such shape that the amount of hay produced will be increased without increase of cost except in harvesting, and will enable the production of dependable crops. He states that on July 21, 1908, he had the opportunity of seeing, at Stratford, Conn., an area of about 1,500 acres of salt marsh drained and partly diked and reclaimed. The largest part of the acreage was devoted to raising salt hay of the best quality, for which good prices were received. On the diked marsh 100 acres had been kept free from salt water since 1904. On this territory strawberries, asparagus, onions, and celery were being raised, and, while the asparagus was not of the best quality and the strawberry plants were in no way unusual, the onions and celery were of the best—in fact the celery was so good that most of the market gardeners in that vicinity preferred to get their supplies from this source.

Doctor Smith points out that there are many hundreds of acres along the shores of Barnegat Bay, and especially along its upper portion, where a very small amount of diking will serve to keep out salt water and fit the land for certain truck crops. He also shows that along a large portion of the Barnegat Bay line cranberry plants grow annually to the very edge of the salt-marsh line, but that these could not be improved because there was no way out across the marsh for surface water. With the ditching going on, this land will become available in large part at least and will allow the owners to derive a revenue from land which is at present practically nonproductive. Of course taxes will then be raised and the income of the townships in which this land lies will be increased.

THE PRACTICAL USE OF NATURAL ENEMIES OF MOSQUITOES.

SALAMANDERS, DRAGONFLIES, PREDACEOUS MOSQUITOES, AND FISH.

Almost no practical use has been made artificially of the natural enemies of mosquitoes except with fish. It is true that about 1898 Mr. Albert Koebele imported from California into Hawaii a large number of western salamanders (*Diemyctylus tortosus* Esch.), which were liberated in the upper part of the Makiki stream in the hope of reducing the large number of mosquitoes breeding in small pools and in the taro fields. He kept two of these salamanders for several weeks in an open tank and they devoured all mosquito larvæ that occurred there; and while hundreds of the newly hatched mosquito larvæ could always be observed, none of them ever reached full growth. Whether these salamanders have increased in Hawaii and at present form an important element in the mosquito environment is not recorded.

Among the predatory insects it has been frequently suggested that dragonflies are such important mosquito enemies that efforts should be made to devise some artificial means of encouraging their increase, and in fact the late Dr. R. H. Lamborn, of New York and Philadelphia, offered a series of prizes for the three best essays regarding the methods of destroying mosquitoes and house flies, especially designating the dragonfly for careful investigation. The prizes were awarded to Mrs. Carrie B. Aaron, of Philadelphia, and Mr. A. C. Weeks and Mr. Wm. Beutenmueller, both of New York, but none of the essayists was able to solve the problem of the practical breeding on a large scale of dragonflies for mosquito extermination.

It has been proposed to breed mosquitoes of the genera Psorophora and Megarhinus, the larvæ of which are extremely active and feed so voraciously upon the larvæ of other mosquitoes, but Psorophora itself in the adult condition is a voracious biter and is a potential carrier of disease, so that to breed it for predaceous purposes is hardly to be considered; in other words, the remedy might prove worse than the disease. However, Dr. Oswaldo Goncalves Cruz, director-general of the board of health in Rio de Janeiro, told the writer in November, 1907, while on a visit to Washington, that *Lutzia bigotii* is used in Rio practically to destroy the larvæ of the yellow-fever mosquito. The Lutzia larvæ are exclusively carnivorous, and this species is introduced in regions where the mosquito abounds, and its larvæ destroy the other larvæ as efficaciously as do fish.

For a long time fish have been used practically on a small scale. For example, it was stated a number of years ago in Insect Life that mosquitoes were at one time very abundant on the Riviera in south Europe, and that one of the English residents found that they bred abundantly in water tanks, and introduced carp into the tanks for the purpose of destroying the larvæ. It is said that this was done with success, but it is rather certain that the fish must have been some other form than carp. It is probable that the fish in question was the common goldfish (*Carassius auratus*).

In the southern United States for many years intelligent persons here and there have introduced fish into water tanks for this purpose. Mr. E. A. Schwarz found in 1895 that at Beeville, Tex., a little fish was used. The fish was called a perch, but its exact specific character is not known. Prior to 1900, Mr. F. W. Urich, of Trinidad, wrote the Bureau of Entomology that there is a little cyprinoid, common in that island, which answers admirably for the purpose. In a letter to the Bureau of Entomology Mr. J. B. Fort, of Athens, Ga., writes that about 1854 his father, Dr. Tomlinson Fort, living at Milledgeville, Ga., found that mosquitoes were breeding extensively in a cistern owned by certain livery-stable keepers. They refused to use oil upon their cistern, and Mr. Fort was instructed by his father to catch some small fish from a creek near by and place them in the cistern. About a dozen or more small fish were so placed, and in a day or so all of the larvæ were destroyed. This instance is mentioned as indicating the early use of fish on a small scale in cisterns.

In "Mosquitoes" (1901) the writer recommended the practical use of sticklebacks, top-minnows (*Gambusia affinis* and *Fundulus notatus*), and the common sunfish or pumpkinseed, and these fish, especially the top-minnows and the sunfish, were used with success in a number of instances in small ponds. An instance has been described in a letter to the Bureau of Entomology by C. T. Anderson, of Anderson, Washington County, Fla., who wrote that he had a spring on his place that swarmed with mosquito larvæ in the summertime. He got about a dozen top-minnows and put them into the spring without telling the rest of the family. In a day or two a member of the family remarked that there were no wrigglers in the water. Mr. Anderson verified the observation, and after many months was able to state that no mosquito larvæ had been seen since.

The common goldfish proves to be an excellent mosquito feeder and during the summer of 1901 Mr. Jacob Kotinsky, then of the Bureau of Entomology, conducted a series of laboratory experiments with goldfish in an aquarium. He found that they were voracious feeders on mosquito eggs, preferring them to larvæ. He further noticed that the fish, after taking several larvæ into the mouth, would eject some of them. Further, he found that in a large jar containing four goldfish and many hundreds of mosquito larvæ, a few of the larvæ succeeded in transforming and emerging as adult mosquitoes. The food supply was evidently in excess of the capacity of the fish.

At an earlier date than this Mr. H. W. Henshaw, of the Biological Survey of the United States Department of Agriculture, was staying at Fruitville, near Oakland, Cal. The house and neighboring houses were badly infested with mosquitoes. He found the source of supply to be a lily pond about 7 by 12 feet in size and fully 3 feet deep, which was fairly swarming with larvæ. He got a half dozen goldfish from San Francisco and put them into the pond. The following day they were so badly bloated that they could hardly swim, and in a few days there was not a single larva left. The fish bred in the pond and from the time of their introduction there was a very marked decrease in the number of mosquitoes in that general locality.

Mr. William Lyman Underwood, of the Massachusetts Institute of Technology, in Science for December 27, 1901, described an interesting experience with goldfish:

About six years ago, at my home in Belmont, near Boston, Mass., I constructed a small artificial pond in which to grow water lilies and other aquatic plants and also to breed, if possible, some varieties of goldfish—though the latter object was a secondary consideration. The advisability of making this pond had been somewhat questioned on account of its close proximity to my house and the fact that such ponds are likely to become excellent places for the propagation of mosquitoes. Nevertheless, the plan was carried out and the pond was stocked with goldfish taken from natural ponds in the vicinity where they had been living and breeding, to my personal knowledge, for a number of years.

The aquatic garden has proved a success and the goldfish have meantime thriven and multiplied. Moreover, no mosquitoes attributable to the pond have appeared and I have been unable to find any larvæ in it, although I have searched repeatedly and diligently for them. I have always believed that the absence of mosquito larvæ from this pond was due to the presence of the goldfish, and I have so stated in a paper, "On the Drainage, Reclamation, and Sanitary Improvement of Certain Marsh Lands in the Vicinity of Boston" in the Technology Quarterly, XIV, 69 (March, 1901), as follows: "In the water (of this pond) are hundreds of goldfish that feed upon the larvæ of mosquitoes and serve to keep this insect pest in check." * * * I took from the pond a small goldfish about three inches long and placed it in an aquarium where it could, if it would, feed upon mosquito larvæ and still be under careful observation. The result was as I had anticipated. On the first day, owing perhaps to the change of environment, and to being rather easily disturbed in its new quarters, this goldfish ate eleven larvæ only in three hours; but the next day twenty were devoured in one hour; and as the fish became more at home the "wrigglers" disappeared in short order whenever they were dropped into the water. On one occasion twenty were eaten in one minute, and forty-eight within five minutes. This experiment was frequently repeated, and to see if this partiality for insect food was a characteristic of those goldfish only which were indigenous to this locality I experimented with some said to have been reared in carp ponds near Baltimore, Maryland. The result was the same, though the appetite for mosquitoes was even more marked with the Baltimore fish than with the others. This was probably due to the fact that they had been in an aquarium for a long time before I secured them, and had been deprived of this natural food. I also tried the experiment of feeding commercially prepared "goldfish food" and mosquito larvæ at the same time, and found that in such a case the goldfish invariably preferred the larvæ.

It is not as generally realized as it should be that goldfish will thrive in our natural northern waters. In my experience they can easily be bred in any sheltered pond where the water is warm and not fed by too many cold springs, and for many years they have been breeding naturally in many small ponds in the vicinity of Cambridge, Massachusetts.

When it is once understood that these fish are useful and ornamental, as well as comparatively hardy, it is to be hoped that they will be introduced into many small bodies of water where mosquitoes are likely to breed, and thus be employed as a remedy for mosquitoes sometimes preferable to kerosene.

The year 1908 in the island of Cyprus proved to be the most malarious year since 1885. Careful examination of conditions was made by Dr. George A. Williamson, whose report will be found in the Journal of Tropical Medicine and Hygiene, September 15, 1909, pages 271–272. A careful search was made in the marshes to the north and south of Larnaca, but no breeding places of Anopheles mosquitoes were found, and subsequent search showed that the malarial mosquitoes were breeding in the tanks and wells of private houses. Here kerosene could not be used, and the use of goldfish was advised. Wherever the advice was followed the results were perfect. One well, described by Williamson, was about 20 feet deep and had a wide mouth. This well contained Anopheles larvæ in enormous numbers, and of five persons living within its immediate neighborhood four became infected with malaria. This well, not being in use, was filled in, but a large tank which was near it was stocked with goldfish and all Anopheles larvæ were destroyed by them.

An excellent discussion of the relative value of the different small fish for practical handling and for practical use against mosquito larvæ has been published by Mr. William P. Seal, a naturalist of many years' experience in handling fishes, and the following paragraphs taken from this article[a] may be considered as authoritative:

As a destroyer of Anopheles the writer has for several years advocated the use of *Gambusia affinis*, a small viviparous species of fish to be found on the South Atlantic coast from Delaware to Florida. A still smaller species of another genus, *Heterandria*

[a] See Scientific American Supplement, vol. 65, No. 1691, pp. 351–352, May 30, 1908.

formosa, is generally to be found with Gambusia and is of the same general character. The females are about one inch long and the males three-quarters of an inch. Both of these species are known as top minnows, from their habit of being constantly at the surface and feeding there. The conformation of mouth, the lower jaw projecting, is evidence of their top-feeding habits. Both of these species are to be found in great numbers in the South in the shallow margins of lakes, ponds, and streams in the tide-water regions wherever there is marginal grass or aquatic and semiaquatic vegetation. They are also to be found in shallow ditches and surface drains where the water is not foul, even where it is but the fraction of an inch deep. In fact, if any fishes will find their way to the remotest possible breeding places of the mosquito, it will be these. And they are the only ones, so far as the writer's observation goes, that can be considered useful as destroyers of Anopheles larvæ.

Gambusia is found in the Ohio Valley as far north as southern Illinois, where the winter climate must be at least as severe as that of the coast of New York and New Jersey.

Dr. Hugh M. Smith, Deputy U. S. Fish Commissioner, informed the writer that he had examined the stomachs of several hundreds of Gambusia in the Chesapeake Bay and Albemarle Sound waters, and had found the contents to be principally mosquito larvæ. * * *

While, as has been stated, all fishes have some measure of usefulness, if only in the way of deterrent effect, there are only a few species likely to be found in waters in which mosquitoes breed. The most important of these are the gold fish (introduced), several species of Fundulus (the killifishes), and allied genera, three or four species of sunfish, and the roach or shiner, and perhaps one or two other small cyprinoids. In addition, there are a few sluggish and solitary species, like the mud minnow (Umbra) and the pirate perch (Aphredoderus). The sticklebacks have been mentioned in this connection, but the Atlantic coast species, and probably the entire family, are undoubtedly useless for the purpose, being bottom feeders, living in the shallow tide pools and gutters, hidden among plants or under logs and sticks at the bottom, where they find an abundance of other food.

In the salt marshes there are myriads of killifishes running in and out and over them with each tide, while countless numbers of other and smaller genera, such as Cyprinodon and Lucania, remain here at all stages of the tide. So numerous and active are all of these, that there is no possibility of the development of a mosquito where they have access.

Of the killifishes two species, Heteroditus and Diaphanous, ascend to the farthest reaches of tide flow, but it is a question as to whether they would prove desirable for the purpose of stocking land-locked waters, since they are a good deal like the English sparrow, aggressive toward the more peaceable and desirable kinds. Even Cyprinodon, which would at first thought be a valuable small species in this respect, is viciously aggressive toward goldfish and no doubt all other cyprinoids. It is so characteristic of all the cyprinodonts, that they can only be kept by themselves in aquaria. They are the wolves or jackals of the smaller species.

The writer has come to the conclusion, after many experiments in both tanks and ponds, that a combination of the goldfish, roach, and top-minnow would probably prove to be more generally effective in preventing mosquito breeding than any other. The goldfish is somewhat lethargic in habit, and is also omnivorous, but there is no doubt that it will devour any mosquito larvæ that may come in its way or that may attract its attention. The one great objection is that they grow too large, and the larger will eat the smaller of them. That is one of the drawbacks to goldfish breeding. There is no danger of overpopulation, but there is of the reverse. Whether or not it is the same with the roach, they are never excessively numerous, although no doubt the most abundant and most widely distributed of the Cyprinidæ. They are largely the prey of predaceous fishes, and never approach to the numbers of the killifishes.

But at all events they are not lethargic like the goldfish, being on the contrary one of the most active of the family, and equally at home in flowing or stagnant water. The roach is always in motion, back and forth, and around and about, on a never-ending patrol.

The top-minnows would supply the deficiencies of the other two species, and in combination they should very thoroughly populate any waters not already stocked with predaceous kinds, and exercise an effective control. One of the great difficulties in the case is that there are dozens of kinds of insect larvæ besides those of the mosquito, and other forms of life as well, which are natural and possibly preferred food of the fishes, thus requiring an enormous population to devour them all.

The larvæ of gnats, midges, ephemera, and other flies and insects which breed in the water, as well as the many small crustaceans, afford a menu of delicacies that would stagger a gourmand. The above combination of mosquito destroyers might be supplemented by two small species of sunfish, *Enneacanthus obesus* and *E. gloriosus*, which live among plants and would be a check on larvæ other than the mosquito. The black-banded sunfish, *Mesogonistius chætodon*, would also be desirable for this purpose if they were not so difficult to obtain in large numbers. One or both species of Enneacanthus can be found wherever there are aquatic plants. The above-mentioned five species in combination seem to be the most suitable for pond protection of all those which are known to thrive in still water and which in any degree possess the desired qualities. As has been stated, the killifishes would probably be found to be undesirable. In their natural habitat, the tidal streams and great expanses of small marsh, their efficiency is unquestioned.

There are many places at the seashore where there are swales or hollows filled with grasses and bushes, which in periods of rainfall become breeding places for the mosquito, especially of Anopheles. If these places are stocked with fish, the result is that when they dry up the fish perish, and the operation must be repeated after each filling.

The writer has suggested digging holes about four feet square down through the turf into the sand stratum in the deepest part. Two feet is usually sufficient to secure a constant water supply where the fish can exist until the hollow is again rain-filled. Cyprinodon and Lucania would be desirable for such places, and they are to be found everywhere in the ditches and tide pools on the flats.

To add variety to the treatment of the subject, it might not be amiss to suggest that there is a fish, Anablaps, inhabiting the fresh waters of South America, which seems to be specially adapted to this purpose. To quote: "These small fishes swim at the surface of the water, feeding on insects, the eye being divided by a horizontal partition into a lower portion for water use and a portion for seeing in the air."

Acting largely upon Mr. Seal's advice, Dr. John B. Smith, the state entomologist of New Jersey, with Mr. Seal's help, in November, 1905, brought *Gambusia affinis* and *Heterandria formosa* from North Carolina into New Jersey, which were distributed as follows: Eight thousand in spring and natural drainage rivulets flowing into the ice pond at Westville, N. J., 600 in a landlocked pond near Delanco, 600 in a mill pond between Merchantville and Evesboro, 600 in landlocked waters near Delair, and 400 in ponds of the Aquarium Supply Company, at Delair. In Doctor Smith's report for the year 1906 it was stated that the experiment was to be written down a failure. Whether it was due to the destruction of the introduced fish by black bass, pike, yellow perch, and sunfish, or whether because of other enemies, or because of their dislike to their changed conditions, they found their way during the spring rains to rivulets flowing to the Delaware River, or whether they escaped in other ways, could not be told. In his report for 1907, however, Doctor Smith states that the Gambusia was found in large numbers in Teals Branch of Pond Creek, a small tributary of Delaware Bay at Higsbie's Beach, by Mr. Henry W. Fowler, of the Academy of Natural Sciences, Philadelphia, and Messrs. H. Walker Hand and O. H. Brown. These gentlemen found it also very abundant in New England Creek, another tributary of Delaware Bay just north. Doctor Smith states that Mr. Seal was inclined to claim that this finding was the result of his work in 1908, but that Mr. Fowler doubted this conclusion since the points where found were 90 miles distant from points of introduction.

FISH INTRODUCED INTO HAWAII TO ABATE MOSQUITOES.

In the early part of 1903 Mr. D. L. Van Dine, then entomologist of the Hawaii Agricultural Experiment station of the U. S. Department of Agriculture, brought up the question of introducing top-minnows into Hawaii, since his investigations of the mosquito problem in the islands indicated that no effective natural enemies existed there. Dr. David Starr Jordan, to whom the problem was referred, informed Mr. Van Dine that while these fish had never been transported for such a great distance, they were extremely hardy, and that the experiment would be well worth while. The cost of the experiment, however, was prohibitive at the time, and it was not until 1904, when a Citizens' Mosquito Campaign Committee was organized in Honolulu, that the requisite funds were raised. Mr. Alvin Seale, an assistant of the Bureau of Fisheries, United States Department of Commerce and Labor, was chosen to do the work, and with an advance of $500 started in July, 1905, from Stanford University to the southern United States. He proceeded to Seabrook, near Galveston, Tex., where he found top-minnows in large numbers. They were swarming in all the stagnant waters at sea level, as well as in various ditches, ponds, and standing pools. Mr. Seale found that mosquitoes were very plentiful about Seabrook, but after careful study he convinced himself that they did not breed at all extensively in the bodies of water containing the fish, but in temporary and artificial breeding places, such as closed pools, tubs, and tin cans, not accessible to fish. Doctor Jordan had advised the collection of fish of the following genera: Mollinesia, Adinia, Gambusia, and Fundulus, all members of the family Pœciliidæ, the top-minnows. Mr. Seale made careful examinations of the stomach conditions of the minnows of the genera recommended by Doctor Jordan., These stomach contents were found to consist largely of larvæ of various insects, including those of mosquitoes, of the egg-masses of mosquitoes, of minute crustacea, and of some vegetation. The fish of the genus Gambusia were found to be the best insect feeders. The temperature of the water ranged from 74° to 87° F. Careful experiments were made with 10-gallon milk cans, in order to determine the conditions under which the fish could be most successfully transported to Hawaii. These experiments included observations on temperature of the water and on changing the water, and from these experiments was ascertained the necessary information in regard to the frequency of changing and the fact that best results could be obtained by transporting them in water of the normal temperature. The three most abundant species, *Gambusia affinis*, *Fundulus grandis*, and *Mollinesia*, were then collected and about 75 were placed in each can, a 20-gallon tin tank full of water being taken along as a supply reservoir. Mr. Seale left Seabrook on September 4, 1905. On the journey the fish were fed sparingly every morning at 8 o'clock on prepared fish food, finely ground liver, or hard-boiled eggs. At half past nine one-half of the water in each can was drawn off from the bottom, thus cleaning the cans and removing uneaten food and excrement. An equal amount of fresh water was added. At noon the cans were aërated by means of a large bicycle pump, a sponge being tied over the end of the hose to separate the air into fine currents. At four in the afternoon 2 gallons of water were drawn off from the bottom and 2 gallons of fresh water put in, and the aëration was repeated just before bedtime. Careful tests of water at each place of changing were made by experimenting with two fish. At El Paso, Tex., there was so much alkali in the new water that the fish were killed; at Los Angeles and at San Francisco the water was good. Twelve fish died between Galveston and San Francisco, and 15 between San Francisco and Honolulu. Honolulu was reached on September 15, 1905, with a loss of 27 out of approximately 450 fish. On arrival the fish were placed in the breeding ponds prepared for them at Moanalua, near Honolulu, where four ponds had been made ready. The fish thrived in all of the ponds almost equally well. They were protected by screens from predatory fish and from being carried out to sea by a freshet. In an official bulletin issued July 25, 1907, Mr. Van Dine reported that the fish had multiplied rapidly and from the few hundred introduced several hundred thousand had been bred and distributed. They had proved very effective against mosquito larvæ and also against mosquito egg-masses. Later advices show that the good work is continuing, and the experiment seems to have been a great success.

FISH IN THE WEST INDIES.

Girardinus pœciloides, a small top-minnow, occurs very abundantly in Barbados, where the popular name "millions" has been applied to them. This fish is very small in size, the grown female measuring about 1½ inches in length, while the male is much smaller. The female is dull in color, without conspicuous markings, while the male is marked with irregular red splotches on the sides and has a circular dark spot on each side. The fish is a rapid breeder and thrives and multiplies in captivity in water-tanks, reservoirs, and fountains, and garden-tubs in which aquatic plants are kept. They are greatly used in this way both in the towns and on the estates to reduce the annoyance of mosquitoes. In 1905 this fish was introduced by the Imperial Department of Agriculture of the British West Indies from Barbados into St. Kitts, Nevis, and Antigua. In 1906 it was introduced into Jamaica and in 1908 into St. Vincent and St. Lucia, and into Guayaquil in Ecuador. An account of these introductions is given in a pamphlet entitled "Millions and Mosquitoes," by H. A. Ballou, issued in 1908 by the Imperial Department of Agriculture of the West Indies (No. 55). In August, 1905, a number of fish were sent to Antigua in a kerosene tin. They arrived in good condition and were kept in a tank at the botanic station until they had sufficiently increased to be distributed. They were liberated in several ponds and streams and increased so rapidly that the country board of health undertook the work of stocking all the ponds and streams of the island. Three years after the first introduction all of the more or less permanent water of Antigua had been stocked, and Mr. Ballou states that many planters and others have commented on the apparent abatement of the mosquito nuisance in many localities. At St. Kitts the introduction was equally successful, but the local government did not take up the distribution of the fish as in Antigua. In Jamaica they were established with good results. "Millions" may be fed in captivity on mosquito eggs and larvæ, on raw beef or hard-boiled eggs, upon small insects of any kind, and even upon corn meal. They are readily transported short distances in a kerosene tin with no other preparation than a wire netting arranged near the top to prevent the fish from being thrown out if the water is splashed about. These fish have been introduced at the Isthmus of Panama.

FISH IN GERMAN EAST AFRICA.

Mr. J. Vosseler, in an article entitled "Fische als Moskito-Vertilger,"[a] gives an interesting account of some experiments with mosquito-feeding fishes in German East Africa. He discusses the question quite as authoritatively as does Mr. Seal, already quoted, and brings out the point that on account of the great physical and chemical differences in the water inhabited by mosquito larvæ the selection of suitable species of fish is made difficult by several restrictions. He states that the shallow shores of rivers or large lakes can be excluded from consideration, since the young of most species of fish

[a] Published in Der Pflanzer. Ratgeber für Tropische Landwirtschaft, for June 13, 1908, vol. 4, No. 8, pp. 118–127.

living there frequent the shores in shoals and prey upon the various forms of animal life, mosquito larvæ included. Many water supplies, however, contain salt and other chemicals, and are polluted from various sources, even from the excrement of game coming to drink; while temporary collections, such as pools, puddles, and irrigation ditches, contain turbulent, muddy water. The level of the water in these different conditions is very variable, and the temperature of the water goes through great variations within a single day, often in midday the heat rising above the limit which most fishes can stand. A fish which would withstand all these conditions would be very exceptional. While we are considering the question of fish introduction, the adaptability of the species to acclimatization, its power of enduring long transportation, and its ability to multiply rapidly, even under adverse conditions, are of vital importance to success. In his travels through the land of Oram (Algeria) in 1892, Mr. Vosseler found a widely distributed species occurring in thousands not only in the springs of salt or magnesia water as well as in the irrigation ditches, but also in the highly polluted, badly smelling pools used to water camels, in which 300 to 400 camels often waded in one day. He found the same species afterwards in pure fresh water, in hot springs, and in brackish water. He also found that it inhabits the subterranean waters of the desert and is probably brought up by boring for artesian wells. One of the officers of the garrison situated in the midst of a salt basin without outlet pointed out to Mr. Vosseler that this little fish eats mosquito larvæ, which explained the comparative absence of mosquitoes in that locality. Mr. Vosseler attempted the introduction of these fish into Germany and succeeded very well in spite of inadequate preparation. They began to lay eggs within a week of their arrival, and have become accustomed to proper food. They always prefer mosquito larvæ and small crustaceans. The fish in question is *Cyprinodon calaritanus*. The female is 8 centimeters and the male 5 centimeters long. The eggs are attached singly to water plants or stones at the rate of one or two a day. Mr. Vosseler states that the excellent qualifications of the species are shared by other members of the same family. In German East Africa at least 2 genera and 5 species are known.

A BRAZILIAN FISH.

Excellently practical results are reached in Rio de Janeiro by the use of a small fish known as the "barrigudo" (*Girardinus caudimaculatus*) which, in the great prophylactic work carried on in that city under the public-health service, is placed in tanks and boxes where it is impossible to use petroleum, and devours the larvæ of mosquitoes most voraciously.

MR. THIBAULT'S OBSERVATIONS.

In considering the normal relation between mosquitoes and fish, Mr. James K. Thibault, jr., of Scott, Ark., in a recent communication presents some interesting views and gives an interesting instance which he considers typical in some localities:

Personally, I do not think that mosquitoes ever breed in the presence of fish if the water is open, allowing the fish free access to the larvæ, yet it is a matter of common observation that under certain favorable circumstances some species do breed regularly in streams where fish are abundant. Yet even where conditions are favorable only a very few species seem to take advantage of it. So far as my own observations go the only mosquitoes that regularly do so in this locality are *Anopheles quadrimaculatus* and *Culex abominator*.

Conditions are favorable when the surface of the water becomes carpeted with aquatic vegetation which restrains the fish in their movements yet allows ample room and protection for the larvæ of the above-named species. There is a certain deep, slowly running bayou here that is the main breeding place for *quadrimaculatus* and *abominator* at present, while two years ago not a larva could be found there at all. The explanation is simple and may be given as a typical example of its kind. Two years ago launches passed through this bayou daily and all logs and drift were removed as soon as found so that the water had free passage and the pondweeds found no foothold, except very near the banks where they were completely destroyed by stock. After the launches stopped passing through this bayou logs soon accumulated and the pondweeds immediately took possession, so that throughout the present season *quadrimaculatus* and *abominator* have bred continuously and abundantly in this bayou.

It must be noted in passing that the larvæ, pupæ, and freshly emerged adults bred in such a location are invariably bright grassy green in color, which gives them an additional advantage over the fishes. This is not the case with larvæ, etc., found in other places.

DESTRUCTION OF LARVÆ.

Of course the abolition of accidental breeding places, the undertaking of drainage measures, and the practical use of natural enemies such as fish, result in the destruction of larvæ, but in this section it is proposed to treat of those measures which involve the use of what have come during recent years to be termed "larvicides." The dictionary definition of the word insecticide is "one who or that which kills insects, as insect powder;" therefore a definition of larvicide would be one who or that which kills larvæ. But in mosquito work it has come to be used for those substances which are applied to bodies of water in which mosquito larvæ are living, and which result in their destruction in one way or another. These substances, for the most part, are either poisons or more frequently oils which, forming a surface film, destroy the larvæ when they come to the surface to breathe. Ronald Ross long ago pointed out the great desideratum in this direction in the following words:

I have long wished to find an ideal poison for mosquito larvæ. It should be some solid substance or powder which is cheap, which dissolves very slowly, and which when in weak solution destroys larvæ without being capable of injuring higher animals. What a boon it would be if we could keep the surface of a whole pond free from larvæ simply by scattering a cheap powder over it, once in six months or so. It is very possible that such a substance exists, but unfortunately we have not yet discovered it.[a]

A great many experiments have been tried with poisonous substances in the search for the desideratum described by Doctor Ross, but although it is now seven years since he wrote this paragraph we still have failed to discover it. As early as 1899 Celli and Casagrandi published an account of an elaborate series of laboratory experiments on the destruction of mosquitoes by various chemicals in a paper entitled "La Distruzione delli Zanzare," published in the Annali d'Igiene Sperimentale. These experiments resulted in little practical good, and practically the best of all the larvicides, namely, the petroleum products, were discredited by the authors in question.

In the last few years many substances have been experimented with, both in the United States and in other parts of the world, and there has been from time to time a newspaper notice, or a series of newspaper notices, of some new substance which careful experimentation has shown to be of little or no service. In this way the use of permanganate of potash received much advertising in 1900, but as the writer has elsewhere pointed out, as a result of careful experimentation it was found that small amounts of the chemical have no effect whatever upon mosquito larvæ, which were, however, killed by using amounts so large that instead of using a handful to a 10-acre swamp, as had been stated in the newspapers, at least a wagon load would have to be used to accomplish any result; moreover, twenty-four hours after the use of this large amount and after the larvæ were killed, the same water sustained freshly-hatched mosquito larvæ perfectly, so that even were a person to go to the prohibitive expense of killing mosquito larvæ in the swamp with permanganate of potash the same task would have to be done over again two days later.

In 1904 a publication by the Bureau of Plant Industry of the United States Department of Agriculture, on the use of sulphate of copper against algæ and other microscopic plant-life, put certain newspaper men on the wrong track, and a number of articles were published making the erroneous statement that the Department of Agriculture recommended sulphate of copper as a perfect remedy against mosquito larvæ. So widely was this alleged discovery heralded that careful experiments were at once made in the Bureau of Entomology, by Dr. John B. Smith, of New Jersey, by Dr. W. E. Britton, of Connecticut, and by other entomologists, with the result that the substance was found to be of very slight value as a larvicide, and of really no practical value whatever.

Several proprietary mixtures or mosquito compounds have been prepared and placed on sale for the purpose of destroying mosquito

[a] Mosquito Brigades, London, 1902, pp. 33–34.

larvæ. A number of these have been brought or sent to the writer for experimentation, but, considering the cost, none of them has been of as great practical value as petroleum. In his report on the mosquitoes occurring in the State of New Jersey,[a] Dr. John B. Smith describes a number of experiments with substances of this kind, notably with certain soluble carbolic acid and cresol preparations, with chloro-naphtholeum, and with phinotas oil, and in his report for 1907 he gives the results of certain experiments with a substance known as "killarvæ." It is not necessary, however, to consider any of these substances in this connection except to state that phinotas oil has met with considerable use, since it forms a milky compound with water which settles through a pool and destroys not only mosquito larvæ, but all other animal life in the pool. It is used in cesspools and receptacles of that kind, and is also found to be of service in the anti-mosquito work on the Isthmus of Panama.

In another section we have spoken of the use of certain aquatic plants as forming so dense a covering over the surface of the water as to exclude mosquito larvæ from access to air, thus bringing about their destruction. Another method which brings about the same results, although in a different way, is described by Consul Wm. H. Bishop, of Palermo, Sicily, in the Monthly Consular and Trade Reports, No. 331, April, 1908, in which he quotes from an account of the experiments made by the chief of the sanitary service at Gaboon, French Africa, with cactus as a substitute for petroleum in the extermination of mosquitoes in warm climates. Beyond this account by Mr. Bishop we have no further information of this remedy:

> The thick, pulpy leaves of the cactus, cut up in pieces, are thrown into water and macerated until a sticky paste is formed. This paste is spread upon the surface of stagnant water, and forms an isolating layer which prevents the larvæ of the mosquitoes from coming to the top to breathe and destroys them through asphyxiation. It is true that petroleum can do the same service, but in warm climates petroleum evaporates too quickly and is thus of little avail. The mucilaginous cactus paste, on the contrary, can hold its place indefinitely, lasting weeks, months, or even an entire year; and the period of the development of the larvæ being but about a fortnight it has the most thorough effect.

After all we are practically reduced to the use of oils in this kind of work. Some effort has been made to find if there are any other oils that could be used to better advantage than petroleum. A suggestion was once made by Mr. W. J. Matheson that corn oil might be used. This is a substance which is made rather extensively in certain parts of the country and which, considering the enormous crops of corn grown in Western States, which in fact are so great that in past years of overproduction corn has been burned as fuel, might reasonably

[a] Report of the New Jersey State Agricultural Experiment Station upon the Mosquitoes Occurring within the State, their Habits, Life History, etc. Trenton, N. J., 1904.

be supposed to be a cheap oil. This, however, is not the case, and its price is prohibitive as compared with ordinary grades of kerosene. Experiments undertaken in 1900 indicated that corn oil does not spread readily. It gathers together in large patches on the surface of the water, and mosquito larvæ rising to the surface and finding themselves under a patch of oil will simply wriggle violently until they find the spaces between the patches where they breathe comfortably and live for several days. In this experiment the object was not only to secure a cheap and efficient oil, but to secure a persistent oil which will not evaporate and which will remain for at least several weeks over the surface of the water. Its nonspreading qualities, however, as well as its price remove it from practical consideration.

To sum up the whole question of larvicides, nothing has been found more satisfactory as regards efficiency and price than common kerosene of low grade, or better still, that grade known as fuel oil. This conclusion has not only been arrived at in the United States, but elsewhere, although petroleum has been more extensively used in the United States than elsewhere, and it is better understood in this country. In choosing the grade of the oil, two factors are to be considered. First, it should spread rapidly; second, it should not evaporate too rapidly. The heavier grades of oil will not spread readily over the surface of the water, but will cling together in spots and the coating will be unnecessarily thick, as in the case of the corn oil just mentioned. The rapidity of spread of film is also important. Ronald Ross, in his "Mosquito Brigades," pages 34 to 35, makes the following statement:

> Mr. Hankins of Agra informs me that the addition of amyl alcohol greatly expedites the formation of the film; and it is very necessary to obtain a film which makes its way between the stalks and leaves of water weeds.

Early in the course of antimosquito work in the United States careful experiments were made by Mr. W. C. Kerr, in the work of the Richmond County Club, on Staten Island, to which we have referred before. He tried several grades of oil and found a low grade of oil known as "fuel oil" to be best adapted to the work. Of the oils which he tried, some contained too much residuum of a thick nature, which appeared as a precipitate and could scarcely be pumped; some were too thick in July weather and could not be pumped at all, while some were limpid, easily handled, made a good uniform coating on the ponds, and were very effective. So long as oil flows readily and is cheap enough the end is gained, provided it is not too light, and does not evaporate too rapidly. The grade known as light fuel oil was recommended by the writer to the United States army workers in Cuba at the close of the Spanish war and was found to be effective. The price of oil of this kind has varied from $2.25 per barrel to $3 per barrel, f. o. b. Philadelphia.

In his early Catskill Mountains experiments the writer ascertained that about an ounce of kerosene to 15 square feet of surface space is about the right proportion, and that such a film would remain persistent for ten days, or slightly longer. He noticed further that even after the iridescent scum had apparently disappeared there was still an odor of kerosene about the water and that adult mosquitoes avoided it.

In the work done by Mr. H. J. Quayle, near San Francisco[a] more or less oiling was done upon ponds that could not be drained, and upon standing pools remaining in creek beds during the summer; and some was also done on marsh lands. The oil used was a combination of heavy oil of 18° gravity, and light oil of 34° gravity in the proportion of 4 to 1, respectively. This mixture made an oil that was just thin enough to spray well from an ordinary spray nozzle, and yet was thick enough to withstand very rapid evaporation. It was applied by means of a barrel pump where this could be used, but in the creeks and other situations, which could not be reached by horse and wagon, the ordinary knapsack pump was used. The price of the heavy oil at Burlingame, Cal., was 2 cents a gallon, and of the lighter oil 2½ cents a gallon. The former was obtained from the Bakersfield district, while the latter was a product of the Coalinga fields. Mr. Quayle found that the duration of efficiency depended somewhat on the nature of the pool and its exposure to the winds, but in no case could it be counted upon as thoroughly effective after a period of four weeks.

This period of four weeks brings up the question as to the frequency of application of kerosene. The persistence of the oil will undoubtedly vary with the temperature and with the character of the pool—whether exposed to the direct rays of the sun or shaded by trees, or exposed to the wind. Three weeks will probably be a good interval with light fuel oil. The army of occupation in Cuba used its oil every two weeks.

The application of kerosene to the surface of the water can be made in any one of several different ways. If it is simply poured upon the surface it will spread itself, or will be spread rapidly by light winds. The spraying method, either witb the barrel pump, or by knapsack pump, or bucket pumps, has been frequently used. The writer watched the oiling of ponds with a spraying pump in a New Jersey town several years ago. The water treated was all in small woodland ponds, and there was a great waste of kerosene. The spray was diffused and became scattered over the vegetation on the borders of the pond, a large share of it being wasted in this way, while the shore vegetation was killed. On small ponds the oil

---

[a] Bul. No. 178, Agr. Exp. Sta., Univ. Cal., 1906.

can be sprinkled to advantage out of an ordinary watering pot with a rose nozzle or, for that matter, pouring it out of a dipper or cup will be satisfactory. In larger ponds, pumps with a straight discharge nozzle may be used. A straight stream will sink and then rise and spread until the whole surface of the pond can be covered without waste. The English workers in Africa advise mopping the petroleum upon the surface of the water by means of cloths tied to the end of a long stick and saturated with kerosene. The use of such a mop may be desirable, even where a straight discharge pump has been used, in order to commingle two or more surface sheets of oil. In some of his early work on Staten Island, Doctor Doty, the health officer of New York, used a pump with a submarine discharge, throwing the oil out at the bottom of a pool and allowing it to rise to the surface. It seems that the idea was to destroy the insects feeding at the bottom more quickly, but as most mosquito larvæ rise to the top to breathe about every minute, there is practically nothing to be gained by such a method of distributing kerosene.

The use of larvacides in tropical regions brings in certain new features which complicate the problem of mosquito destruction to a certain extent. Colonel Gorgas and his corps of workers at Panama have been using petroleum very extensively just as they did at Habana. They find, however, that at Panama the rapid growth of vegetation prevents the oil from spreading uniformly and that it can not make a thin uniform film over the surface of water in which vegetation grows. They find also that algæ on the surface of the waters form with the oil a dark scum, which collects at the bottom of shallow pools. This scum later breaks up and floats about on the surface, rendering succeeding oilings less efficacious and necessitating the use of larger quantities of oil. They also find that where vegetable débris collects in a large body of water it will be blown about as a mass, its location changing with the wind, and thus break the film of oil. Mosquito larvæ also hide in this vegetation, which protects them from fish. The wind blows the oil to one side of the surface and it evaporates very rapidly in the Tropics. During the rainy season it is washed away very rapidly before it destroys all of the larvæ and of course where the film is not perfect the larvæ find free places to breathe. The bulk of the oil and the cost of transportation in rough territory for work on a large scale are disadvantages. In their work they find that they must constantly occupy themselves in removing vegetation before oil is applied, in order to prevent the necessity of using excessive amounts of oil. They find that new growths of algæ appear to develop very rapidly after the oil has united with the previous crop and sunk to the bottom.

In the course of the Panama work, as previously stated, phinotas oil has been used, and has been found to have the following advantages over crude oil: It acts as a poison and kills the larvæ very rapidly. It brings the larvæ out of their hiding places at once and is useful as an aid to the detection of the presence of mosquito larvæ. It is found also that in continuous heavy rains the larvæ are killed by the phinotas oil before the rain dilutes the treated water to any great extent. They find, however, that phinotas oil has certain disadvantages: It kills fish in a solution of 1 to 5,000, and it loses its efficiency very soon after application, so that eggs are laid upon the treated water quickly and the larvæ develop. Doctor Gorgas points out that there is considerable variation in the quality of this substance as shipped to the Isthmus. Some barrels will kill larvæ quickly in a solution of 1 to 3,000 parts of water, while other lots require for the same results 1 part to 1,000. Doctor Gorgas has recently published a list of the desiderata for the perfect larvacide for use in the Tropics, agreeing with the opinion expressed by Ronald Ross when he returned from his first visit to Africa that nothing as yet known is perfectly satisfactory:

(a) Low ultimate cost.

(b) Ability to affect and kill mosquito larvæ promptly, the more rapidly the better. It must be effective in moving water as well as in still water.

(c) Ability to form a solution with water and to thoroughly diffuse and mix with all the water of a small pond if applied only to one part thereof. Also the substance must not lose its larvicidal properties for a week or more after its application. The longer it will retain its larvicidal properties after it has been placed in the body of water the more valuable it will be.

(d) Ability to diffuse in water and through all parts of a body of water such as in a pond containing grass, water lilies, other aquatic vegetation, and vegetable débris.

(e) Ability to kill green algæ promptly.

(f) A concentrated larvicide is necessary so that one part of it to five thousand or more parts of water will promptly kill mosquito larvæ and pupæ.

(g) Nonpoisonous to human life or animals when taken in a strength of 1 to 1,000 and accidentally used as drinking water.

(h) That it have the property of discoloring the water to which it is applied, or of giving off sufficient odor to induce persons not to use water containing it in solution for drinking purposes.

(i) That the odor, if present, be not so obnoxious as to make its presence in water in ponds or streams near habitations undesirable.

(j) That it shall have a safe flash test and be nonexplosive.

(k) That it shall be sufficiently stable so that it may be kept "standardized."

Decoctions and emulsions of *Derris uliginosa* have been recommended for larvicidal use, but experiments conducted at the Wellcome Research Laboratories at Khartoum show that while it has considerable potency it also kills fish, and that even in regions where these plants are native the different species of Derris have only a limited use as insecticides.

During the 1905 outbreak of yellow fever in New Orleans an attempt was made to destroy mosquito larvæ in the open gutters of the city by the use of common salt. Dr. H. A. Veazie wrote us that the results were good where the work was properly done. Shortly after operations were begun there was a flight into the city of *Aëdes sollicitans* from the salt marshes northeast of New Orleans. Indignant citizens, ascertaining from experts the name and habits of the species, jumped to the conclusion that salting the ditches had brought about suitable breeding conditions for *sollicitans* and that the invasion of the city by that species was a direct result of the work of the sanitary officials. Charging mosquito pools with electricity does not seem to have been tried. Mr. Aaron Aaronsohn, director of the Jewish agricultural experiment station at Haifa, Palestine, tells the writer that Professor Blasius, of Berlin, reading a newspaper account that some electrical workers engaged in the vicinity of a river used the electrical current to catch fish, began, some little time ago, to study the effect of electricity on fish, and that he found that by discharging a current into the water he could stun the fish, but did not kill them. Mr. Aaronsohn suggests that this plan may perhaps be tried to advantage in certain favorably situated localities to ascertain whether it can be practically used against mosquito larvæ.

In the course of the experimental work with larvicides carried on at the Isthmus of Panama Colonel Gorgas and his assistants have constructed a larvicide plant at Ancon, and in the August, 1909, Report of the Department of Sanitation of the Isthmian Canal Commission it is stated that 14,600 gallons of larvicide were made at a cost of $0.1416 per gallon. The following is quoted from this report:

The method of making same is as follows: 150 gallons of carbolic acid is heated in a tank to a temperature of 212° F.; then 150 pounds of powdered or finely broken resin is poured in. The mixture is kept at a temperature of 212° F., 30 pounds of caustic soda is then added and solution kept at 212° F. until a perfectly dark emulsion, without sediment, is obtained. The mixture is thoroughly stirred from the time the resin is used until the end.

The resultant emulsion makes a very good disinfectant or larvacide. In fact, 1 part of it to 10,000 parts of water will kill Anopheles larvæ in less than half an hour, and 1 part to 5,000 parts of water will kill Anopheles larvæ in from five to ten minutes or less. This property of killing larvæ rapidly is of great importance in the Tropics, where continuous rainy periods make crude oil or kerosene much less valuable as a larvicide than it is in northern latitudes having less rainfall. Also, the larvicide acts as an algicide, and thus destroys the food and the hiding places of Anopheles larvæ. As it takes up very little room, compared with the area it can be spread over, the cost of distribution will be much less than that of crude oil or kerosene. Considering the large territory which the antimalarial work covers, this item alone is of great financial advantage to the department.

Tests have recently been made to determine approximately how much of the new larvicide will be needed per month (rainy season) for each district.

Although this larvicide will be used to a large extent, yet we shall continue to use crude oil for streams having a fair velocity, as such application gives excellent results and is as economical as larvicide would be, as the oil is spread in a very fine film automatically. In order to make the crude oil drip with continuous regularity, a piece of metal similar to that part of a flat-wick lamp which holds the flat wick is fastened to the oil container. It is made somewhat larger than the wick, so that the wick fits it loosely when saturated with the grade of fuel oil we use. This metal wick chamber is fitted to the oil container about 3 inches from its base. The space below the wick chamber is filled with a solution of caustic soda or of larvicide. As the oil is attracted along the wick by capillary attraction, it comes into contact with the larvicide or caustic soda and is "cut"—rendered thinner. This method of procedure prevents the wick from being clogged by the thick fuel oil and enables the wick to drip the oil desired.

In the September, 1909, report it is stated that the new larvicide was giving very satisfactory results and would undoubtedly reduce the cost of antimalarial work, besides being more effective than crude oil in many places. It seems to have some value as a destroyer of vegetation. In the October report satisfaction with its use is again expressed, and it is stated that the fact that it kills the grass at the edges of the ditches will be of importance in reducing the cost of antimalarial work.

ORGANIZATION FOR COMMUNITY WORK.

While in a large measure it is true that every individual householder practically rears upon his own premises the majority of the mosquitoes that bother him, still in a closely built city those reared by one's neighbors must be taken into consideration. In isolated country houses the character of the adjacent region must be considered by the individual who concerns himself with this work, but even here some sort of an organization is desirable, and even frequently necessary, as in cases where swamp lands are to be drained or where occasional invasions of such a migratory species as *Aëdes sollicitans* are to be feared. The control of all sources of mosquito supply in case of fresh water or brackish swamp land is usually too great a task for the individual, although on the large estates of great proprietors such work has been done at individual expense. In any sort of community, however, organization is necessary, not only to carry out the actual work, but to produce and to emphasize a universal sentiment in favor of the mosquito crusade—a sentiment so strong and so general that every individual will cheerfully take part in the work. The pioneers in this country who, in 1901 and 1902, attempted to arouse such a public sentiment had much difficulty in educating the people and in securing funds, but lately it has been an easier matter. Many communities, large and small, have taken up antimosquito measures, and such large cities as New York, Baltimore, New Orleans, and Nashville have given the question serious consideration in their city councils and in their boards of health, and have entered upon measures of greater or less efficacy. Many smaller towns have begun the crusade also, and those which have been especially active have been communities of summer resort. One of the early attempts was the formation of the North Shore Improvement Association of Long Island, which undertook a mosquito campaign involving over 25 square miles of territory along the north shore of Long Island, the territory including several villages and many country homes of wealthy people. Following the first year's work of this association a national antimosquito society was formed to encourage just this kind of work, and this society has published instructions and pamphlets of information which are at the disposal of all communities desiring to enter upon the task of freeing themselves from mosquitoes.

Work of this kind carried on in Cuba, in Panama, and in various English colonies will be referred to in later sections. All have been well organized and actively carried forward and have been successful in reducing the number of mosquitoes and in correspondingly reducing such diseases as are carried by mosquitoes.

Theoretically, community work should be done under official auspices, and should be inaugurated by boards of health, but official action is slow, even in the United States, where there is, as a rule, less red tape than in older countries. Moreover, official action in sanitary measures is often conservative, as well as slow. As already pointed out, the health question is not the only one involved. Abundance of mosquitoes means enormous economic loss to a community, entirely aside from the important question of health, and individual property owners realize this more than do official bodies. It is only necessary to cite the increased value of real estate at summer resorts where the mosquito scourge has been wiped out, and the great value of reclaimed marsh land for manufacturing sites in the immediate vicinity of great cities, or for agricultural purposes at a greater distance from the great centers of population. An unusual reason for anti-mosquito work developed a few years ago. A famous sportsman, who was at the same time a captain of industry and had also been a cabinet officer at Washington, spent large sums of money in the vicinity of Sheepshead Bay, Long Island, to reduce the abundance of mosquitoes, because his blooded race horses were losing condition from their bites, although he had previously paid no attention to the mosquito problem from the standpoint of human health and convenience or from the standpoint of the value of the real estate in that vicinity, of which he was a large holder.

In community work, therefore, as well as in most other measures of reform, the organization of private citizens has usually been the initial step. Many communities have their own village or town improvement associations, and many cities have their citizens' associations constantly alert to discover needed reforms and improvements and to bring them emphatically to the notice of their elected representatives on the city council and to the mayor's appointees on the board of health. It is through the mosquito committees of such associations that very much of the work in this direction has been agitated and inaugurated, and doubtless this method will continue most effectively for some time to come.

The first step in undertaking such work is to interest several responsible persons whose names carry weight in the community, and then to raise a small fund, either by appropriations from funds at the disposal of the improvement society, or whatever it may be, or by private subscription. Then these persons, forming a committee, should issue a circular to every householder, signed by the whole committee, reciting very briefly the well-known facts concerning the breeding places of mosquitoes and the measures which should at once be taken by householders. A good plan also would be to have a public lecture given by some expert, well illustrated, to which all householders should be invited. An excellent circular of the character just described was issued in the early summer of 1901 as follows:

THE VILLAGE IMPROVEMENT SOCIETY OF SOUTH ORANGE.

SOUTH ORANGE, N. J.

MAY 27, 1901.

The breeding place of the mosquitoes that may infest your house may be looked for within your own house or grounds, or in your immediate neighborhood.

The mosquito lays its eggs *only upon standing water* and passes the first ten days of its existence in the water.

Without standing water there can be no mosquitoes.

Dr. Howard says: "I feel sure that the cesspools in South Orange must be responsible for a great deal of your mosquito supply." Therefore:

Look to your cesspools, cisterns, water tanks, and any barrels or other receptacles in which water may stand for a few days, either inside or outside the house.

It is suggested that you at once do away with every unnecessary water receptacle.

Put kerosene oil in your cesspools and on surface of necessary standing water once in three weeks.

Oil placed on surface should not affect the taste of water drawn from beneath the surface, but when that is not considered advisable water receptacles should be screened with a fine mesh screen.

The mosquito being not only a serious annoyance, but a constant menace to health, its extermination becomes a matter of public concern.

The cooperation of every household is requested.

Please report to .... the location of any pools of stagnant water in your neighborhood.

After the issuing of the circular or the holding of the public lecture, or both, if the members of the committee are too busy, as they are likely to be, to engage to any extent in the actual superintending work, an intelligent superintendent must be chosen who will familiarize himself with the biology of mosquitoes and especially with the character of mosquito breeding places in general. He should at once be put to work upon a survey of the mosquito topography of the neighborhood. It will be well for him to make a map upon which every breeding place, aside from the chance receptacles about houses, should be noted with the greatest accuracy and care. Every house having an uncovered water-tank or having rain-water barrels should also be noted, and for each locality the most effective as well as the most economical remedy should be recorded. If these remedies demand any large-scale work estimates of the necessary expenditures should be indicated.

Such a careful report and map having been prepared and placed in the hands of the committee the amount of funds necessary can readily be estimated, and the expenditure of such sums as it is found possible to raise can be considered and agreed upon. The work can then be easily carried on through the summer under the direction of this superintendent, and of course the amount of the expenditure and the number of employes will depend entirely upon the local mosquito-breeding possibilities.

Some small communities will find that a full understanding of the problem on the part of individual householders will bring about great relief as the result of individual work, and that the only organization necessary will be perhaps the signing of a pledge by individuals to take care of their own premises. In other communities the matter will be a little more serious, but there will be some where the employment of a single man for two or three days a week throughout the summer will result in freedom from mosquitoes. Again, however, in larger communities the enforcement of municipal regulations will be found to be necessary before a desirable result can be obtained, and where the village is built upon swampy land or is surrounded by swamps the expenditure of considerable sums of money will be found to be imperative.

In every community, however, there will pretty surely be ultra-conservative, recalcitrant, and ignorant citizens—people who will not take the trouble to prevent the breeding of mosquitoes on their own premises—people in fact who will violently object to the entrance on their premises of an individual who will do the work for them. Such cases are not numerous, but they are always difficult to handle, and, in the absence of municipal action, moral suasion must be tried in the most ingenious ways which the committee can devise. Dr. Ronald Ross, in his excellent work "Mosquito Brigades," in writing of such persons, puts it very happily in the following words:

> The qualities chiefly necessary [in a superintendent] are energy, persistence, and an entire indifference to public or private opinion. The need of the first two is obvious; that of the last requires some explanation. The self-appointed superintendent will be at once astonished, and perhaps alarmed, at finding that his philanthropic and wholly harmless efforts are met at the outset by a storm of letters to the local press, demonstrating the absurdity and even immorality of his intentions; proving that mosquitoes cannot be destroyed, that they spring from grass and trees; that they can be destroyed, but that it is wicked to make the attempt because they were created to punish man; that they do not carry malaria, because malaria is a gas which

rushes out of holes in the ground, and rises as a blue mist over the country; they do not carry yellow fever, which is due to the effect of the tropical sun on rotting vegetation; that they do carry malaria and yellow fever, but in such small quantities that they act beneficially as unpaid vaccinators of these diseases; and so on.[a] It is possible to ignore all such epistles, because where they do not contradict each other, some one else is sure to contradict them; but an occasional letter in reply does good, and, to speak practically but rather cynically, serves to stimulate the necessary public interest in the work by keeping the letter-writers at such a pitch of exasperation that they give the campaign a constant stream of gratuitous advertisement in the newspapers. We are permitted to be cynical in a good cause.

Fortunately, operations against mosquitoes can be conducted on a large scale without much reference to private opinion—fortunately, because the inertia of the masses regarding new pathological discoveries is so great that were we to depend upon converting them, nothing would be done for half a century. For some inscrutable reason the man in the street, though he would scarcely think of contradicting a lawyer or an engineer on matters of law or engineering, finds himself quite equal to exposing the absurdities of the whole medical faculty on a medical matter.

These operations require no sacrifices or cooperation on the part of the general public. Most householders are glad enough to have their mosquito larvæ destroyed, and their backyards cleaned up for nothing. The reader, therefore, if he sees fit to start the work we are considering, may quietly proceed in it undisturbed by criticism, and may calculate upon receiving not only as much public support as his work will require during its progress, but the thanks of his fellows at its termination. Indeed, the majority of the public will not be slow to recognize the value of his efforts, even if they do not understand the scientific reasons which have induced him to make them.

In community work, after making an effort to insure the absence of household breeding, the attention of the superintendent should be devoted to chance pools along the public roadway and to breeding places in unused land. Drainage or filling are the best measures to adopt. The superintendent will find it advisable to attempt first to extirpate those breeding places from which the greatest numbers of mosquitoes are issuing. In this way he will the sooner bring about an appreciable diminution of the number of the insects, and of course the sooner this diminution is noticed by the citizens the sooner will popular sentiment unanimously support the work. The less populous breeding places may await treatment until a later date.

Large-scale operations requiring a considerable expenditure of money must be organized very perfectly as to detail. The first example of this large-scale work done in the United States was carried on in the most intelligent way by the North Shore Improvement Association of Long Island, mentioned above. Here, as an initial step, work was done by the superintendent and engineer, Mr. H. C. Weeks, during the summer of 1901. Mr. Weeks completed the survey of the large territory and estimated the cost of all operations. Another survey was made by two biologists, Prof. C. B. Davenport and Mr. F. E. Lutz, of the Cold Spring Harbor laboratory, then of the Brooklyn Institute of Arts and Sciences. These gentlemen positively

---

[a] NOTE.—Dr. Ross states that he has seen every one of these statements, and many others equally absurd, made at least half a dozen times in the British press.

identified all breeding places. Still another survey was made by the late Prof. N. S. Shaler, of Harvard University, who advised concerning the best methods of reclaiming the salt marshes included in the territory where the brackish-water mosquito breeds. Upon the basis of these surveys and reports the association began in 1902 its active work of extermination.

The following is Doctor Ross's summary of antimosquito work, and it is so admirable that it is quoted in full:

SUMMARY.

17. Summary of objects:

(1) We do not propose to exterminate mosquitoes in any entire Continent.

We propose only to deal with them in the town in which we live, and in its suburbs.

(2) We do not propose to get rid of *every* mosquito even in this town.

We aim only at reducing the number of the insects as much as possible.

(3) We do not think it possible to drain or otherwise treat every breeding-place in the town.

We aim at dealing with as many as possible.

(4) We can not exclude mosquitoes which may just possibly be blown into the town from miles away.

We content ourselves with preventing the insects breeding in the town itself.

18. Summary of methods:

(1) We start work at once with whatever means we can scrape together.

(2) We operate from a center outward.

(3) We clear houses, back yards, and gardens of all rubbish; empty tubs and cisterns containing larvæ, or destroy the larvæ in them by means of oil.

(4) We show people how to do these things for themselves, and how to protect tubs and cisterns by means of wire gauze.

(5) When we have cleared as many houses as we determine to deal with, we clear them over again and again.

(6) We fill up or drain away all the pools, ditches, old wells, and puddles we can—especially those which contain most larvæ.

(7) Such pools as can not be filled up or drained are deepened and cleared of weeds if they contain larvæ.

(8) Streams and water courses which possess larvæ are "trained."

(9) Where we can do nothing else we destroy the larvæ periodically with oil, or by brushing them out with brooms, or by other means.

(10) We endeavor to interest our neighbors in the work, and to educate the town into maintaining a special gang of men for the purpose of keeping the streets and gardens absolutely free of stagnant, mosquito-bearing water.

19. Motto: Our motto should be one which I think will shortly become the first law of tropical sanitation, namely, "*No Stagnant Water.*"

After concluding an account of his own personal work at Lloyds Neck, Long Island, and of the work done by the North Shore Improvement Association, Mr. W. J. Matheson, speaking before the First Anti-Mosquito Convention in New York, December 16, 1903, concluded that as the result of the work carried on it had been demonstrated that, with the exception of the salt-marsh mosquitoes, the mosquito nuisance can be controlled and abated in almost any locality where intelligent cooperation can be secured and a systematic inspection made of the premises for the purpose of destroying the breeding places. Extermination, in his opinion, will exterminate just as far as the intelligent landowner is willing to carry it, but that it can not be done once and for all any more than weeding a garden or the cropping of a lawn can be done once and for all. He concludes his paper with the following words:

So far as my experience goes, it has been demonstrated that mosquitoes can be as completely exterminated in any locality as dirt can be swept from a building, or as weeds from a walk, with the possible exception of *Culex sollicitans*, and with the exercise of no more intelligence and much less labor than is required in the performance of many domestic duties. My experience would lead me to conclude that if mosquitoes continue to exist in any locality it is because the people are too indifferent to the nuisance to take the trouble to be rid of it.

THE IMPORTANCE OF INTERESTING CHILDREN.

Under the general head of "Remedies" we have mentioned the efforts made by Professor Hodge, in Worcester, Mass., to interest the school children of the city in the search for mosquito breeding places. This must have been in 1901–2. But the most serious and productive effort seems to have been made at San Antonio, Tex., a year or so later, at the initiative of Dr. J. S. Lankford, of that city.

In November, 1903, there were cases of yellow fever in San Antonio which caused several deaths, and an inexcusable interruption of commerce that cost hundreds of thousands of dollars. In the effort to allay the panic, the existence of yellow fever was denied, not only by persons having business interests in the city, but by many medical men as well. Very many adults not only denied the existence of the fever in the city, but denied the relation between the mosquitoes and the fever. Perhaps the majority of the adults seemed too old to learn; and to the enlightened physicians it appeared that it was impossible to begin education at the wrong end of life.

The chairman of the sanitary committee of the school board (Doctor Lankford) grasped the happy idea that if the children were properly educated, sanitary matters in the future would be much better attended to. He suggested to the board that it would be valuable to educate all of the school children of the city in prophylaxis and make sanitarians out of them all. The school board heartily approved of the proposition, and the campaign was at once begun to educate the children on the subject of *Insects as Disease Carriers*. The best recent medical literature on the subject was procured and furnished to the teachers, and a circular letter was sent to them outlining a proposed course and offering a cash prize for the best model lesson on the subject. Teachers became deeply interested in the subject. A crude aquarium, with eggs and wrigglers, was kept in every schoolroom, where the pupils could watch them develop; and large magnifying glasses were furnished in order that they might study to better advantage. The children were encouraged to make drawings on the blackboard of mosquitoes in all stages of development; lessons were given and compositions were written on the subject. Competitive examinations were held, and groups of boys and girls were sent out with the teachers on searching expeditions to find the breeding places. Rivalry sprang up between the 10,000 public school children of the city in the matter of finding and reporting to the health office the greatest number of breeding places found and breeding places destroyed. Record was kept on the blackboards in the schools for information as to the progress of the competition and great enthusiasm was stirred up. In addition to these measures, a course of stereopticon lectures was arranged, grouping the pupils in audiences of about 1,000 from the high school down, and, in Doctor Lankford's words—

It was an inspiring sight to watch these audiences of a thousand children, thoughtful, still as death, and staring with wide-open eyes at the wonders revealed by a microscope. It seemed to me that in bringing this great question of preventive medicine before public school children we had hit upon a power for good that could scarcely be overestimated.

The result of this work, it is pleasing to say, was a decided diminution in the matter of mosquitoes in San Antonio. There was some opposition among the people, but the movement on the whole was very popular. One result of this work was that while there had previously been from 50 to 60 deaths a year from malarial trouble, the mortality was reduced 75 per cent the first year after this work was begun, and in the second year it was entirely eliminated from the mortality records of San Antonio.

In organizing community work against mosquitoes, the school children hereafter must be counted upon as a most important factor. Almost every child is a born naturalist, and interest in such things comes to them more readily than anything else outside of the necessities of life. They are quick-witted, wonderfully quick-sighted, and as finders of breeding places they can not be approached except by adults of the most especial training. One of the first steps that a community should take is, therefore, the encouragement of the interest of the children in the public schools.

RECENT WORK IN GERMANY.

The city of Leipzig quite recently has begun a crusade against malaria under the direction of the city council. The following account of this work was sent in by United States Consul S. P. Warner, and is published in the Daily Consular and Trade Reports for April 20, 1909:

So many cases of malaria have recently occurred in those sections of Leipzig which are adjacent to any one of the four rivulets which flow through the city that the city council has decided to adopt stringent measures to exterminate the mosquitoes (Anopheles) that spread the disease.

In order that the work of extermination may be thoroughly and systematically carried out, the city council has notified all housekeepers in the infected sections of the city to carefully examine their houses or apartments for mosquitoes and to destroy any that may be found. Every household in the districts concerned has been furnished by the city council with a large circular, which, in addition to information as to the cause and spreading of malaria, contains advice as to the best means of destroying the malaria mosquitoes.

Certain dates have been specified between which the houses are to be searched and the mosquitoes destroyed. At the expiration of the time specified inspectors appointed by the city council will visit each house and apartment and make careful examinations to see that the work of exterminating the mosquitoes has been properly carried out. Those who fail to comply with the regulations promptly and thoroughly will be subject to a fine of about $7.50.

WORK ALONG RIVER FRONTS IN EGYPT.

Communities living along river fronts may have good antimosquito work hampered by the constant reintroduction of a mosquito supply from boats landing at their river fronts. This point has been especially noted in the course of the excellent work done at Khartoum. The following passage is taken from the first report of the Wellcome Laboratories, pages 21–22:

At an early period the steamers were found to be largely infected, especially with the larvæ of *Stegomyia fasciata*, and to a less extent by those of *Culex fatigans*. Anophelines, either as larvæ or imagines, have never been met with; but up-country, as will be noted later, the adults are frequently to be seen on board, and may remain as passengers for a considerable period. At first it was decided to use lime for the steamer bilges, but this was said, erroneously I believe, to act upon iron and to be unsuitable. Consequently crude petroleum was recommended, though not so good nor so easily applied. Along with this the periodical emptying of the bilge and fumigation with the sulphur squibs described by Colonel Giles were advised, the latter to get rid of the adult insects. Unfortunately in the case of the steamers, familiarity had evidently bred contempt, for, at first, despite the cooperation of the director of the steamers and boats department, little energy was displayed by the engineers in charge and the preventive measures were largely ignored, and in some instances even ridiculed. This was the more to be regretted, as there is no doubt that mosquitoes can be banished from all the steamers if a little care and trouble were taken. Mr. Beadnell, of the Geological Survey, carried out these simple methods on the S. S. "Nubia," and practically cleared her of mosquitoes, so that for the first time he was able to sleep below in comfort. A great improvement also resulted in the case of the gunboat "Zafir," in which I went to Dueim and found to be simply swarming with adult Culices and their larvæ, while these measures absolutely prevented any mosquitoes breeding out on board the S. S. "Amka" during a period of nearly two months, the greater part of which was passed in regions swarming with these winged pests. Latterly, I am glad to say, the engineers have been impressed with the necessity of doing all in their power to aid the brigade. This is the more necessary, as it is easy for the steamers to infect the town and thus spoil much of the work done and render it futile. I am certain that this has occurred in many instances * * *.

EXAMPLES OF MOSQUITO EXTERMINATIVE MEASURES IN DIFFERENT PARTS OF THE WORLD AND OF THE SANITARY RESULTS FOLLOWING THEM.

It is proposed in this section to describe briefly some of the most striking examples of successful warfare against mosquitoes that have been carried out since 1900 and to bring them together into one consecutive account, a task that has heretofore not been attempted. Of many of them the details are not well known on account of the inaccessibility of the documents of record.

FEDERATED MALAY STATES.

The work was begun at Klang and Port Swettenham in 1901 and 1902, the object being to abolish malaria, which was disastrous in its prevalence and virulence, by the extermination of mosquitoes by means of extensive drainage and the abolishing of breeding places. The town of Klang is situated on swampy ground lying between the Klang River—from which it takes its name—and a semicircle of low hills. Klang was formerly the terminus of the government railway and the port of the State. The river navigation, however, was difficult, and a new port was selected near the mouth of the river, which was opened in September, 1901, and named Port Swettenham. The anchorage was good, but a half mile of mangrove swamp intervened between the shore and a wide extent of flat peaty land. The mangrove swamp was intersected by a narrow road running up from the coast to Klang, some 5 miles away.

After Port Swettenham was opened malaria increased alarmingly; almost all of the laborers were attacked, and many severe cases occurred on board ships lying alongside the wharves. A commission was formed consisting of physicians and engineers, and antimosquito work of an extremely effective and complete character was carried out. The following condensed account of the operations, and the tables showing striking results in the reduction of malaria, are taken from an article by E. A. O. Travers, state surgeon, Selangor, and Malcolm Watson, district surgeon, Klang, published in the Journal of Tropical Medicine for July 2, 1906:

Port Swettenham.—An area of about 110 acres, formerly low-lying swampy land covered with mangrove trees, has been cleared and carefully drained. In the neighborhood of the railway, government buildings, and town site a considerable area has been filled in and leveled, partly to do away with the breeding grounds of mosquitoes and partly to provide building sites. The whole area not occupied by buildings or roads is now covered by grass.

The total expenditure on works other than the preparation of building sites has been (to the end of 1905) £7,000 [$34,020], and the annual cost of upkeep of drains, etc., is approximately £40 [$194.40] for clearing earth drains, and for town gardeners, £100 [$486].

Klang.—The area affected by the operations is about 332 acres. Twenty-five acres of virgin jungle and 80 acres of dense secondary growth (in places 30 to 40 feet high) have been cleared and 36 acres of permanent swamp have been drained. The areas cleared are now mainly under grass.

The total expenditure to end of 1905 has been £3,100 [$15,066], and the cost of annual upkeep is about £60 [$291.60] for clearing earth drains, and £210 [$1,020.60] for town gardeners.

As will be seen from the following statistics of cases of malaria treated at the district hospital, Klang, the improvement in the health of the inhabitants of the areas treated began immediately after the completion of the drainage and other works and has continued to date.

Table showing the number of cases of malaria admitted to the Klang hospital from Klang town and Port Swettenham, as compared to the number of cases admitted from other parts of the district.

Residence.	1901.	1902.	1903.	1904.	1905.
Klang	334	129	48	28	12
Klang and Port Swettenham [a]	88	....	....	....	....
Port Swettenham	188	70	21	4	11
Other parts of district	197	204	150	266	353
Total	807	....	219	298	376

[a] Certain persons lived some nights in Klang and some in Port Swettenham.

The following table shows the number of deaths from fever and other diseases which have occurred at Klang and Port Swettenham during the last six years. The population in 1901 was about 4,000, but has largely increased since.

Deaths in Klang and Port Swettenham corrected for deaths in hospital.

Year.	1900.	1901.	1902.	1903.	1904.	1905.
Fever	259	368	59	46	48	45
Other diseases	215	214	85	69	74	68
Total	474	582	144	115	122	113

It will be noted that the remarkable improvement in the health of the inhabitants which occurred in 1902, immediately after the antimalarial works had been completed, has been well maintained.

The following table shows the number of deaths occurring in the district of Klang, excluding the town of Klang and Port Swettenham. (Population 14,000 in 1901, since largely increased.)

Deaths in Klang district, excluding Klang town and Port Swettenham.

Year.	1900.	1901.	1902.	1903.	1904.	1905.
Fever	173	266	227	230	286	351
Other diseases	133	150	176	198	204	271
Total	306	416	403	428	490	622

These figures are especially valuable as a proof that the marked improvement in the health of the inhabitants of the towns of Klang and Port Swettenham is due to the antimalarial measures carried out, and not to a general improvement in the health of the district.

In Klang and Port Swettenham we have 368 deaths due to fever in 1901, and 45 only in 1905; whereas in the rest of the district, which has not been dealt with by any special antimalarial works, we have 266 deaths due to fever in 1901 and 351 in 1905.

It may here be mentioned that Klang is a large planting district about 380 square miles in extent, that it is mainly low-lying flat land, utilized for the cultivation of rubber, and that it would be almost impossible to protect the scattered population from malaria by drainage and filling in swamps. A great deal is now being done on most of the estates by regular administration of quinine, and also by protection from mosquitoes.

Malaria in children as evidenced by examination of blood.—No better indication of the presence or absence of malaria in any given district can be obtained than by a systematic examination of the blood of children.

The following details of the results of examinations carried out by Dr. Watson in 1904 and 1905 are of considerable interest:

Results of examination of blood of children in Klang and Port Swettenham (specially drained areas).

	November and December, 1904.			November and December, 1905.		
	Number examined.	Infected.	Percentage infected.	Number examined.	Infected.	Percentage infected.
Klang	173	1	0.57	119	1	0.84
Port Swettenham	87	1	1.14	76	1	.00
Total	260	2	.76	195	2	.51

Results of blood examinations in other parts of district not especially drained.

November and December, 1904.			November and December, 1905.		
Number examined.	Infected.	Percentage infected.	Number examined.	Infected.	Percentage infected.
298	101	33.89	247	59	23.8

Improvement in health of government employees.—The remarkable way in which the health of the government employees residing at Klang and Port Swettenham has been affected is well shown by the following figures. It may be mentioned that in 1901 the number of persons residing at Port Swettenham, employed by the Government, was 176, and in 1904, 281.

Table showing number of sick certificates and number of days' leave granted on account of malaria.

	1901.	1902.	1903.	1904.	1905.
Certificates	236	40	23	14	4
Days of leave	1,026	198	73	71	30

The conclusions to be arrived at from the figures given in this report are very evident:

(1) Measures taken systematically to destroy the breeding places of mosquitoes in the towns, the inhabitants of which suffered terribly from malaria, were followed almost immediately by a general improvement in health and decrease in death rate.

(2) That this was due directly to the works carried out, and not to a general dying out of malaria in the district, is clearly shown by figures pointing out that while malaria has practically ceased to exist in the areas treated, it has actually increased to a considerable extent in other parts of the district where antimalarial measures have not been undertaken.

The fact that the statistics for 1905 are even more favorable than those for 1902 is very strong evidence in favor of the permanent nature of the improvement carried out.

If, as it is hoped, malaria has been permanently stamped out from Klang and Port Swettenham by works undertaken in 1901, our experience in the Malay States should be of value to those responsible for the health of communities similarly situated in many other parts of the world.

THE WORK IN HABANA DURING THE AMERICAN OCCUPATION, 1901-2.

One of the most striking examples of clean, efficient antimosquito work is that done by the American troops in Habana at the close of the Spanish war, under the direction of the Army Medical Corps and under the especial direction of Col. W. C. Gorgas, U. S. Army. In the statements which follow, Colonel Gorgas's published writings have been freely used.

Yellow fever had been endemic in Habana for more than 150 years, and Habana was the source of infection for the rest of Cuba. Other towns in Cuba could have rid themselves of the disease if they had not been constantly reinfected from Habana. By ordinary sanitary measures of cleanliness, improved drainage, and similar means, the death rate of the city was improved from 1898 to 1902 from 100 per thousand to 22 per thousand, but these measures had no effect upon yellow fever, this disease increasing as the nonimmune population increased, and in 1900 in fact there was a severe epidemic.

Aëdes calopus was established as the carrier of the fever early in 1901, and then antimosquito measures were immediately begun. Against adult mosquitos no general measures were attempted, although screening and fumigation were carried out in quarters occupied by yellow fever patients or that had been occupied by yellow fever patients. It was found that *calopus* bred principally in the rain-water collections in the city itself; that *Culex quinquefasciatus* bred everywhere, and that *Anopheles argyritarsis* bred principally in the suburbs in pools and puddles well protected with grass. Two mosquito brigades were started—one to take care of *calopus* and the other *Anopheles*.

The work of the so-called "Stegomyia brigade" was confined to the built-up portions of the city. The city was divided into about thirty districts, and to each district an inspector and two laborers were assigned, each district containing about a thousand houses. The mayor of Habana issued an order requiring all collections of water to be so covered that mosquitoes could not have access, a fine being imposed in cases where the order was not obeyed. The water supplied Habana was very hard, and it was customary for every family to collect rain water in barrels. As the majority of the people in the large tenement houses were poor, and as each family had a rain barrel, the health department covered these barrels at public expense, leaving a small screen opening through which the water could run and placing a spigot at the bottom through which it could be drawn. Every house in Habana, on the average, has a cesspool, the liquid contents generally seeping into the soil. The inspector on each visit had from 4 to 6 ounces of petroleum poured into the cesspool, and where this was not accessible it was poured into all closets connected with the cesspool; all receptacles containing fresh water that did not comply with the law were emptied, and, on a second offense, destroyed. If the owner was an old offender, he was prosecuted under the law and fined.

As a result of this work of the so-called "Stegomyia brigade," whereas in January, 1901, there were 26,000 fresh-water receptacles containing mosquito larvæ, in January, 1902, there were less than 400 such receptacles containing larvæ; mosquitoes had rapidly decreased, and were entirely absent in many parts of the city. The result of this work, thoroughly done, was to wipe out yellow fever in Habana, and there has not been a certain endemic case since.

The "Anopheles brigade" was organized for work along the small streams, irrigated gardens, and similar places in the suburbs, and numbered from 50 to 300 men. No extensive drainage, such as would require engineering skill, was attempted, and the natural streams and gutters were simply cleared of obstructions and grass, while superficial ditches were made through the irrigated meadows. Among the suburban truck gardens Anopheles bred everywhere in the little puddles of water, cow tracks, horse tracks, and similar depressions in grassy ground. Little or no oil was used by the Anopheles brigade, since it was found in practice a simple matter to drain these places. At the end of the year it was very difficult to find water containing mosquito larvæ anywhere in the suburbs, and the effect upon the malarial statistics was striking. In 1900, the year before the beginning of the mosquito work, there were 325 deaths from malaria; in 1901, the first year of mosquito work, 151 deaths; in 1902, the second year of mosquito work, 77 deaths. Since 1902 there has been a gradual, though slower decrease, as follows: 1903, 51; 1904, 44; 1905, 32; 1906, 26; 1907, 23.

WORK AT THE ISTHMUS OF PANAMA.

The United States Government has very properly used the services of Colonel Gorgas, who was in charge of the eminently successful work at Habana, by appointing him chief sanitary officer of the Canal Zone during the digging of the canal. In 1904 active work was begun, and Colonel Gorgas was fortunate in having the services of Mr. Le Prince, who had been chief of his "mosquito brigades" in Habana, and therefore was perfectly familiar with antimosquito methods. In Panama, as in Habana, the population had depended principally upon rain water for domestic purposes, so that every house had cisterns, water barrels, and such receptacles for catching and storing rain water. The city was divided up into small districts with an inspector in charge of each district. This inspector was required to cover his territory at least twice a week and to make a report upon each building with regard to its condition as to breeding places of mosquitoes. All the cisterns, water barrels, and other water receptacles in Panama were covered as in Habana, and in the water barrels spigots were inserted so that the covers would not have to be taken off. Upon first inspection, in March, 4,000 breeding places were reported. At the end of October less than 400 containing larvæ were recorded. This gives one a fair idea of the consequent rapid decrease in the number of mosquitoes in the city. These operations were directed primarily against the yellow-fever mosquito, and incidentally against the other common species that inhabit rain-water barrels. Against the Anopheles in the suburbs the same kind of work was done which was done in Habana, with exceptionally good results.

The same operations were carried on in the villages between Panama and Colon. There are some twenty of these villages, running from 500 to 3,000 inhabitants each. Not a single instance of failure has occurred in the disinfection of these small towns, and the result of the whole work has been the apparent elimination of yellow fever and the very great reduction of malarial fever. The remarkable character of these results can only be judged accurately by comparative methods. It is well known that during the French occupation there was an enormous mortality among the European employees, and this was a vital factor in the failure of the work. Exact losses can not be estimated, since the work was done under 17 different contractors. These contractors were charged $1 a day for every sick man to be taken care of in the hospital of the company. Therefore it often happened that when a man became sick his employer discharged him, so that he would not have to bear the expense of hospital charges. There was no police patrol of the territory, and many of these men died along the line. Colonel Gorgas has stated that the English consul, who was at the Isthmus during the period of the French construction, is inclined to think that more deaths of employees occurred out of the hospital than in it. A great many were found to have died along the roadside while endeavoring to find their way to the city of Panama. The old superintendent of the French hospital states that one day 3 of the medical staff died from yellow fever, and in the same month 9 of the medical staff. Thirty-six Roman Catholic sisters were brought over as female nurses, and 24 died of yellow fever. On one vessel 18 young French engineers came over, and in a month after their arrival all but one died. Now that the mosquito relation is well understood, it was found during the first two years under Doctor Gorgas that although there were constantly one or more yellow-fever cases in the hospital, and although the nurses and doctors were all nonimmune, not a single case of yellow fever was contracted in that way. The nurses never seemed to consider that they were running any risk in attending yellow-fever cases night and day in screened wards, and the wives and families of officers connected with the hospital lived about the grounds, knowing that yellow fever was constantly being brought into the grounds and treated in near-by buildings. Americans, sick from any cause, had no fear of being treated in the bed immediately adjoining that of a yellow-fever patient. Colonel Gorgas and Doctor Carter lived in the old ward used by the French for their officers, and Colonel Gorgas thinks it safe to say that more men had died from yellow fever in that building than in any other building of the same capacity at present standing. He and Doctor Carter had their wives and children with them, which would formerly have been considered the height of recklessness; but they looked upon themselves, under the now recognized precautions, as safe almost as they would have been in Philadelphia.

No figures of actual cost of the antimosquito work either in Habana or in the Panama Canal Zone are accessible to the writer, but it is safe to say that it was not exorbitant and that it was not beyond the means of any well-to-do community in tropical regions.

WORK IN RIO DE JANEIRO.

One of the most difficult problems of this character was that of freeing Rio de Janeiro from its reputation as the great yellow fever center. The difficulties were very great, and the amount of money required for efficient work was enormous. Rio de Janeiro has a population of more than 800,000 people; it extends over an area of 430 square miles; it is very irregular in its topography, varying in altitude from 1 to 460 meters (3 feet to 1,509 feet) above the sea level; it has 82,396 houses, and, as in all great centers of population, the inhabitants of very many of the houses, if not resisting the efforts of the sanitary authorities, surely did not facilitate them. The effort was begun in April, 1903, under the direction of the public-health service, but the organization effected was of a temporary character and needed the passage of new laws by congress, which was effected in January, 1904, and resulted in the reorganization of the hygienic service of Brazil and created a service for the stamping out of yellow fever. One million six hundred and fifty thousand dollars was appropriated annually for this work. The service established included 1 medical inspector, 10 sanitary inspectors (physicians), 1 administrator, 1 customs inspector, 1 accountant, 70 medical students, 9 subchiefs, 200 overseers, 18 guards of the first class, 18 guards of the second class, and 1,000 workmen; and in addition to this personnel, the assistance of the public-health service corps of inspectors was called upon. The city was divided into zones, according to the density of the population, and the work was divided into two sections: (1) Isolation and sanitation; (2) the policing of the infected districts. Under the first section, yellow-fever patients were removed to the pesthouse, residents were isolated, and houses were disinfected. Under the second, the sanitary police fôrce visited every building in the city, destroyed the early stages of mosquitoes, and screened standing water where possible. One force worked in buildings, and another in vacant lots, streams, marshy lands, etc. The following paragraphs relative to this work are quoted from an address made before the Latin-American Medical and Sanitary Congress, held in Rio de Janeiro August 1 to 10, 1909, by Dr. Oswaldo Cruz:

> Yellow-fever cases were made known to the sanitary inspectors by the reports of medical assistants, of the head of the family in which a case occurred, or by any one to whom the facts of the case were known, in accordance with the requirements of the law. The sanitary service being advised, a competent group of inspectors and authorities were at once dispatched to the locality, having with them a physician. The latter ascertained if the case was one for isolation treatment (whether under or over four days after the onset of the disease), and if the case required isolation the same was carried out either in the dwelling house or in the hospital, hospital treatment being resorted to only when the dwelling was unsuited to isolation treatment or when the patient wished it. In such cases the patient was taken to hospital in a vehicle closed against the entrance of mosquitoes, and the house was disinfected in accordance with the system below outlined. In the case of isolation in the home the physician chose a roomy quarter of the house with door opening into another secluded part of the house and with windows. If there were more than one door, the others were temporarily closed. The patient was kept under a netting enveloping the bed upon which he lay during the time permanent quarters were being arranged. The doors and windows of the room to be isolated and of the rest of the house as well were sealed to prevent the exit of mosquitoes existing there, the windows of the isolated room being fitted with wire screens in such a way as not to interfere with ventilation, all other openings to the outside or to other parts of the house being sealed with cloth or paper. The only door to be used in the use of the room must be specially fitted with a double door drum, provided with an arrangement which does not permit of both doors being opened at the same time. This apparatus prevents the entrance and exit of mosquitoes, and after the room is thus prepared the door and windows are closed and camomile is burned in the room 3 to 4 hours in the proportion of 10 grams per cubic meter of space. The room is then well ventilated and is ready to receive the patient. The rest of the house is well calked and isolated from the room in which the patient is placed, and disinfected with sulphur gas, as below indicated. During this operation a sanitary inspector remains in the room

with the patient and stops the entrance of any gas which may possibly find its way through some overlooked crevice. During the preparation for disinfection the sanitary authorities make a thorough inspection and destroy any mosquito larva they find, pick up or destroy any vessels lying about which might serve as a receptacle for mosquito-breeding water, and close water boxes against the same danger. The patient remains in isolation for seven days, after which isolation may terminate, if the family so wishes. The infected district is then treated as above indicated; that is, by disinfection, sanitary policing, and medical supervision. Disinfection is carried on in two ways, one force working from the center toward the outer limits of the district and the other from the boundaries of the district inward. The area of infection being determined over as large an area as possible, these two sections separate, one of which begins immediately with the house in which the case of yellow fever occurred, the other beginning at those houses which might possibly have been infected at the greatest possible distance from the case in isolation. The purpose of such a system was to destroy all mosquitoes which might have carried infection within the district.

While the disinfecting force is thus at work the police division, under the direction of a physician and of students who direct the different sections, operates throughout the infected district, making every effort to destroy all mosquito larvæ and to prevent the possible breeding of mosquitoes outside as well as inside the house. Where larvæ are likely to exist in stagnant water or refuse of any sort, petroleum mixed with creoline, lysol, or similar products is thrown over the water or refuse in sufficient quantity to kill the larvæ instantly. Where it is impossible to use petroleum, as in the case of tanks and boxes for household use, a small fish, the "barrigudo" or *Girardinus caudimaculatus*, is placed in large numbers in the water. This fish destroys the larvæ of mosquitoes most voraciously. Larvæ in the drains are destroyed by the use of "Clayton gas," which is pumped into the sewer, which has been previously divided into compartments. Simultaneously with the disinfection the sanitary inspectors make daily inspection of the suspected district, examining every inhabitant supposed not to be immune—that is, children under 5, and all foreigners of less than 5 years' residence in Rio. These are subjected to the closest vigilance, being placed in isolation at the least tendency to rising temperature. Reports are made in writing, those to whom this duty falls being required to fill out daily a bulletin sent out by the medical inspector to the chief of each district. In this report must be given the record of any who work outside the district or who for any reason absent themselves therefrom, a record of their condition being also kept by the physician in the district in which they work or are temporarily resident. When any inhabitant absents himself from the district the record must show his address, where he will be subjected to vigilance on the part of the authorities there. If the person under vigilance evades the attention of the physician and withdraws without giving notice, the owner of the house in which he lived is fined, he himself is apprehended by the sanitary police, fined, and subjected to renewed vigilance.

The vigilance in each district extends over a period of one month after the appearance of the last case. To give an idea of this service we will note the figures covering the prophylactic campaign in the infected district about the cotton factory, "Fabrica das Chitas," in 1906. The inspection was carried out by 18 doctors, who examined daily all suspected persons—in all, 7,966 persons, of whom 2,989 were not immune. Sixty cases were reported, of which only 19 proved to be yellow fever, and the district was declared entirely freed of infection after six months. With the combination of the three systems there is no doubt about cleaning up effectively any district in which yellow fever may appear. In normal conditions the police service is carried out with equal painstaking, especially in the districts where infection last appeared. When, after some time, there seems no longer to be danger of new infection, the inspectors allow water to stand in several marked spots most favorable to mosquito breeding.

These pools are then carefully watched, and examined at frequent intervals. This is a sure way to indicate the presence of the mosquito, and is a trap for those about to spawn. They are thus most easily destroyed. In many zones of the city these traps revealed the presence of no mosquitoes whatever.

The actual results which followed this admirable work are shown by a table indicating the death rate from yellow fever in Rio from 1872 to date, which indicates that perfect success has been reached.

Mortality from yellow fever in Rio de Janeiro from 1872 to August, 1909.

Year.	Deaths.	Year.	Deaths.
1872	102	1891	4,456
1873	3,659	1892	4,312
1874	829	1893	825
1875	1,292	1894	4,852
1876	3,476	1895	818
1877	282	1896	2,929
1878	1,176	1897	159
1879	974	1898	1,078
1880	1,625	1899	731
1881	257	1900	344
1882	89	1901	2,299
1883	1,608	1902	984
1884	863	1903	584
1885	445	1904	48
1886	1,449	1905	289
1887	137	1906	42
1888	747	1907	39
1889	2,156	1908	4
1890	719	1909	0

WORK IN ALGERIA.

In 1902 an antimalarial campaign was begun in Algeria under the auspices and at the expense of the Pasteur Institute of Paris. The work was begun in a small way, and the service was afterwards extended and supported by the Algerian government and is still being carried on. Dr. Edmond Sergent was assigned to the work, and in 1903 published an account of the early demonstrations. The investigators propounded to themselves the following question: Is it possible, under the practical conditions existing in Algeria, to defend a group of Europeans from malaria? And they decided to use no prophylactic measures whatever except the destruction of Anopheles. The management of the East Algerian Railroad placed at the disposal of the service one of the stations of that line. This station, which was called Alma, was a hotbed of malaria. Nine agents had been stationed there between the 1st of July, 1894, and the 1st of December, 1901. All of them were seriously ill with malaria, and the first eight left their positions on account of malarial fever on the advice of their physicians. The ninth was the man in charge at the time, who was very thoroughly infected. The families of these agents, concerning which there were no statistics, were all and always feverish, according to the best information. It seems that there did not exist a person who had ever lived in this station a single summer without contracting malaria.

At the time when the work began, June 26, 1902, there were 13 people living in the station; among them 9 had been there a year or more and were malarious; 4 had arrived during the winter and had never had any fever. In the neighborhood of the station there were two families, one of Arabs and one of French. All members of these two families were malarious and refused to be protected, and therefore constituted a constant source of infection for the Anopheles. It was the same way with the travelers who came to the station to wait for trains leaving in the evening or at night. Most of them were Arabs coming from near-by places notoriously unhealthy. The conditions of the problem were then severe. It was necessary to protect from the bite of infected Anopheles 4 persons not previously exposed and 9 others already malarious, the latter from reinfection. The measures undertaken were to protect this group of people from adult Anopheles and to destroy the Anopheles larvæ. This was done in the usual way. The openings to the buildings were screened—doors, windows, and chimney. All breeding places were searched for and found and were treated with kerosene. On leaving the station at night veils and gloves were used; but in spite of this watchfulness it was not certain that all of the house people invariably observed this precaution. The results were excellent. The numbers of the mosquitoes were greatly reduced by the work against the early stages; the building was almost entirely protected, so much so that but 9 Anopheles succeeded in gaining entrance. At the end of the season not one of the 4 new people had shown the slightest symptoms of malaria, a condition which it is safe to say had not occurred before in that locality, and the others, although having some fever, showed no indication of reinfection.

This was only an initial experiment to prove what could be done, and the results were placed before the governor-general of Algeria and the members of congress as well as the departmental and communal authorities. The expenses incurred amounted to $58.83. The governmental efforts since that time seem to have been very considerable. In 1904 malaria was pandemic in Algeria, but by increased knowledge and increased efforts the report for 1908 shows that in that year the situation was very much better and not to be compared with that of 1904. The effort takes the form of conducting demonstrations in order to give lessons to the people and to widen each year the territory covered, and to organize antimalarial campaigns in different malarial localities by the physicians, the engineers, etc., stationed in those localities. Propagandic work of all kinds is going on, including placards in the railway carriages and elsewhere and teaching antimalarial measures in all the schools. The last report published—that giving an account of the operations for 1908—indicates an awakening of the country that can not fail to be productive of great good.

WORK IN ISMAILIA.

Another striking example of excellent work of this kind is found in the report, published in 1906, on the suppression of malaria in Ismailia, issued under the auspices of the Compagnie Universelle du Canal Maritime de Suez. Ismailia is now a town of 8,000 inhabitants. It was founded by De Lesseps in April, 1862, on the borders of Lake Timsah, which the Suez Canal crosses at mid-distance between the Red Sea and the Mediterranean. Malarial fever made its appearance in very severe form in September, 1877, although the city had up to that time been very healthy, and increased so that since 1886 almost all of the inhabitants have suffered from the fever. In 1901 an attempt to control the disease was made on the mosquito basis, and this attempt rapidly and completely succeeded, and after two years of work all traces of malaria disappeared from the city. The work was directed not only against Anopheles mosquitoes, but against other culicids, and comprised the drainage of a large swamp and the other usual measures. The initial expense amounted to $9,650 and the annual expenses since have amounted to about $3,531.90.

The results may be summarized about as follows: Since the beginning of 1903 the ordinary mosquitoes have disappeared from Ismailia. Since the autumn of 1903 not a single larva of Anopheles has been found in the protected zone, which extends to the west for a distance of 3,281 feet from the first houses in the Arabian quarter and to the east for a distance of 5,906 feet from the first houses in the European quarter. After 1902 malarial fever obviously began to decrease, and since 1903 not a single new case of malaria has been found in Ismailia.

WORK IN VERACRUZ.

The president of the superior board of health of the Republic of Mexico, Dr. Eduardo Liceaga, was one of the first to grasp the importance of the mosquito discoveries of the American army board and one of the first to make an effort to put them into effect. As elsewhere, he met with conservatism and a certain amount of disbelief, but it was not long before he succeeded in establishing an anti-mosquito service for practically all of the towns in which the disease appeared to be endemic, and devoted especial attention to the larger seaports most frequently entered by foreign vessels. In 1893 the disease spread in an epidemic form to several cities of the Gulf States of Mexico and to some interior cities as well, such as in the States of Nuevo Leon and San Luis Potosi. By the aid of strong executive orders on the part of President Diaz, the superior board of health was able to take action in all of the States except one, and was able to arrest the epidemic. The plan of campaign was based upon the mosquito doctrine, and the measures involved the isolation of patients, the rigorous disinfection of dwellings by sulphur dioxid, the drainage of swamps, covering of drinking-water reservoirs, and the use of petroleum.

In the course of this work and that which followed, with the understanding that Veracruz is the oldest and most permanent focus of endemia of the Mexican Republic, and that all the epidemics had found their origin in that place, the principal attention of the superior board of health was devoted to that city. The town was divided into four districts, each of which was placed under the charge of an experienced physician, and each of these had first-class sanitary agents. Subordinate to these, other second-class agents were appointed, and a certain number of laborers were added. As a result of this effective organization, Carroll, writing his chapter on yellow fever for Osler's Modern Medicine, at the close of 1906, was able to make the following statement:

In Mexico yellow fever has been eradicated from its endemic focus at Veracruz through the able efforts of Eduardo Liceaga, the president of the superior board of health, whose complete grasp of the problem and whose enlightened and energetic action has added support to the mosquito doctrine, and would have controlled the disease absolutely if the same means of enforcement were available in Mexico as in Cuba in 1901.

The later developments of the work in the Mexican Republic under Doctor Liceaga's leadership have been remarkable. In the American Journal of Public Hygiene, new series, Volume VI, No. 1 (February, 1910), is published Doctor Liceaga's Annual Report on Yellow Fever in the Mexican Republic, from August 16, 1908, to date, a paper read before the American Public Health Association, at Richmond, Va., October, 1909. The following paragraphs concluding this report will give an idea of the excellent results which have followed the work of the sanitary officials in Mexico:

The campaign against yellow fever, which commenced in the Mexican Republic in the year 1903, has continued uninterrupted up to this date, without even suspending it during the winter months as is done in other countries; that the war on the mosquitoes is so efficacious that there are none left in Veracruz, and, consequently, there are no stegomyias, as demonstrated by the reports rendered by the physician of the Public Health and Marine-Hospital Service of the United States, who is resident in that port.

The cases which have been observed in Merida and surrounding villages arise from the existence in that city of over thirty thousand water tanks which could not be so easily and securely watched as those of Veracruz.

In the entire section which was formerly devastated by yellow fever we continue to canalize the deposits of standing water and to fill up the hollows, as well as to spread oil on all those ponds which cannot be otherwise filled in or covered.

We continue to fumigate the dwelling houses, workshops, schools, etc., in which we have encountered either cases of yellow fever or any suspected cases.

We continue the surveillance over the passengers who travel by rail in any part of the region which formerly suffered from yellow fever, and this service is especially active along the line of the Tehuantepec Railroad.

In the ports of Coatzacoalcos, on the Gulf coast, and Salina Cruz, on the Pacific, it is nearly four years since a single case of yellow fever was observed.

WORK IN JAPAN.

Work in Japan as early as 1901, under Surgeon Major Tsuzuki, confirmed experimentally the malarial relations of Anopheles, and later a large-scale experiment was carried on among the Japanese troops occupying Formosa, which, on account of its extent, served to set at rest any doubts which had previously existed as to the value of mosquito protection. Portions of Formosa are malarious, and the following table indicates the conditions existing among these troops from 1897 to 1900:

	Number of patients.	Number of deaths.	Ratio of patients.	Ratio of deaths.
			Per cent.	*Per cent.*
1897	41,825	267	272.435	1.739
1898	34,752	270	249.394	1.938
1899	29,371	284	221.263	2.139
1900	30,224	272	222.414	2.002

On the 21st of September, 1901, and extending through to the 28th of February, 1902, work was carried on by order of the governor of Formosa, on the advice of Doctor Koike, surgeon-general, as follows. This account of the experiment is taken from an address by Dr. K. Tamura, delegate from Japan to the Eleventh Annual Meeting of the Military Surgeons of the United States Army, June 7, 1902:

Half of the second company, first battalion of infantry at Kirun, Formosa, 115 in number, was employed from the day of their landing at Kirun, and we gave it the name of "protected troops." This troop was thoroughly provided with means of protection from mosquito bites. They were confined in the casern from half an hour before sunset to half an hour after sunrise, the casern having been specially made to prevent mosquitoes entering, and they wore gloves and coverings of the head specially made for that purpose when on service at night.

The results of these new methods for the prevention of malaria were absolutely good. Another half of the second company (called by us "comparison troop") and all the other companies of the battalion (called by us "unprotected troop") had a great many malaria patients, but the protected troop had none.

The table of the number of patients is as follows:

	Average number of men.	Number of patients.	Ratio of patients.
			Per cent.
Protected troop	114.49	0	0
Comparison troop	104.34	34	32.59
Unprotected troop	646.36	285	44.09

The experiment of Grassi in Italy shows that 5 cases of malaria were observed among 112 persons, and Celli observed 11 cases in 203 persons, but our case shows none in 114 persons.

The news was spread rapidly in the whole island and all the troops despatched there became very cautious regarding the bites of mosquitoes. This caution itself gave good results, and the number of patients and deaths decreased distinctly last year, compared with the preceding years:

	Number of patients.	Number of deaths.	Ratio of patients.	Ratio of deaths.
			Per cent.	*Per cent.*
From 1897 to 1900, average	34,043	27,325	242.514	1.947
1901	22,438	14,500	173.211	1.119

Now it is very clear that the prevention of malaria is secured by guarding against mosquitoes, and we believe that Formosa will become a healthy island within a few years.

In the recent war between Russia and Japan, the Japanese gave the world an example of field sanitation hitherto unequaled in history, a vivid account of which will be found in "The Real Triumph of Japan," by Dr. Louis Livingston Seaman, formerly surgeon-major, United States Volunteers (New York, 1907), from which the following facts are drawn:

Longmore's tables, based on the records of the battles of the last two hundred years, show that there has rarely been a conflict of any long duration in which there have not been four deaths from disease to one from bullets. In the Spanish-American war there were 14 deaths from disease to 1 from battle. Japan in her war with China in 1894 lost 3 from disease to 1 from bullets; but from February, 1904, to May, 1905, in her war with Russia 4 were lost in battle to 1 only from disease, the exact figures being 52,946 lost in battle and 11,992 lost from disease, and the significant fact must be added that of the total sick only 3.51 per cent were sick with infectious diseases. There were only 1,257 cases of malaria in the whole army, 600,000 strong, in the eighteen months duration of the war, whereas in 1894, in the war with China, there had been 41,734 cases of malaria. At the outset of the campaign the purifying of cities occupied was begun and attention was paid to mosquito breeding-places. One of the orders issued was that the waste water of the barracks should be connected with the town gutters. Incidentally it may be noted that all articles sold publicly were required to be covered to protect them from flies. In the book of health instructions issued to soldiers occurred the paragraph, "Malaria is spread by mosquitoes; therefore protect yourself from them as much as possible." The soldiers had their camp kettles with them, they were furnished with water boilers, and all water had to be boiled before being drunk. They were furnished with mosquito bars, and every man was enveloped in a bar during the mosquito season. The result of 1,257 cases of malaria out of an army 600,000 strong must be contrasted with a telegram sent from General Shafter at Santiago on August 8 during the Spanish-

American war, which read "At least 75 per cent of the command has been down with malarial fever, from which they recover very slowly * * *." It should be noted that Major Seaman was disappointed not to find mosquito nettings in the main hospital in Tokio and that he states that this hospital was inferior in this and certain other respects to the second and third reserve hospitals in Manila. He states that at some of the hospitals netting was added as the mosquito season approched, but it is only fair to infer that at this main hospital the Japanese surgeons knew what they were about and were certain that the absence of the mosquito bars involved no danger to the patients.

ANTIMOSQUITO WORK IN OTHER PARTS OF THE WORLD.

Nothing has been said in this bulletin about the admirable work which had been carried on in Italy. Taking a prominent part in the demonstration of the conveyance of malaria by Anopheles, the Italian investigators were practically the first to begin active antimosquito work. Their results were so striking that they received the attention of the entire civilized world, many accounts having been published in newspapers and magazines and in more permanent form. The whole world may, in fact, be said to be familiar with this work, which will be, however, more extensively mentioned in a bulletin on malaria and the malaria mosquitoes which it is hoped to publish later in the year.

Active and well-organized antimalarial work is being carried on in many places in the Tropics, and an effort has been made to establish an antimalarial league in Greece which has the support of wealthy people and of the nobility of several countries, but in practically none of the well-settled countries in temperate regions has any work of importance been done, even in regions whose development is distinctly held in check by this disease. The government of India has never been able to carry out broad concerted measures of any great importance, although most important investigations have been carried on in that country. It was recently decided to convene a conference to examine the whole question and to draw up a plan of campaign for the consideration of the general government and of the local governments. This conference assembled at Simla on October 11, 1909. In the resolution which brought about the call it is pointed out that the actual death rate from malarial fever in India is 5 per 1,000; that this represents about 1,130,000 deaths, and, as mortality in malarial fever is ordinarily low, a death rate of even 5 per 1,000 indicates an amount of sickness, much of it preventable, which clearly calls for the best efforts that government can make to diminish it. An editorial in the Journal of Tropical Medicine and Hygiene for

September 15, in speaking of this resolution and the proposed conference, anticipated that nothing will come out of the movement. It says:

> To those, however, who have read many similar resolutions and have perhaps acted on committees of the sort, the solemn rigmarole, with its characteristic touch on the "prohibitive costs of attempts to exterminate the mosquito," implies no more than an expedient to stave off the dreaded day when public opinion will force the government of India to act instead of to talk on this really and literally vital question.

The report of the conference as given in Nature, November 5, 1909, indicates that many important addresses were made, including one by Colonel Leslie, the sanitary commissioner of the government of India, and others by such well-known workers as Major James and Captain Christophers, of the Indian medical service. Colonel Leslie advocated quinine prophylaxis. Major James introduced a discussion upon the distribution of malaria in India and advocated a general investigation in every province similar to that which Captain Christophers made in the Punjab. Quite in the line of prophecies of the editorial in the Journal of Tropical Medicine and Hygiene, Major White, of the Indian medical service, stated that he considered the recommendations of past malaria conferences are costly, and almost prohibitively so if undertaken annually, and contended that more should be done with the propagation of fish which prey upon mosquito larvæ. At the termination of the conference various conclusions and recommendations were drawn up under the following main headings: (1) Scientific investigation; (2) the agency by which investigation should be made; (3) practical measures, including (a) extirpation of mosquitoes, (b) quinine treatment and prophylaxis, (c) education, and (d) finance.

In the United States, it is sad to relate, almost nothing has been done in the way of an active campaign against malaria alone, even in restricted localities. It is true that extensive work has been done against mosquitoes, but in the most of these cases the incentive does not seem to have been to better the health of the people or to stamp out malaria. We have shown that in the New Jersey work the item of personal comfort is concerned and that of the enhanced value of real estate and the enhanced taxable value of land to the community, but the main fight there is conducted against mosquitoes that have no relation to disease, although Doctor Smith has written much against malarial mosquitoes and has conducted a strong educational campaign. We have shown also that the fight against mosquitoes in the marshlands back of Brooklyn was financed by a wealthy man whose immediative motive was to keep his race horses in better condition by preventing the annoyance to them of mosquitoes. In different communities there have been intelligent and up-to-date citizens who have made strong efforts to start malarial campaigns, but we have not reached success, through indifference on the part of city councils or other bodies controlling public funds. Many health officers themselves have seemed indifferent on this subject. In some localities citizens' associations, civic improvement societies, and women's clubs have made efforts to improve the situation. Good work was done by such an orgainzation in South Orange, N. J., and instances of this kind are scattered here and there at very long intervals over the country, but these efforts as a rule were at first spasmodic and only temporary in their effects.

The city of Baltimore offers an excellent example of what we have just stated. It was early shown that a very large part of the mosquito supply could easily be handled, and there were not lacking intelligent and enterprising citizens who, year after year in the public press and before the board of health and the city council, continually agitated the subject of antimosquito work. Finally in 1907 Mr. George Stewart Brown, a member of the city council, succeeded in getting an appropriation to start the work for that year. Much of this money was expended in expensive advertising in the street cars, etc., but the remainder was expended very efficiently, but necessarily with only partial results, by organizing a gang of men to drain and fill up pools in vacant lots around the suburbs. The next year the appropriation was reduced, and only the gang of men was continued. During 1909 no appropriation was made, the gang of men was dropped, and the whole question was abandoned. It should be stated, however, that before the appropriation was made an ordinance was passed by the city council requiring every householder to remove, screen with wire netting, or keep covered with oil, all standing water on his premises, but it seems that no real attempt was ever made to enforce this ordinance. Of course such an attempt could hardly be successful at first without the aid of a special appropriation for the purpose. At the present time the ordinance seems to be a dead letter.

It is true that even where not directed specifically against malaria, but against the mosquito nuisance, the breeding places of Anopheles are disposed of, and they are for the most part prevented from breeding, together with the other species of mosquitoes, and for this reason a little space will be devoted to some of the productive efforts which have been made in the United States aside from those which have already been considered at some length in the section on drainage and other neighboring sections.

In the early days of antimosquito work in this country, 1901 and 1902, the rather rare citizens who appreciated the situation and who did their best to stir up their communities to organized effort should be mentioned, and among them we have specifically in mind Dr. Albert F. Woldert, of Philadelphia and later of Texas; Dr. Henry Skinner, of Philadelphia; Dr. H. A. Veazie and Dr. H. G. Beyer and a little later Dr. Quitman Kohnke, of New Orleans; Mr. H. C. Weeks, of Bayside, Long Island; Mr. W. J. Matheson, of Lloyds Neck, Long Island; Major Barton, of Winchester, Va.; Dr. W. S. Thayer, of Baltimore; Mr. Wm. Lyman Underwood, of Boston; Dr. A. H. Doty, of New York; Mr. Spencer Miller, of South Orange, N. J.; Dr. W. F. Robinson, of Elizabeth, N. J.; and Dr. J. W. Dupree, of Baton Rouge, La. We have not mentioned any entomologists in this list, but surely Dr. John B. Smith, of New Jersey; Prof. Glenn W. Herrick, of Mississippi; Dr. E. P. Felt, of New York; Prof. H. A. Morgan, of Louisiana; Dr. W. E. Britton, of Connecticut; and Mr. D. L. Van Dine, of Hawaii, should be named, and of course since those early days nearly every economic entomologist has become an apostle. After 1902 the ranks became greatly increased, and at the present time conditions are being bettered, although still without the existence of any large well-organized campaign directed solely against malaria.

One of the best pieces of work with a direct antimalarial bearing that has been carried on in this country, and that was begun at an early date, is that started on Staten Island under Doctor Doty, the health officer of the port of New York. The following account is largely taken, word for word, from a letter recently received from Doctor Doty, but it can not be directly quoted on account of occasional necessary alterations of the verbiage of a personal letter.

Staten Island, lying in New York Harbor, had had a rather unenviable reputation on account of the great number of mosquitoes present and the continued presence of malaria. It was largely on account of the latter condition that Doctor Doty began his investigation in 1901. He soon found that there were two factors to deal with in this work, namely, the inland mosquitoes and the salt-marsh mosquitoes.

In the extermination of the inland mosquitoes, the section of Staten Island which was known to contain many cases of malaria both in the acute and chronic forms was selected for experimental work. This section consisted of a basin or lowland about a mile square, containing about 100 small dwelling houses some distance apart. Within its boundaries were a large number of stagnant pools varying in size from 10 feet in diameter to an acre or more in area. A house-to-house visit showed that at least 20 per cent of the inhabitants of this district were suffering with some form of malaria, and in the immediate vicinity of every house were found typical breeding places in the shape of old tinware, rain-water barrels, cisterns, cesspools, and ground depressions, many of which contained larvæ. For the purpose of detecting the presence of adult Anopheles, glass tubes fitted with cotton plugs were distributed among the occupants of these houses, with the request that the mosquitoes found in the house at night be captured and placed in the tubes. In the collection were found many Anopheles. These were particularly numerous in tubes coming from a small group of houses. In one of the latter was found a family consisting of five persons, all of whom showed the acute or chronic form of malaria. Doctor Doty himself secured live mosquitoes from the interior of this house. On the first evening 5 were captured, and all but one were Anopheles. On the second evening 22 were collected, and of these more than one-half were Anopheles. In a house on the opposite corner was found a patient suffering from an acute attack.

In the beginning considerable difficulty was found in detecting the breeding places of the Anopheles, but this became easier as the inspections became more thorough. For instance, in a group of two or three houses close together, a number of Anopheles were captured, but their breeding place could not be found for some time. Finally, in the backyard of one of the houses, overgrown with weeds, was discovered a very large metal receptacle filled with Anopheles larvæ and with many adults in the immediate vicinity. This receptacle was almost entirely covered by underbrush.

After this experience the men employed learned to make the closest possible search and to find probably every breeding place.

The island was then divided into small districts, which were visited by a mosquito corps consisting of five men, one of whom was a sanitary police officer connected with the New York City department of health. The equipment of the mosquito corps consisted of a large wagon provided with spades, rakes, hoes, scythes, and petroleum oil. A house-to-house inspection was made in each district. House owners or tenants were required to remove from about the premises all receptacles which might act as breeding places, or to protect them. Rain-water barrels and cisterns were covered with wire netting, all roof gutters were repaired, and pools of water were covered with petroleum. In certain instances orders were sent to the owners of property containing depressions in the soil to fill them or drain them. If these orders could not be enforced, the mosquito corps returned every ten days or two weeks and applied more petroleum. Copies of a circular of information were delivered so far as possible to each house on Staten Island by police officers, and this educational campaign brought about valuable cooperation on the part of the public.

In 1905 the details of this work were presented to the department of health of the city of New York, and the city government granted an appropriation for the drainage of the swamp land along the entire coast of the island. With the aid of this appropriation, ditching was carried on somewhat in the same manner in which it has been carried on in New Jersey. Down to the present time between 800 and 1,000 miles of ditches have been dug. The swarms of mosquitoes soon practically disappeared, window screens were discarded, and meals were served upon the verandas of the hotels.

With the malarial and other inland mosquitoes the work was carried on in the manner above described, not only in the built-up portion of the island, but also in the open spaces between the small and scattered settlements. During the past two years cases of malaria on Staten Island have become practically unknown, and for the past year Doctor Doty has been unable to secure any Anopheles, whereas in the beginning of the investigation they were found almost everywhere on the island. The statistics of the department of health indicate the decrease of malaria from 1905 on. Prior to 1905 malaria was not regularly reported, but the number of cases was surely very much greater than that reported in that year. Since 1905, however, they are stated to be as follows: 1905, 33 cases; 1906, 54 cases; 1907, 4 cases; 1908, 6 cases; 1909, 5 cases.

The work of exterminating malarial mosquitoes has been necessarily slow, as the area involved is considerable, the island being about 16 miles long and from 4 to 6 miles wide, probably containing over 80,000 inhabitants, with large areas between the various towns.

The expense of the operations down to the present date has been about $50,000; this of course includes the expense of the extensive drainage operations in the salt marshes. Doctor Doty, in addition to being the health officer of the port of New York, is a commissioner of health of New York City, and he carried out this work in his capacity as a municipal officer and not as a state official.

There were some earlier and very much smaller pieces of work, which have previously been described by the writer.

Dr. W. N. Berkeley, in the Medical Record of January 26, 1901, gave a most interesting account of a malarial outbreak in a small town near New York City during the summer of 1900. Around a large pond in the vicinity of the town four or five fresh cases had recently developed in August. The first case was that of a coachman, who had caught malaria elsewhere and had relapsed. From his quarters in a long row of stables on one side of the pond the infection had passed along to other stablemen and servants on the same side, to the distance of a quarter of a mile from the original site, and a quarter of a mile in another direction across the pond one other case appeared in a small child. Doctor Berkeley went to the town and discovered that *Anopheles quadrimaculatus* was fairly abundant in every bedroom in that area in which proper search was made. The breeding places seemed to be segregated pools at the end of the pond (the pond itself contained fish) and post holes and excavations. These last were numerous, as many buildings were going up. The following practical measures were adopted: (1) Extermination of all the Anopheles found in houses by a party of men sent out for the purpose, and this was followed by a systematic introduction of screens in windows and doors; (2) filling in of the smaller breeding places and the drainage of the pond; (3) the seclusion of every malarious patient by netting and otherwise from the bite of mosquitoes, so long as he had germs in his capillary blood. The results were as prompt as they were gratifying. Not a single new case of malaria developed; Anopheles disappeared entirely from houses where it had been previously a night terror, and Culex was greatly diminished in numbers.

Another interesting case has been described by Rev. William Brayshaw, of Chaptico, Md. Chaptico is situated at the head of a widespreading bay or elbow of the Wicomico River, about 8 miles from the point where this river enters into the Potomac at Rock Point. The tide is ordinarily about 2 feet at the full. The village rests between two hills of 80 or 90 feet elevation. The valley is almost flat, and consists of marshy pools, in which the mud or ooze can easily be pierced with a strong pole to a depth of several feet. Three of these pools or ponds are directly in the rear of the house known as the rectory, in which he resided with his wife on June 24, 1890. Neither of them had ever had malaria or fever before, but the mosquitoes were so numerous that it was impossible to take rest at night for a while. On July 11 his wife was taken with malaria, and on September 4 had to be removed to the mountains. Mr. Brayshaw himself was sick most of the time, and every house in the village had from one to five persons suffering from malaria. He proposed ditching and drainage, but there was no money, and everybody laughed at the idea, as many of the citizens had lived there from childhood to an advanced age. There did not seem to be sufficient fall to carry off the "effete matter." On May 19, 1900, he gained the consent of the property owners to ditch through their land a distance of 560 feet to Chaptico Creek. He paid for this himself. The expense was about $40. The result he sums up as follows:

> During the summer of 1899, from May to October, the mosquitoes were so numerous that life was a burden during the night, and they were so small that nets seemed to have no effect upon them. From May to October, 1900, quite a number visited us, until June 12, when they disappeared, and we were free from them until the last six days in September, when I found a local cause for their breeding. In the summer of 1899 every house in the village had from one to five persons sick with chills and fever and other malarial troubles; doctors in constant attendance. In the summer of 1900 there were only two sporadic cases of chills, both caused by negligence or inattention to ordinary caution. Everyone in the village seems quite free from malaria since July 10.

Later some excellent work was instituted through the combined action of the boards of health of Cambridge and Belmont, Mass., to improve the sanitary condition of the cities of Cambridge, Somerville, and the towns of Arlington and Belmont, at the inspiration of Mr. W. L. Underwood, a member of one of the boards of health. This was effectively carried out at an expense of $600 without assessment upon landholders. An account of this work by Mr. Underwood is given in the Technology Quarterly of March, 1901.

The work of the North Shore Improvement Association of Long Island has been mentioned rather fully in the sections on remedies. This work was thorough and resulted in the improved sanitation of that portion of Long Island. In 1903 some extensive work was done in Newport, R. I., at the expense of the property holders, under the direction of Mr. Henry Clay Weeks, with good results. The Citizens' Association of Flushing, Long Island, later took up the problem, and with the assistance of the board of health extensive drainage operations have been carried on but are not yet completed. At Wellfleet, Mass., other work of a somewhat similar character, but directed for the most part against the salt-marsh mosquitoes, is now under way.

A most interesting bit of work was carried on in the southern part of the Borough of Brooklyn in 1902–3, under the supervision of Mr. Weeks, which has been described in the chapter on remedies. This work, which was of an expensive character, was lately paid for by a private citizen, Mr. Whitney.

An important step forward was taken in 1903 in the formation of the American Mosquito Extermination Society, in which W. J. Matheson, of New York, the president, and Henry Clay Weeks, also of New York, the secretary, were the leading movers. This society, in which nearly all persons actively interested in the mosquito crusade became interested, was started for the purpose of educating the public, bringing about legislation, and securing cooperation and interchange of ideas. It held its first antimosquito convention December 16, 1903, in the rooms of the Board of Trade and Transportation, Mail and Express Building, New York City. The convention was called to order by Mr. Henry Clay Weeks as acting chairman, who made some introductory remarks, after which officers were elected. The following papers were read:

"How a State Appropriation May be Spent," by John B. Smith.

"What a Rural Community Can Do," by Walter C. Kerr.

"The World-Wide Crusade," by L. O. Howard.

"Does Extermination Exterminate Mosquitoes?" by W. J. Matheson.

"Remarks on Extermination Work at Morristown, New Jersey," by John Claflin.

"The Extermination and Exclusion of Mosquitoes from Our Public Institutions," by P. H. Bailhache, surgeon, U. S. Public Health and Marine-Hospital Service.

"Government Antimosquito Work," by Dr. J. C. Perry.

"The Sphere of Health Departments," by Dr. E. J. Lederle.

"The Exactness of Proofs of Transmission of Malaria by Mosquitoes," by Dr. W. N. Berkeley.

"The Long-Distance Theory," by Spencer Miller.

"The Value of Reclaimed Swamp Lands for Agricultural Uses," by Milton Whitney.
"Antimosquito Work in Havana," by Col. W. C. Gorgas, U. S. A.
"How the Law Should Aid," by Paul D. Cravath.
"New York State's Part in Mosquito Extermination," by E. P. Felt.
"What the Government Should Do," by F. C. Beech.
"Mosquito Engineering," by Henry Clay Weeks.
"The Work of the Department of Health, New York City," by Henry C. Weeks.

Following this organization meeting, a somewhat elaborate organization was perfected, including an advisory board and an advisory board of entomologists. The proceedings of the convention were published in pamphlet form and were distributed free of charge. A mosquito brief was published as a folder giving mosquito information. In November, 1904, Bulletin No. 1 of the society was published, which contained in digested form an account of the work which had been going on in the meantime. Bulletin No. 2 contained a report of the president and secretary to the executive council, published September 26, 1905, and in 1906 was also published a yearbook for 1904–1905, which contained the proceedings of the second annual convention of the organization. These proceedings contained a number of valuable addresses, some of which may be mentioned:

"Diversities among New York Mosquitoes," by E. P. Felt.
"Mosquito Extermination in New Jersey," by John B. Smith.
"Extermination and Dissection of Mosquitoes," by M. J. Rosenau of the United States Public Health and Marine-Hospital Service.
"Mosquito Extermination in New York City," by Thomas Darlington.
"The Mosquito Question," by Quitman Kohnke.
"The Relation of Mosquito Extermination to Engineering," by Cornelius C. Vermeule.

The society continued its work, and unquestionably well justified its organization. In 1907, however, it was deemed by the officers of the society that the objects of its existence could well be taken over by the National Drainage Association, which had then recently been formed and which placed among its most prominent motives the idea of securing favorable government action in redeeming the marshes and swamps of the country. It was decided that the society should retire from its field of work and leave the same to the Government, States, and other authorities and to individuals, and the society then disbanded.

In 1903–1904 work against mosquitoes was undertaken by the State entomologist of Connecticut, Dr. W. E. Britton, who made careful mosquito surveys over the whole State and who published in his annual report for 1904 a careful and well-illustrated article devoted to showing how the mosquito nuisance can be abated. Since that time some active work has been taken up. In 1906 the board of health of Millburn Township in New Jersey secured the services of Mr. Weeks, and published a pamphlet entitled "The Mosquito Nuisance in Millburn Township and How to Abate It."

At Worcester, Mass., an interesting crusade was begun early under the direction of Dr. William McKibben and Prof. C. F. Hodge. In Michigan work was carried on upon the campus of the Michigan Agricultural College. In Connecticut work was earlier done at Pine Orchard and Ansonia, as well as at Bridgeport, Branford, Fairfield, and Hartford; and in Maine at Old Orchard Beach. Excellent work was also done at a very early date at Lawrence, Long Island, largely against malarial mosquitoes, under the auspices of the board of health, working with an appropriation of $1,000 and with a privately contributed fund of $1,678.84. A small crusade was also carried on at an early date under the auspices of the civic committees of the Twentieth Century Club at Richmond Hill, Long Island. In the Southern States the boards of health of Atlanta and Savannah began work in 1903 and certain regulations were enforced. At Talladega, Ala., work was also begun in the same year. The excellent work done at Morristown, N. J., under an improvement society in 1903 should not be forgotten.

The work which has been done in Cuba and in the Isthmian Canal Zone has been elsewhere described. In the Territory of Hawaii work was begun in Honolulu in 1903 against the local mosquito plague. It should be stated that Anopheles mosquitoes are not known in Hawaii, and that although the yellow fever mosquito occurs there in numbers the disease has never been introduced. A general campaign, however, was begun under the auspices of the board of health and commercial bodies of Honolulu, and a meeting was held on August 15, at which a citizens' committee of Honolulu was organized to work in cooperation with the board of health and to be supported by subscriptions. The president of the board of health was made chairman of the committee, and a salaried agent was placed in charge of the work. A campaign was continued for a year and a half, at a cost of nearly $3,000, donated entirely by public-spirited citizens. With the help of this fund the citizens' committee demonstrated conclusively that it was possible to rid the city of the mosquito nuisance. Continuation of the work, however, on the basis of private subscriptions, was found impracticable, and later the work was turned over to the board of health and an item of $7,200 to continue the campaign for two years was proposed for the regular appropriation bill of that department of the territorial government at the session of the next legislature. The item, however, did not receive the indorsement of the administration in the interests of economy, and the board of health since that time has relied upon money from private subscriptions and carried on the work as actively as possible with the small amount gathered both in Honolulu and other districts of the island. In the course of this work mosquito-eating fish were introduced, as shown in the chapter on utilization of natural enemies of mosquitoes.

CONCLUSION.

It will thus appear that, considering the economic loss existing in the United States through malaria, nothing like the competent work has been done that should have been done, or really that should have been done in the past eight years within the territorial limits of the United States themselves. The United States Government has done admirable work in Cuba, for another people, and it has done excellent work in the Isthmian Canal Zone, but in its own home territory it has done nothing. State governments have done almost nothing, if we except the drainage work done in New Jersey. Malaria campaigns have been local and on the whole very unsatisfactory.

The writer in 1903, in a paper read before the First Anti-Mosquito Convention in New York, December 16, after summarizing the work which had already been done in different parts of the world, under the title "The World-Wide Crusade," said:

> The main incentive to all this world-wide movement has been the prevention of disease. Probably nowhere else in the world has the motive of personal comfort entered into the crusade as it has in the United States, and we have already carried this aspect of the work much further than any other country. When we consider the enormous sums of money spent in the United States for luxuries, how much more should be spent for bare comfort and peace!
>
> Abundant evidence has been gained in the important work which has been done here and elsewhere during the past two years to show that mosquitoes in any definite region can be reduced to a point far below the danger line and quite within the comfort line, and in many instances it has been shown that they can be exterminated, at least for a time. This work will undoubtedly continue, but there are many communities which need constant prodding. The organization of the antimosquito forces in this convention which you are to hold will greatly stimulate public opinion, and will induce many of the indifferent to take a more sanguine view of possibilities, and perhaps more energetic action toward actual work.

The same comparative indifference holds in other countries, and often even where work is begun under good auspices and with excellent indications it has failed of securing the best results. Maj. C. E. P. Fowler, R. A. M. C., in his report on malarial investigations in Mauritius, 1908, points out that on that island the great fault has been in nonattention to small details, such as the formation of an organization to deal with the neglected surface water found in the small ditches along roadsides, in field drainage channels, and small collections of water in holes in the ground, and to keep up the larger work which has already been carried out. He states that no allowance or forethought seems ever to have been expended on keeping the work already carried through in proper working order. Where drains or ditches had been laid down only a few months previously he found them time after time choked with vegetation and forming excellent places for Anopheles. The same thing was found in the rivers; the government had cleared them, but it seems to have been nobody's business to keep them clear. According to this report, there seems to be a general impression among all classes of people, not only in Mauritius but elsewhere, that to carry on antimalarial work means the outlay of vast sums. People prefer to sit idle and complain that they have not the means to carry out the work. He shows that a few gangs of men can do a great deal in the way of ridding a district of breeding grounds, and that their employment does not need a heavy outlay.

Looking over the whole field, it is easily seen that work in this direction has hardly begun. There is so much to do in comparison with what has been accomplished or what has really been undertaken that it is almost discouraging when we consider that it is already eleven years since the function of mosquitoes in the carriage of disease was established. It seems as though such a discovery as this should have commanded immediate and widespread attention and should have caused the liberal expenditure of money from many sources in the effort to rid the human race of some of the most serious obstacles to sanitary progress.

INDEX.

Page.

Adinia, enemy of mosquitoes 68

Aëdes calopus (see also *Stegomyia fasciata* and Mosquito, yellow fever).
  breeding places 19–22
  in Habana 92–93
  protective liquids applied at night not effective repellents 13
 cantans abundant on Wicken Fen 27
 cantator, distribution and seasonal appearance in New Jersey 51
 sollicitans, distribution and seasonal appearance in New Jersey 51
  in New Orleans 79
 tæniorhynchus, distribution and seasonal appearance in New Jersey 51

Africa, German East, fish destructive to mosquitoes 70–71

Alabama, mosquito exterminative measures 113

Alcohol as remedy for mosquito bites 41
  castor oil, and oil of lavender as protection from mosquito bites 12

Algæ. (*See* Water plants.)

Algeria, mosquito exterminative measures 98–99

Ammonia as remedy for mosquito bites 41

Amyl alcohol and kerosene against mosquito larvæ 75

Anablaps, enemy of mosquitoes 67

Anopheles argyritarsis in Habana 92–93
  bifurcatus, breeding in water of peat cuttings 27
   deterred from breeding by growth of *Lemna arrhiza* and *L. minor* 29
  in Algeria 98–99
   Cyprus 65
   Ismailia 100
   Staten Island 107–109
  maculipennis (see also *Anopheles quadrimaculatus*).
   as affected by fumigation with Mimms Culicide 34
   deterred from breeding by growth of *Lemna arrhiza* and *L. minor* 29
   in peaty water and near peat piles 27
   unaffected by pawpaw or castor-oil plants 24–25
  nigripes, breeding in water of peat cuttings 27
  quadrimaculatus, breeding in places inaccessible to fish 72
   in small town near New York City 109–110

Aphredoderus, enemy of mosquitoes 66

Aquatic vegetation. (*See* Water plants.)

Azolla. (*See* Duckweeds.)

Baltimore, Md., mosquito exterminative measures 106

Page.

Barrels, water, breeding places of mosquitoes........ 19, 20
    screening against mosquitoes........ 18–19
"Barrigudo." (See *Girardinus caudimaculatus.*)
"Basil" plant as deterrent against mosquitoes........ 27
Belgium, reclaimed marsh lands........ 53
Bergamot oil and kerosene as protection from mosquito bites........ 14
Black flies. (*See* Flies, black.)
Bottles, breeding places of mosquitoes........ 19
    broken, forming cheval-de-frise on stone wall, breeding places of mosquitoes........ 20
Boxes, tin and wooden, breeding places of mosquitoes........ 19
Brazilian fish, enemy of mosquitoes........ 71
Brooklyn, reclamation of salt marsh........ 55
Buckets, fire, breeding places of mosquitoes........ 20
Cactus, sticky paste made from leaves as mosquito larvicide........ 74
California, drainage measures against mosquitoes........ 44–47
    reclaimed swamp lands........ 54
Camphor spirits, as protection from mosquito bites........ 12
    oil of citronella, and oil of cedar as protection from mosquito bites........ 13
Canopies and screens as protection from mosquito bites........ 14–18
Cans, tin, breeding places of mosquitoes........ 19
Carassius auratus. (*See* Goldfish.)
Carbolic acid preparations as mosquito larvicides........ 74
    resin, and caustic soda as mosquito larvicide........ 79
Carica papaya. (*See* Pawpaw.)
Carp, reported enemy of mosquitoes........ 63
Cascarilla bark smudge against mosquitoes........ 30
Cassia, oil, as protection from mosquito bites........ 13
Castor oil, alcohol, and oil of lavender as protection from mosquito bites........ 12
    plant as deterrent against mosquitoes........ 23–25
Catch-basins in sewers, breeding places of mosquitoes........ 21–22
Caustic soda, resin, and carbolic acid as mosquito larvicide........ 79
Cedar oil, spirits of camphor, and oil of citronella as protection from mosquito bites........ 13
Center Island in Long Island Sound, drainage measures against mosquitoes........ 9, 43
Ceratopogon, capture in trap for adult mosquitoes........ 40
Cesspools, breeding places of mosquitoes........ 20–21
Chaptico, Md., mosquitoes and malaria........ 110
Chinaberry trees as deterrents against mosquitoes........ 25
Chloral vapors as fumigant against mosquitoes........ 37
Chlorin gas as fumigant against mosquitoes........ 37
Chloro-naphtholeum as mosquito larvicide........ 74
Chrysanthemum powder. (*See* Pyrethrum powder.)
Citronella oil and vaseline as protection against mosquito bites........ 13
    application to screens to keep mosquitoes from passing through........ 15
    mutton tallow, black tar, and pennyroyal as protection against mosquitoes and black flies........ 13
    protection from mosquito bites........ 13
    spirits of camphor, and oil of cedar as protection from mosquito bites........ 13
Connecticut, mosquito exterminative measures........ 112, 113
Copper sulphate, impractical as mosquito larvicide........ 73

Page.
Corn oil, impractical as mosquito larvicide.................................... 74–75
Cover, cheap, for well-mouths or water barrels.................................. 19
Cresol preparations as mosquito larvicides...................................... 74
Culex abominator, breeding in places inaccessible to fish........................ 72
fatigans along river front in Egypt.. 88
dwarf individuals, how caused.. 16–17
pungens (see also *Culex pipiens*).
as affected by fumigation with Mimms Culicide.................. 34
larvæ asphyxiated in lemna-covered water...................... 30
pipiens (see also *Culex pungens*).
breeding places... 19–22
unaffected by pawpaw or castor-oil plants....................... 24–25
quinquefasciatus, breeding places.. 19–22
destroyed in fumigation with Mimms Culicide........ 33
in Habana... 92–93
Culicide, Mimms, fumigant against mosquitoes.................................. 33–34
Culiseta annulata in peaty water and near peat piles........................ 27
Cups of water used to insulate table legs from ants, breeding places of mosquitoes. 20
Cyprinodon calaritanus, enemy of mosquitoes.................................. 71
enemies of mosquitoes... 66, 67
Cyprinoid fish in Trinidad, enemy of mosquitoes................................ 63
Cyprus, malarial mosquito larvæ destroyed by goldfish........................ 65
Dalmatian insect powder. (*See* Pyrethrum powder.)
Datura stramonium. (*See* "Jimson" weed.)
Derris uliginosa, decoctions and emulsions as mosquito larvicides............. 78
Diaphanous, enemy of mosquitoes.. 66
Diemyctylus tortosus, enemy of mosquitoes.................................... 62
"Dimorphism of seasons"... 17
Dinitrocresol as fumigant against mosquitoes.................................... 37
Ditching machinery (*see also* Excavating machinery).
used in drainage work in New Jersey....................... 51
Dragonflies, enemies of mosquitoes.. 62
Drainage investigations of U. S. Department of Agriculture................... 55–58
measures in controlling mosquitoes.................................. 42–53
Duckweed, rootless. (See *Lemna arrhiza*.)
Duckweeds (see also *Lemna arrhiza* and *L. minor*.)
as deterrents against mosquito larvæ............................... 28–30
Egypt, work against mosquitoes along river fronts............................... 88
Electricity, suggested use against mosquito larvæ............................... 79
Enemies, natural, of mosquitoes, their practical use........................... 62–72
England, reclaimed marsh lands... 53, 54
Enneacanthus gloriosus, enemy of mosquitoes................................... 67
obesus, enemy of mosquitoes... 67
Ephemera larvæ, food of fish.. 67
Eucalyptus as deterrent against mosquitoes..................................... 22–23
Excavating machinery (*see also* Ditching machinery).
for digging ditches and building levees, publication thereon 55–56
Federated Malay States, mosquito exterminative measures....................... 89–92
Filariasis, use of sulphur dioxid in disinfection................................ 37
Fire buckets. (*See* Buckets, fire.)

Page.
Fish and mosquitoes, Mr. Thibault's observations on normal relation 72
enemies of mosquitoes 63–72
in Brazil that destroy mosquitoes 71
German East Africa that destroy mosquitoes 70–71
West Indies that destroy mosquitoes 69–70
introduction into Hawaii to abate mosquitoes 68–69
New Jersey to destroy mosquitoes 67–68
Flea bites, naphthaline moth balls as remedy 41
Flies, black, mixture as protection from bites 13
Fly, house, as affected by fumigation with Mimms Culicide 34
Footprints of cattle and horses in marshy ground, breeding places of mosquitoes. 20
Formaldehyde gas as fumigant against mosquitoes 37, 38
Fountains, breeding places of mosquitoes 21
Fumigants against mosquitoes 30–40
Fundulus (*see also* Killifishes).
grandis, introduction into Hawaii to abate mosquitoes 69
notatus, enemy of mosquitoes 63
sp., use against mosquitoes in New Jersey 52
Furrows in garden containing water, breeding places of mosquitoes 20
Gambusia affinis, enemy of mosquitoes 63, 65, 67–68
introduction into Hawaii to abate mosquitoes 69
Georgia, mosquito exterminative measures 113
Germany, recent work against mosquitoes 87–88
reclaimed marsh lands 53
Girardinus caudimaculatus, use in destroying mosquito larvæ 71, 97
pœciloides, enemy of mosquitoes 69–70
Gloves as protection from mosquito bites 14
Glycerin as remedy for mosquito bites 41
Gnat larvæ, food of fishes 67
Goldfish, enemy of mosquitoes 63, 64–67
Greece, antimalarial league 104
Green Harbor, Mass., reclaimed marshes 54
Habana, mosquito exterminative measures, 1901–2 92–93
Hawaii, fish introduced to abate mosquitoes 68–69
mosquito exterminative measures 113
Hay crops on salt marsh lands before and after drainage 60–61
Heterandria formosa, enemy of mosquitoes 65–66, 67
Heteroditus, enemy of mosquitoes 66
Holland, reclaimed marsh lands 53, 54, 58
Holy-water fonts, breeding places of mosquitoes 20
Hot lamp chimney as remedy for mosquito bites 42
Illinois, reclaimed swamp lands 54
India, conference regarding mosquito control 104–105
Indiana, reclaimed swamp lands 54
Indigo lump, remedy for mosquito bites 41
Insect powder, Dalmatian. (*See* Pyrethrum powder.)
Persian. (*See* Pyrethrum powder.)
Iodin and saponated petroleum as remedy for mosquito bites and wasp stings .. 42
as remedy for mosquito bites 41
Ismailia, mosquito exterminative measures 100
Italy, drainage work near Milan, benefits therefrom 59
mosquito exterminative measures 104

Page.
Japan, experimental and protective measures against mosquitoes 102–104
"Jimson" weed, powdered, as smudge against mosquitoes 37
Kerosene against mosquito larvæ, early recommendations 7–9
and amyl alcohol against mosquito larvæ 75
bergamot oil as protection from mosquito bites 14
apparatus for automatically and regularly distributing it on surface of streams to kill mosquito larvæ 79–80
application to screens to keep mosquitoes from passing through 15
as mosquito larvicide 75–77
drawbacks to use in tropical regions 77
protection from mosquito bites 13–14
use in catching adult mosquitoes 41
"Killarvæ" against mosquitoes 74
Killifishes (*see also* Fundulus).
enemies of mosquitoes 66–67
Klang. (*See* Federated Malay States.)
Lands, reclaimed, their value 53–62
Larvicides against mosquitoes 72–80
Larvicide used against mosquitoes at Isthmus of Panama 79–80
Lavender oil, alcohol, and castor oil as protection from mosquito bites 12
Lawrence, L. I., drainage measures against mosquitoes 43–44, 113
Leaves of broad-leaved water plants, breeding places of mosquitoes 21
Lemna arrhiza and *L. minor* as deterrents against mosquito larvæ 29
Lemon juice as protection from mosquito bites 12
Long Island, drainage measures against mosquitoes 9–10, 43–44, 47, 113
Lucania, enemies of mosquitoes 66, 67
Lutzia bigotii, enemy of yellow-fever mosquito 63
Macrosomia in plants and animals 16–17
Maine, mosquito exterminative measures 113
Malaria and mosquitoes in Algeria 98–99
Chaptico, Md 110
China 103
Cuba 103–104
Cyprus 65
Federated Malay States 89–92
Formosa 102–103
Habana, 1900–1907 93
India 104–105
Ismailia 100
Italy 104
Japan 102–104
Japanese army 102–104
Leipzig, Germany 87
Mauritius 114–115
Panama 94
small town near New York City 109–110
Staten Island 107–109
United States 105–111
U. S. Army, Santiago, Cuba 103–104
use of sulphur dioxid in disinfection 37
Marshes, drainage in control of mosquitoes 42–53
Massachusetts, mosquito exterminative measures 110–111, 113

Page.
Mauritius, mosquito exterminative measures 114–115
Megarhinus, enemies of other mosquitoes 62
Mercuric chlorid as fumigant against mosquitoes 39–40
Mesogonistius chætodon, enemy of mosquitoes 67
Michigan, mosquito exterminative measures 113
reclaimed swamp lands 54
Microsomia in mosquitoes 16–17
plants and animals 16–17
Midge larvæ, food of fishes 67
"Millions." (See *Girardinus pœciloides.*)
Mimms Culicide. (*See* Culicide, Mimms.)
Minnow, mud. (*See* Umbra.)
Mollinesia, introduction into Hawaii to abate mosquitoes 68–69
Mosquito bites, canopies and screens as protection 14–18
gloves as protection 14
netting as protection 15, 17–18
protection therefrom 12–19
protective liquids 12–14
remedies 41–42
screens and canopies as protection 14–18
veils as protection 14, 15
breeding places, abolition 19–22
campaigns, absurd arguments against them 83–84
along river fronts in Egypt 88
in Germany, recent work 87–88
interesting children in San Antonio, Tex 86–87
Worcester, Mass 11, 86
motto 85
organization 80–88
summary of methods 85
objects 85
Extermination Society, papers read at conventions 111–112
exterminative measures in Algeria 98–99
Federated Malay States 89–92
Habana, 1901–2 92–93
Ismailia 100
Isthmus of Panama 93–95
Italy 104
other parts of the world 104–113
Rio de Janeiro 95–98
United States 105–113
Veracruz 100–101
larvicide, properties of the ideal substance 72–73, 78
larvæ, destruction 72–80
of certain kinds occurring in waters well covered by duck-weeds 30
nettings. (*See* Nettings.)
problem in India 104–105
yellow fever (see also *Aëdes calopus* and *Stegomyia fasciata*).
in Hawaii 113
Lutzia bigotii an enemy 63
protective liquids applied at night not effective as repellents 13

	Page.
Mosquitoes and fish	63–72
Mr. Thibault's observations on normal relation	72
malaria, experimental and protective measures in Japan	102–104
in Algeria	98–99
Chaptico, Md	110
China	103
Cuba	103–104
Cyprus	65
Federated Malay States	89–92
Formosa	102–103
Habana, 1900–1907	93
India	104–105
Ismailia	100
Italy	104
Japan	102–104
Japanese army	102–104
Leipzig, Germany	87
Mauritius	114–115
Panama	94
small town near New York City	109–110
Staten Island	107–109
United States	105–111
yellow fever in Habana	92–93
Isthmus of Panama	94–95
Rio de Janeiro	95–98
Veracruz	100–101
apparatus for catching adults	40–41
deterrent trees and plants	22–30
drainage measures in control	42–53
fumigants and smudges	30–40
household species, breeding places	19–22
natural enemies, their practical use	62–72
of New Jersey, salt-marsh species in different parts of the State	51
organization for community work against them	80–88
preventive and remedial work, conclusion	114–115
introduction	7–12
protection from bites	12–19
protective liquids against them	12–14
remedies for bites	41–42
screening breeding places	18–19
smudges and fumigants	30–40
Mutton tallow, black tar, oil of citronella, and pennyroyal as protection against mosquitoes and black flies	13
Naphthaline as remedy for bites of mosquitoes, other Diptera, and fleas	41
National Drainage Association	112
Nettings as protection from mosquito bites	15, 17–18
Netting, size of mesh with reference to mosquitoes	17
New Jersey, act to provide for abolishing mosquito-breeding places	48–50
drainage measures against mosquitoes	47–53, 113
fish introduced to destroy mosquitoes	67–68
salt-marsh lands, value before and after reclamation	59–62
New Orleans, swamp lands	55
York, marshes in vicinity	55

Page.
Newport, R. I., mosquito exterminative measures........................ 111
North Shore Improvement Association, drainage measures against mosquitoes 43, 111
mosquito campaign.............. 80–81, 84–86
Ocimum minimum.. 26
viride as deterrent against mosquitoes........................... 26
Ohio, reclaimed swamp lands.. 54
Oil, crude. (*See* Kerosene.)
Orange peel, dried, as smudge against mosquitoes....................... 38
Oscillatoria, deterrent effect on breeding of mosquitoes............... 29
Oyster Bay, drainage measures against mosquitoes....................... 43
Panama, mosquito exterminative measures............................. 93–95
larvicide... 79, 80
Pans in poultry yard, breeding places of mosquitoes.................... 19
Pawpaw plant as deterrent against mosquitoes........................ 24, 25
Peat as deterrent against mosquitoes................................... 27
Pennyroyal, mutton tallow, black tar, and citronella as protection against mosquitoes and black flies.. 13
oil, as protection from mosquito bites........................ 12
Peppermint, oil, as protection from mosquito bites..................... 12
Perch, pirate. (*See* Aphredoderus.)
"Perch," used to destroy mosquito larvæ in water tanks.................. 63
Permanganate of potash, impractical mosquito larvicide.................. 73
Persian insect powder. (*See* Pyrethrum powder.)
Petroleum. (*See* Kerosene.)
saponated, and iodin, as remedy for mosquito bites and wasp stings. 42
Phinotas oil as mosquito larvicide................................ 74, 77–78
"Phu-lo" plant, reported as repellent to mosquitoes................. 25–26
"Phul" plant... 26
Pipes, breeding places of mosquitoes................................... 20
Pitchers, breeding places of mosquitoes................................ 20
Plants and trees reported as deterrent against mosquitoes........... 22–30
Pœciliidæ. (*See* Top-minnows.)
Ponds, ornamental, breeding places of mosquitoes........................ 21
Port Swettenham. (*See* Federated Malay States.)
Potassium permanganate. (*See* Permanganate of potash.)
sulphate. (*See* Sulphate of potash.)
Psorophora, enemies of other mosquitoes.............................. 62–63
Puget Sound, tide marsh reclamation..................................... 54
Pumpkinseed. (*See* Sunfish, common.)
Pyrethrum cinerariæfolium, cultivation.............................. 30–31
powder, as smudge against mosquitoes......................... 30–32
roseum, cultivation... 30
Pyrofume as fumigant against mosquitoes.............................. 34–35
Rain-water barrels and tanks, screening against mosquitoes........... 18–19
Reclaimed swamp lands, value.. 53–62
Reclamation work of United States Government............................ 55
Remedies for mosquito bites... 41–42
Resin, carbolic acid, and caustic soda as mosquito larvicide............ 79
Ricinus communis. (*See* Castor-oil plant.)
Rio de Janeiro, mosquito exterminative measures....................... 95–98
Roach, enemy of mosquitoes.. 66
Roof gutters, breeding places of mosquitoes............................. 19
Salamanders, enemies of mosquitoes...................................... 62

Page.
Salt as mosquito larvicide 78–79
marsh lands in New Jersey, value before and after reclamation 59–62
Screening, annual cost in United States 14
breeding places against mosquitoes 18–19
Screens and canopies as protection from mosquito bites 14–18
size of mesh with especial reference to yellow fever mosquito 16–17
"Seasonal lethargy" 17
Sewer catch-basins, breeding places of mosquitoes 21–22
traps, breeding places of mosquitoes 20
Sheepshead Bay, reclamation of salt marsh 55
Shiner. (*See* Roach.)
Smudges against mosquitoes 30–40
Soap, moist, as remedy for mosquito bites 41
South Orange, N. J., mosquito exterminative measures 82, 106
Staten Island, drainage measures against mosquitoes 47
mosquito exterminative measures 107–109
Stegomyia fasciata (see also *Aëdes calopus* and Mosquito, yellow fever).
along river fronts in Egypt 88
as affected by fumigation with Mimms Culicide 34
dwarf individuals, how caused 16–17
Sticklebacks, enemies of mosquitoes 63, 66
Stratford, Conn., drainage measures against mosquitoes 42
Sulphate of copper. (*See* Copper sulphate.)
potash solution as protection from mosquito bites 13
Sulphur dioxid as fumigant against mosquitoes 35–37
Sunfish, black-banded. (See *Mesogonistius chætodon*.)
common, enemy of mosquitoes 63
species that destroy mosquitoes 66, 67
Swamp and overflowed lands of the United States, area, present and potential value, and cost of drainage 56–58
lands near Milan, Italy, reclamation and benefits therefrom 59
their value when reclaimed 53–62
Swamps, drainage in control of mosquitoes 42–53
Tanks in water-closets, breeding places of mosquitoes 20
rain-water, breeding places of mosquitoes 19
screening against mosquitoes 18–19
supplying water to bath rooms in country houses, breeding places of mosquitoes 21
Tar, black, mutton tallow, oil of citronella, and pennyroyal as protective liquid against mosquitoes and black flies 13
oil, as protection against mosquito bites 12
Thibault, James K., jr., observations on normal relation between mosquitoes and fish 72
Top-minnows, enemies of mosquitoes 63–64, 66–67, 68–70
Trap for catching adult mosquitoes 40–41
Trees and plants reported as deterrent to mosquitoes 22–30
Troughs of underground-conduit electric railways, suggested as breeding places of mosquitoes 22
water. (*See* Water troughs.)
Umbra, enemy of mosquitoes 66
United States, mosquito exterminative measures 105–113
mosquitoes and malaria 105–111
swamp and overflowed lands, area, present and potential value, and cost of drainage 56–58

Page.
Urns in cemeteries, breeding places of mosquitoes.......... 20
Vaseline and citronella as protection against mosquito bites.......... 13
Vases, breeding places of mosquitoes.......... 20
Veils as protection from mosquito bites.......... 14–15
Veracruz, mosquito exterminative measures.......... 100–101
Verbascum. (*See* "Phul" plant.)
Vinegar as protection from mosquito bites.......... 12
Washington State, reclaimed swamp lands.......... 54
Washstands, stationary, breeding places of mosquitoes.......... 20
Wasp stings, iodin and saponated petroleum as remedy.......... 42
Water accumulations under water tanks, breeding places of mosquitoes.......... 20
  cup of grindstone, breeding place of mosquitoes.......... 19–20
  plants deterrent to mosquito larvæ.......... 27–30
  troughs for domestic animals, breeding places of mosquitoes.......... 19
Wells, disused, breeding places of mosquitoes.......... 20
West Indies, fish destructive to mosquitoes.......... 69–70
Whitney, Milton, statement as to value of swamp lands.......... 54–55
Wisconsin, reclaimed swamp lands.......... 54
Yellow fever and mosquitoes in Habana.......... 92–93
      Isthmus of Panama.......... 94–95
      Rio de Janeiro.......... 95–98
      Veracruz.......... 100–101
  in Rio de Janeiro, measures of supression.......... 96–98
      mortality therefrom, 1872–1909.......... 98
  mosquito. (*See* Mosquito, yellow fever, *Aëdes calopus*, and *Stegomyia fasciata*.)
  periodicity.......... 17
  use of sulphur dioxid in disinfection.......... 37

O

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN NO. 89.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE GRAPE ROOT-WORM

WITH ESPECIAL REFERENCE TO INVESTIGATIONS IN THE ERIE GRAPE BELT FROM 1907 TO 1909.

BY

FRED JOHNSON AND A. G. HAMMAR,

Engaged in Deciduous Fruit Insect Investigations.

IN COOPERATION WITH THE OFFICE OF THE STATE ZOOLOGIST,
PENNSYLVANIA DEPARTMENT OF AGRICULTURE.

ISSUED OCTOBER 20, 1910.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

BUREAU OF ENTOMOLOGY.

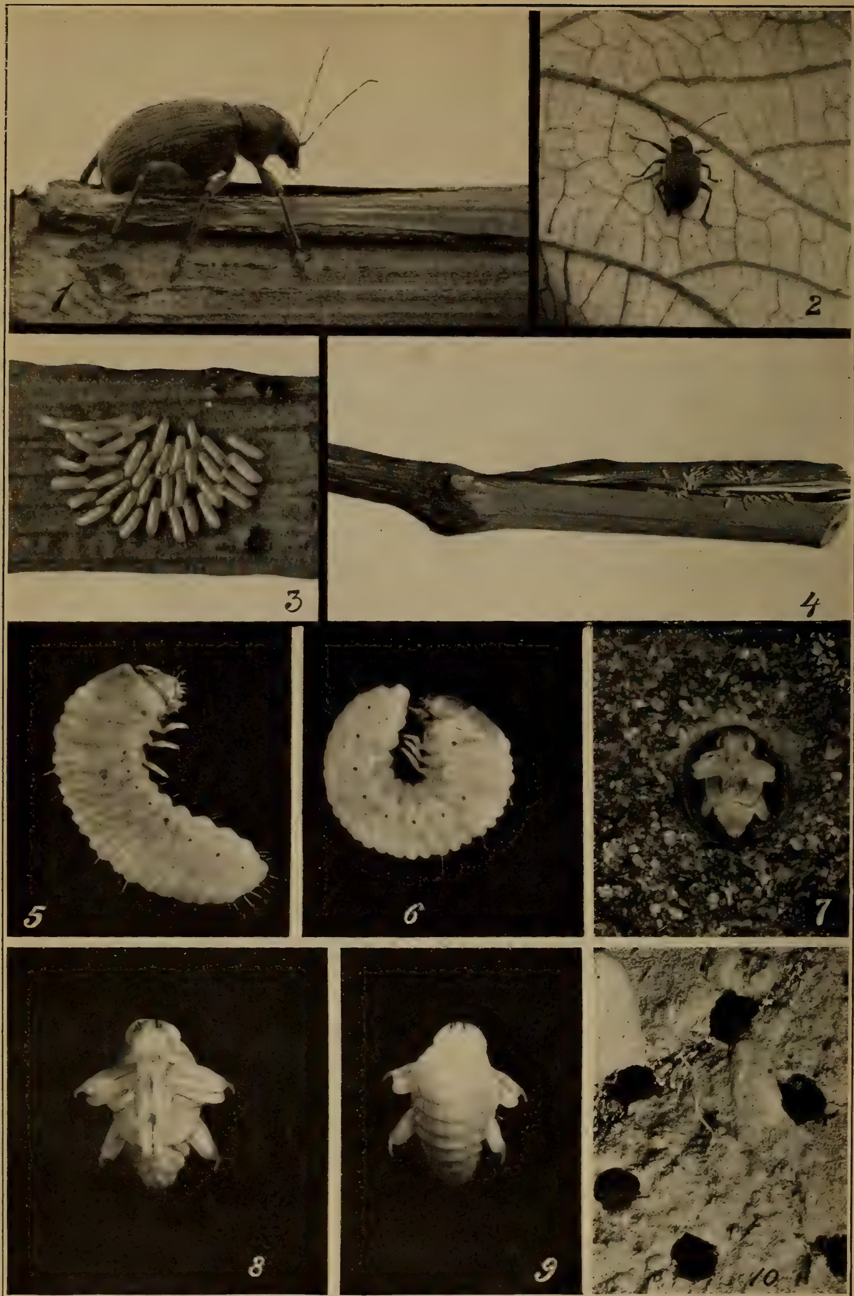
L. O. Howard, *Entomologist and Chief of Bureau.*
C. L. Marlatt, *Assistant Entomologist and Acting Chief in Absence of Chief.*
R. S. Clifton, *Executive Assistant.*
W. F. Tastet, *Chief Clerk.*

F. H. Chittenden, *in charge of truck crop and stored product insect investigations.*
A. D. Hopkins, *in charge of forest insect investigations.*
W. D. Hunter, *in charge of southern field crop insect investigations.*
F. M. Webster, *in charge of cereal and forage insect investigations.*
A. L. Quaintance, *in charge of deciduous fruit insect investigations.*
E. F. Phillips, *in charge of bee culture.*
D. M. Rogers, *in charge of preventing spread of moths, field work.*
Rolla P. Currie, *in charge of editorial work.*
Mabel Colcord, *librarian.*

Deciduous Fruit Insect Investigations.

A. L. Quaintance, *in charge.*

Fred Johnson, S. W. Foster, E. L. Jenne, P. R. Jones, A. G. Hammar, R. W. Braucher, C. W. Hooker, J. R. Horton, W. Postiff, J. B. Gill, *agents and experts.*
E. W. Scott, C. H. Gable, J. F. Zimmer, *entomological assistants.*



THE GRAPE ROOT-WORM (FIDIA VITICIDA).

Fig. 1.—Female beetle ovipositing. Fig. 2.—Beetle on the lower side of a grape leaf. Fig. 3.—Egg cluster with average number of eggs. Fig. 4.—Grape cane showing eggs beneath the bark. Figs. 5, 6.—Full-grown larvæ. Fig. 7.—Pupa in cell. Figs. 8, 9.—Lower and upper views of pupa. Fig. 10.—Openings in the ground from which beetles emerged. Figs. 3, 5, 6, 8, 9, enlarged; figs. 2, 10, about twice enlarged; fig. 7, about three times enlarged; fig. 1, five times enlarged; fig. 4, natural size. (Original.)

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN NO. 89.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE GRAPE ROOT-WORM

WITH ESPECIAL REFERENCE TO INVESTIGATIONS IN THE ERIE GRAPE BELT FROM 1907 TO 1909.

BY

FRED JOHNSON AND A. G. HAMMAR,

Engaged in Deciduous Fruit Insect Investigations.

IN COOPERATION WITH THE OFFICE OF THE STATE ZOOLOGIST, PENNSYLVANIA DEPARTMENT OF AGRICULTURE.

ISSUED OCTOBER 20, 1910.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., June 8, 1910.

Sir: I have the honor to transmit herewith for publication a manuscript entitled "The Grape Root-Worm, with Especial Reference to Investigations in the Erie Grape Belt from 1907 to 1909," by Fred Johnson and A. G. Hammar, agents and experts, of this Bureau.

The grape root-worm is by far the most serious pest of American varieties of grape at the present time and its ravages have caused a great depreciation in the value of vineyard properties as well as a marked reduction in the yield of fruit. The present report furnishes a careful account of the life history and habits of the pest, embodies a report on the work undertaken by the Bureau of Entomology in the spring of 1907 in the Erie Grape Belt, at the instance of vineyardists, and provided for by Congress, and points out practical remedial measures whereby the vineyardists will be able largely to avoid future losses.

During the years 1908 and 1909 the work has been in cooperation with the office of the zoologist of the Pennsylvania state department of agriculture, as further detailed in the preface.

I recommend the publication of the accompanying manuscript as Bulletin No. 89 of this Bureau.

Respectfully,

R. S. Clifton,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The grape root-worm, the subject of the present report, is an insect which during the last ten or fifteen years has attracted much attention on account of its ravages in vineyards along the southern and eastern shores of Lake Erie, comprising in general the grape-growing territory of northern Ohio and the Erie and Chautauqua grape belts of Pennsylvania and New York, respectively. American varieties of grapes, exclusively grown in the above-mentioned regions, have heretofore been singularly free from insects attacking the roots of the plant. The Phylloxera, so destructive to the roots of vinifera varieties in Europe and in California and elsewhere in the United States where these are grown, fortunately does not seriously injure varieties of American grapes. The grape root-worm, however, has come to be recognized as the most serious of the two hundred or more species of insects in the United States which feed directly or indirectly upon our native grapes.

The destructiveness of the insect in the Erie grape belt in the general neighborhood of North East, Pa., led, through the representations of prominent vineyardists, to a provision by Congress for an especial investigation of the pest by the Bureau of Entomology. This work was begun in the spring of 1907, and a laboratory was established at North East, Pa., which place has been continued as headquarters during the years 1908 and 1909. During the latter two years, by contract entered into between the Hon. James Wilson, Secretary of the United States Department of Agriculture, and the Hon. N. B. Critchfield, secretary of agriculture of the State of Pennsylvania, the investigation has been in cooperation with the office of the state zoologist of the Pennsylvania department of agriculture. The work has covered a wide range of investigations, including a thorough inquiry into the life history and habits of the insect, large-scale experiments with remedial measures, and the demonstration of the effectiveness of measures known to be of value, including the renovation and improvement of young and old vineyards already seriously injured.

Mr. Fred Johnson has been in immediate charge of the field work during the entire period of the investigation, and was assisted in 1907 by Messrs. W. B. Wilson and P. R. Jones, the former engaged in field work and the latter in life-history studies. During the years

1908 and 1909 Mr. A. G. Hammar was detailed to the grape root-worm investigation and devoted his attention particularly to life-history studies, assisted by Mr. E. Selkregg. Prof. H. A. Surface, state zoologist of Pennsylvania, assigned, as a representative of the Pennsylvania department of agriculture, Mr. F. Z. Hartzell during 1908, and Mr. H. B. Weiss during the year 1909. These gentlemen assisted in field operations and rendered most efficient service, contributing much to the success of the investigation. In the present report Mr. Johnson has prepared the manuscript detailing results of field experiments and Mr. Hammar the manuscript detailing results of life-history studies, and most of the illustrations.

The results obtained by this study, as detailed in the subsequent pages, will, it is believed, furnish entirely practicable and economical measures for the control by vineyardists of this serious insect pest. It is essential, however, in order that satisfactory results may be secured, that the recommendations given be followed in a thorough and timely manner.

The authors desire to express their thanks to the following vineyardists of North East, Pa.: Mr. George Blaine, Mr. W. S. Wheeler, Mr. R. Davidson, Mr. W. E. Gray, Mr. H. S. Mosher, and Mr. A. I. Loop, for their direct assistance in the conduct of this investigation by placing large blocks of their vineyards at the disposal of the Bureau of Entomology for several seasons and assisting in conducting experiments thereon. They also wish to thank the large number of vineyardists whose interest in the work during its progress has been a source of inspiration and gratification to them throughout this period.

A. L. QUAINTANCE,
In Charge of Deciduous Fruit Insect Investigations.

CONTENTS.

	Page.
Introduction	9
History	10
Origin and distribution	12
Food plants	13
Character of injury and destructiveness	14
Beetles related to the grape root-worm beetle	15
Beetles frequently mistaken for the grape root-worm beetle	16
Description	19
The egg	19
The larva	19
The pupa	20
The adult or beetle	21
Seasonal history	22
The adult or beetle	22
The process and time of emergence	22
Variation in the time of emergence	25
Feeding before and after egg deposition	25
Mating and its bearing upon egg deposition	28
Process of egg deposition	28
Variation in the number of eggs per cluster	29
Number of separate ovipositions by individual females	29
Number of eggs deposited by individual female beetles	30
The oviposition period for the season of 1909	31
Longevity of male and female beetles	32
The egg	33
Incubation period of the egg	33
The larva	35
Vitality of the newly hatched larva	35
Feeding and development of the larva before wintering	35
Wintering of the larva in an earthen cell	36
Spring feeding of the larva	37
Time and making of the pupal cell	37
The post-larval stage	38
The pupa	39
The process of pupation	39
Position of the pupa in the cell	39
Time of pupation in the field and in breeding cages	39
Duration of the pupal period	40
Life cycle of the grape root-worm as determined by rearing	40
Seasonal variations in the life history of the grape root-worm	41
Rearing and experimental methods	44
Summary of life-history studies of the grape root-worm	50

Page.
Natural enemies........ 50
Predaceous insects........ 50
Parasitic insects........ 51
Life history of *Fidiobia flavipes* Ashm........ 52
A dipterous parasite........ 55
Double parasitism........ 56
Vineyard conditions in the Lake Erie Valley........ 57
Remedial measures for the control of the grape root-worm........ 59
Evolution of preventive measures........ 59
Cultural methods for the destruction of pupæ........ 61
Effect of poison sprays on the beetle in the field........ 63
Cage experiments with poison sprays against the beetles........ 64
Field experiments with poison sprays against the beetles........ 66
Comparative effectiveness of arsenate of lead and arsenite of lime........ 68
Results of vineyard experiments with poison sprays........ 70
Results of vineyard renovation experiments........ 75
Renovation experiment on an old vineyard........ 75
Methods of obtaining and recording results........ 78
Renovation experiment on a young vineyard........ 80
Sprays........ 83
Arsenical poisons........ 83
Combining insecticides with fungicides........ 84
Preparation of Bordeaux mixture........ 84
Plants for preparation of the spray mixture........ 85
Time of application of sprays........ 86
Number of spray applications........ 86
Pressure to be maintained in spray applications........ 88
Spraying apparatus........ 88
Horse-power sprayers........ 88
Gasoline-engine sprayers........ 88
Compressed-air outfits........ 88
Carbonic-acid-gas sprayers........ 89
Hand pumps........ 89
The care of spraying apparatus........ 89
Nozzle adjustment........ 89
Nozzles........ 89
Recommendations........ 89
Destruction of the adults or beetles........ 89
Destruction of the pupæ........ 90
General treatment of infested vineyards........ 91
Bibliography........ 93
Index........ 98

ILLUSTRATIONS.

PLATES.

Page.

PLATE I. The grape root-worm (*Fidia viticida*). Fig. 1.—Female beetle ovipositing. Fig. 2.—Beetle on the lower side of a grape leaf. Fig. 3.—Egg-cluster with average number of eggs. Fig. 4.—Grape cane, showing eggs beneath the bark. Figs. 5, 6.—Full-grown larvæ. Fig. 7.—Pupa in cell. Figs. 8, 9.—Lower and upper views of pupa. Fig. 10.—Openings in the ground from which beetles emerged. .... Frontispiece.

II. Feeding marks on grape leaves, made by the beetle of the grape root-worm. Fig. 1.—Appearance of fresh feeding marks. Fig. 2.—Feeding marks which have become enlarged with the growth of the leaf.......... 14

III. Feeding marks on the larger roots and underground part of the stem of a grapevine by larvæ of the grape root-worm, resulting in the death of the plant.......... 14

IV. Destruction of root fibers by larvæ. Fig. 1.—Five-year-old grapevine with normally developed root-system; enlarged portion showing root fibers. Fig. 2.—Four-year-old grapevine, showing result of feeding by larvæ of the grape root-worm.......... 16

V. Ridge of soil under trellis. Fig. 1.—Vineyard view in the spring, showing ridge of undisturbed soil under the trellis. Fig. 2.—Vineyard view, showing ridge of soil under trellis as formed at the last cultivation of the preceding summer. North East, Pa.......... 62

VI. General view of Mr. Roscoe Davidson's vineyard at North East, Pa., where spraying experiments against the grape root-worm were conducted during 1907, 1908, and 1909.......... 70

VII. Views of experimental plats in Mr. Roscoe Davidson's vineyard at North East, Pa. Fig. 1.—Retarded growth of vines in the unsprayed plat. Fig. 2.—Vigorous growth of vines in the sprayed plat.......... 74

VIII. Views of the Porter experimental vineyard, showing comparative growth of the vines in 1907 at the beginning of the experiment (upper figure), and in 1909 at the end of the experiment (lower figure). North East, Pa.......... 80

IX. Condition of fruit on vines in plats of the Porter experimental vineyard. Fig. 1.—Average condition of berries in the untreated plat. Fig. 2.—Average condition of berries in the treated plats. North East, Pa., 1909.......... 80

X. Spraying outfits for vineyards, in use at North East, Pa. Fig. 1.—Spray-mixing plant. Fig. 2.—Gasoline-engine sprayer in operation. Fig. 3.—Compressed-air sprayer. Figs. 4, 5.—Horsepower or geared sprayers.......... 86

TEXT FIGURES.

FIG. 1. Map showing distribution of the grape root-worm (*Fidia viticida*) 12

2. The California grape root-worm (*Adoxus obscurus*): Adult or beetle.......... 15

3. The grapevine Fidia (*Fidia longipes*): Adult or beetle.......... 16

	Page.
FIG. 4. The grapevine flea-beetle (*Haltica chalybea*): Adult	16
5. The rose-chafer (*Macrodactylus subspinosus*): Adult or beetle	17
6. The redheaded Systena (*Systena frontalis*): Adult or beetle	18
7. The grapevine Colaspis (*Colaspis brunnea*): Adult or beetle	18
8. The grape root-worm (*Fidia viticida*): Larva and details	19
9. The grape root-worm: Pupa and details	19
10. The grape root-worm: Adult or beetle	20
11. The grape root-worm: Structural parts of beetle	21
12. Diagram showing time and development of a single individual of the grape root-worm under average conditions, as observed in 1909, at North East, Pa	23
13. Curve showing time and relative emergence of beetles of the grape root-worm from the ground in rearing cages at North East, Pa., 1909	24
14. Curves showing variations in time of emergence of beetles of the grape root-worm from different kinds of soil. From rearing experiments during 1909 at North East, Pa	25
15. Curve showing time of egg deposition and relative abundance of eggs laid in rearing cages by beetles of the grape root-worm at North East, Pa., during 1909	32
16. Diagram showing variation in time of emergence of beetles of the grape root-worm during 1907, 1908, and 1909, at North East, Pa	42
17. Temperature curves showing the daily records of the maximum and minimum temperature during the breeding period of 1909 at North East, Pa	43
18. Portion of the outdoor rearing shelter used in the rearing of insects at North East, Pa., during 1909	45
19. Wooden-frame box with glass bottom and wire-screen cover used in studying the pupal stage of the grape root-worm beetle	45
20. Earthen pot with glass cyclinder used in rearing the grape root-worm	46
21. Rearing cage with glass sides used in the study of the larva of the grape root-worm beetle	47
22. Earthen pot with wire-screen cover used in rearing the grape root-worm	48
23. Diagram illustrating seasonal history of the grape root-worm as observed during 1909 at North East, Pa	49
24. *Fidiobia flavipes*, an egg-parasite of the grape root-worm: Adult and enlarged antenna	52
25. Diagram showing the relation between the three generations of the Fidiobia parasite and the relative occurrence of eggs of the grape root-worm at North East, Pa., during 1909	55
26. Larva of an undetermined insect parasite of the eggs of the grape root-worm	56
27. *Lathromeris fidiæ*, an egg-parasite of the grape root-worm: Antenna and forewing	57
28. Horse hoe used in removing the soil from beneath the trellis in vineyards	61
29. Young grapevine, unsprayed, showing extensive feeding by beetles of the grape root-worm. North East, Pa., 1909	66
30. Young grapevine sprayed with arsenate of lead against the beetles of the grape root-worm. North East, Pa., 1909	87
31. A large nozzle of the cyclone type	89

THE GRAPE ROOT-WORM

WITH ESPECIAL REFERENCE TO INVESTIGATIONS IN THE ERIE GRAPE BELT FROM 1907 TO 1909.

INTRODUCTION.

During the past decade the insect *Fidia viticida* Walsh (Pl. I), a chrysomelid beetle known to the vineyardists of the Lake Erie Valley as the "grape root-worm" beetle, which in the larval stage feeds upon the roots of the grapevine, has become by far the most destructive insect pest attacking the grape in that region.

The following pages present the extent and findings of an investigation conducted at North East, Pa., during the seasons of 1907, 1908, and 1909. These investigations were undertaken in order to make a thorough study of the life history and habits of this insect, to conduct experiments with a view to its control, and to make field experiments to demonstrate the practical commercial value of those methods giving greatest promise of effective results.

Since the grape root-worm is a grape pest of long standing, a brief résumé of its history is given, both from the standpoint of entomological classification and from that of the development of remedial measures for its control.

Its origin, distribution, and food plants are considered, brief descriptions of allied beetles and of those beetles found upon grapevines likely to be mistaken for the grape root-worm are given, and also a description of the character of the injury to the vine wrought by the insect and the extent of its destructiveness.

The technical descriptions of the different ages of the insect are followed by a presentation of life-history studies involving many careful experiments with numerous individuals. These studies were undertaken to determine the length of the stages and the time at which the different changes occur. This work was conducted for three consecutive years with a view to determine the effect, in the development of the insect, of seasonal variations due to varying climatic conditions, and it has been productive of very interesting results which have an important bearing on the time of application of remedies. Soil conditions and altitude of vineyards are also considered in this same relation.

Preceding the discussion of remedial measures a brief summary is given of the conditions in vineyards in the Lake Erie Valley since their invasion by the grape root-worm, dealing with the age and condition of vines at the time of its advent, the increase in area of new vineyards, the insect's comparative destructiveness to old and newly planted vines, and the relative responsibility of the pest for the fluctuations of crop yields during the past decade.

Cultural methods are considered with special reference to the destruction of pupæ in the soil.

In the presentation of the data dealing with poison sprays for the destruction of the beetles, details of experiments are given, first, to show the efficiency of arsenicals as a direct killing agent of the beetles in confinement and also in the open field; second, to show the relative value of arsenate of lead and of arsenite of lime; and, third, to show the cumulative value of poison-spray applications on large vineyard areas, both in crop yield and in vigor of vines as a result of three consecutive years of this treatment.

Following this experimental data on poison sprays the details are given of field demonstration experiments with two run-down vineyards, conducted for three consecutive seasons. One, an old vineyard of about 10 acres, the other a young vineyard of about 5 acres. The condition of each of these vineyards at the time the experiment was undertaken is described and the plan of treatment—covering general vineyard practice, such as pruning back of badly injured vines, fertilizing, cultivation, and spraying with arsenicals—is given, accompanied by the collected data showing the results of this treatment in lessening deposition of eggs by the grape root-worm beetles, in the diminution of grape root-worm larvæ in the soil about the roots of the vine, in the increase in crop yield, and in the general effect of this combined treatment upon the health and vigor of the vines.

The remaining pages contain a brief discussion of arsenicals as stomach poisons against the grape root-worm beetles, the desirability of combining them with a fungicide when spraying for this pest, spraying methods and spraying machinery as related to vineyard treatment, and recommendations as to time and manner of making applications.

HISTORY.

The first record of the beetle, *Fidia viticida*, the adult of the grape root-worm, as a pest of economic importance upon grapevines was made by B. D. Walsh in 1866 in the Practical Entomologist (see Bibliography), and it is also to him that we are indebted for the first description of this species of the genus Fidia. Yet as far back as 1826 this insect appears in entomological literature under a variety of names. The first reference we find to this species is in M. J. Sturm's Catalog Insecten Sammlung, at that date (1826) under the name of *Colaspis flavescens*. Under a later catalogue (1843) by the same author it is listed under the name of *Fidia lurida* Dej. Dejean, in his Catalogue des Coléoptères (1837), names two species, *Fidia lurida* Dej. and *Fidia murina* Dej.

The genus Fidia was first characterized by Baly in 1863, who used the name Fidia suggested earlier by Dejean. Crotch, however, in 1873, described this insect under the name of *F. murina* and Lefevre, in 1885, described it under *F. lurida*. In 1892, when Dr. George H. Horn revised the Eumolpini of Boreal America, *F. murina* and *F. lurida* were found to be synonyms of *Fidia viticida* as described by Walsh in 1867.[a]

Since 1866, when this insect was first reported as occurring in destructive numbers in Kentucky, it has developed into the most serious insect infesting vineyards east of the Rocky Mountains. At that date only the adult form and its injury to the vine by feeding upon the foliage was known. Walsh assumed that the larval habits of the pest were similar to those of the grape flea-beetle (*Haltica chalybea* Ill.), and that it would be found the most destructive in this stage feeding upon the foliage. In the former assumption he was correct, for it is the injury of the larval form which is inimical to infested vines, not upon the leaves, however, as Walsh supposed, but upon the roots, as shown by later investigations. The year following, the insect was reported from St. Louis and Bluffton, Mo., and in 1868 Prof. C. V. Riley, in his first report on injurious and beneficial insects of Missouri, mentions it as "the worst foe to the grapevine in Missouri." In 1870 specimens were received by Riley from Bunker Hill, Ill., and in 1872 Mr. S. H. Kridelbaugh reported it present in Iowa in injurious numbers.

It was not until 1893, however, that some light was thrown upon the earlier stages of the pest. In December of that year Prof. F. M. Webster, then entomologist of the Ohio Agricultural Experiment Station, received larvæ from the vicinity of Cleveland, Ohio, where they were said to occur in great numbers about the roots of vines. Later there developed from these larvæ the complete form which proved to be the beetle *Fidia viticida*, hitherto the only stage of the

---

[a] The validity of the technical name of the grape root-worm (*Fidia viticida* Walsh) might be questioned. The names *lurida* and *murina* were used previous to *viticida*, but as *nomina nuda;* the specific description was first given in 1867, when Walsh described the insect under the name *Fidia viticida*. Baly in 1863 characterized the genus and designated *lurida* as the type of the genus, though the species under that name had not yet been described. The specific name *viticida* Walsh has the priority, since the valid name *murina* was first used in 1873 by Crotch, and *lurida* in 1885 by Lefevre, both writers using the early manuscript name of Dejean.

insect known to entomologists. During the season of 1894 Professor Webster made a detailed and accurate study of the life history of the insect, described its immature stages, and made numerous field experiments to determine effective methods of control, which are referred to in another part of this bulletin.

In 1896 Prof. J. T. Stimson recorded injury caused by this insect in Arkansas. Dr. John B. Smith, in his Catalogue of Insects of New Jersey, 1900, reports its occurrence throughout that State. Dr. L. O. Howard reported it from Bloomington, Ill., in 1901. In later years the insect appeared as a pest in the grape region of Pennsylvania and New York, where from 1900 to 1906 it was the subject of detailed studies, treating both of its life history and remedial measures, by the late Prof. M. V. Slingerland, of Cornell University,

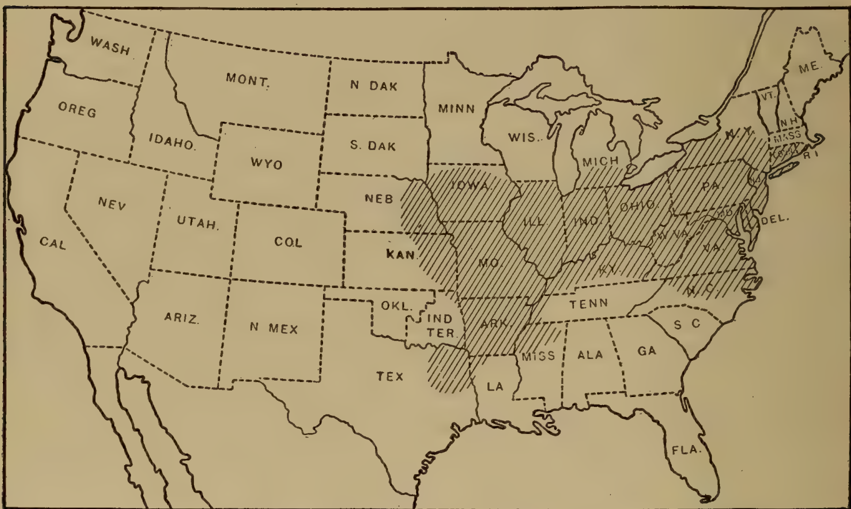


FIG. 1.—Map showing distribution of the grape root-worm (*Fidia viticida*). (Original.)

and by Dr. E. P. Felt, state entomologist of New York. The reports of the investigations by the former are embodied in the bulletins of the entomological division of Cornell University, and the publications of the New York State Museum contain reports of those made by the latter; all publications of these two investigations are listed in the bibliography accompanying this bulletin.

ORIGIN AND DISTRIBUTION.

The grape root-worm has at present been recorded only from North America, and it is without doubt a native species, feeding originally on wild grapevines, as it still does to some extent.

The insect is widely distributed in the Mississippi Valley and in the Eastern States. The map (fig. 1) shows the distribution as recorded at present.

In literature the insect is reported from the following States: Arkansas (Riley, Howard, and Stimson); Illinois (Walsh and Riley); Iowa (Kridelbaugh); Kansas (Webster); Kentucky (Walsh); Missouri (Riley); New Jersey (Smith); New York (Lintner, Slingerland, and Felt); Ohio (Webster); Pennsylvania (Slingerland and Felt).

According to records of the Bureau of Entomology the insect occurs in Illinois, Kentucky, Michigan, Mississippi, Missouri, New York, North Carolina, Ohio, Pennsylvania, Texas, Virginia, and West Virginia.

In the collections of the National Museum are specimens from the following States: District of Columbia, Illinois, Kansas, Maryland, Missouri, Nebraska, New York, North Carolina, Ohio, Pennsylvania, Texas, and Virginia.

From the following localities it has not yet been recorded, but probably does occur as these are neighboring sections of infested places: Southern parts of Indian Territory, Tennessee, and Wisconsin; northern parts of Alabama, Georgia, Louisiana, and South Carolina.

FOOD PLANTS.

From early records of this insect it is evident that the beetle of the grape root-worm was observed feeding upon wild grapes long before it was known to infest cultivated varieties. Riley reported the beetle feeding upon the leaves of wild grapes and upon the redbud (*Cercis canadensis*). Several writers have found it feeding upon the foliage of the Virginia creeper (*Ampelopsis quinquefolia*). With the extensive cultivation of improved varieties of native species of grapes, the insect has found in these a more available food plant. The larval form and its underground habits became first known through its abundance and destructiveness in vineyards.

On the wild grapevine the grape root-worm does not breed in extensive numbers, because the conditions in woodlands are less favorable than those existing in vineyards. The chances for the newly hatched larvæ to reach the roots of the wild grapevine are greatly limited, since the plants spread their aerial growth extensively and in such a manner that the parts of the vine above ground are not directly above the root system. Under such conditions numbers of the larvæ on dropping to the ground do not reach the needed food plant and probably perish. A single female beetle, however, lays a considerable number of eggs, and out of the many hatching larvæ the chances are that always several will survive to perpetuate the species.

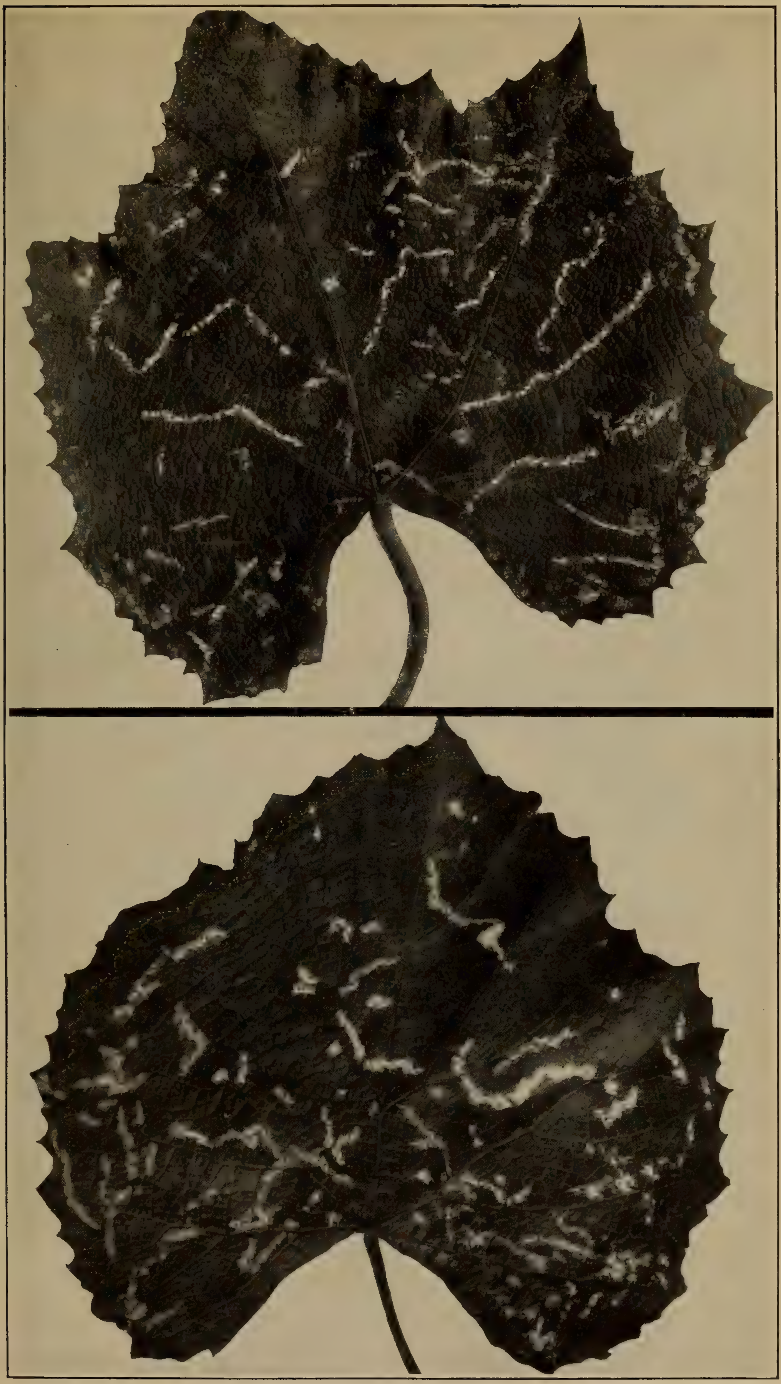
In the course of this investigation at North East, Pa., several attempts were made to locate the larvæ on roots of wild grapevines, but in no instance were larvæ found or any signs of feeding observed on the roots. In the breeding work, however, larvæ were reared on wild grapevines, which shows that it is possible for the larvæ to exist on these plants. In 1909 larvæ hatching July 26 were placed in large earthen pots (fig. 22) in which, some time previously, wild grapevines had been planted. On examining the cages in the fall of the same year (1909) a number of larvæ were found to have attained their normal growth, as compared with other larvæ reared under similar conditions on cultivated vines.

CHARACTER OF INJURY AND DESTRUCTIVENESS.

The injury wrought by this pest on the grapevine occurs both above and below the surface of the ground; however, by far the greater damage results from its work upon the roots. The injury above the ground is done by the beetles; that upon the roots by the grubs or larvæ.

The first intimation that the observant vineyardist is likely to obtain of the presence of this pest upon his vines is the appearance, late in June or early in July, of chainlike markings upon the upper surface of the foliage (Pl. II). These markings are made by the beetle. Ordinarily this scoring of the leaves is not sufficient to materially affect the health of full-grown thrifty vines. Where the beetles are very numerous, however, and the foliage sparse, it not infrequently happens that the leaves are so badly scored that in a short time they take on a brown appearance and hang about in shreds. In the case of newly planted vines (fig. 29) extensive feeding by the beetles greatly retards the growth of the young plant and proves a great obstacle in the starting of a new vineyard. On the thick-leaved varieties of grapes, such as the Concord, Worden, and Niagara, this feeding does not extend through the heavy pubescence on the lower surface. The pubescence holds together only a short time, however, and soon either dries out or is torn apart by the growth of the leaf. On the thin-leaved varieties, as the Delaware, and on the wild species of grape, holes are eaten entirely through the leaf, usually assuming the characteristic chainlike irregularity of form.

It is, however, to the larvæ of this pest feeding upon the roots of the vines that the direct cause of the injury and death of so many vines is due. The work of the larvæ upon the roots may be recognized, when the vines are removed from the soil, by the absence of root fibers, by channels along the larger roots, and by pittings on the main trunk. (See Pl. III.) Vines that have become well established before the infestation by larvæ will sometimes withstand the attack of a considerable number of grubs, especially if the soil is rich and has been well tilled. The evidence of continued heavy infestation is indicated by absence of fibers upon the whiplike roots



FEEDING MARKS ON GRAPE LEAVES, MADE BY THE BEETLE OF THE GRAPE ROOT-WORM.

Fig. 1.—Appearance of fresh feeding marks. Fig. 2.—Feeding marks which have become enlarged with the growth of the leaf. Natural size. (Original.)

FEEDING MARKS ON THE LARGER ROOTS AND UNDERGROUND PART OF THE STEM OF A GRAPEVINE BY LARVÆ OF THE GRAPE ROOT-WORM, RESULTING IN THE DEATH OF THE PLANT. LOWER FIGURE NATURAL SIZE. (ORIGINAL.)

(Pl. IV, fig. 2, in comparison with fig. 1) extending from the main root a distance of several feet. The extremities of such roots are frequently dead and in a decaying condition, and the portion near the stem is much channeled and pitted by the feeding of the larger larvæ (Pl. III). The life of such vines during this infestation has been sustained by the throwing out of new fibrous roots either at the crown or from the large lateral roots at a short distance from the base of the vine. If the number of larvæ increases sufficiently to eat off these new fibers, the whole vine declines quite rapidly, and the effect of the attack is readily recognized by a sickly stunted growth of vine and undersized clusters of fruit, and in extreme cases by the early shedding of foliage and actual shriveling of fruit before the ripening period.

BEETLES RELATED TO THE GRAPE ROOT-WORM BEETLE.

The grape root-worm is a member of the large group of leaf-eating beetles known as the Chrysomelidæ. To this family belong the common Colorado potato beetle (*Leptinotarsa decemlineata* Say), the elm leaf-beetle (*Galerucella luteola* Müll.), the asparagus beetle (*Crioceris asparagi* L.), several important pests of the genus Diabrotica, the grapevine flea-beetle (*Haltica chalybea* Ill.), and many other injurious beetles.

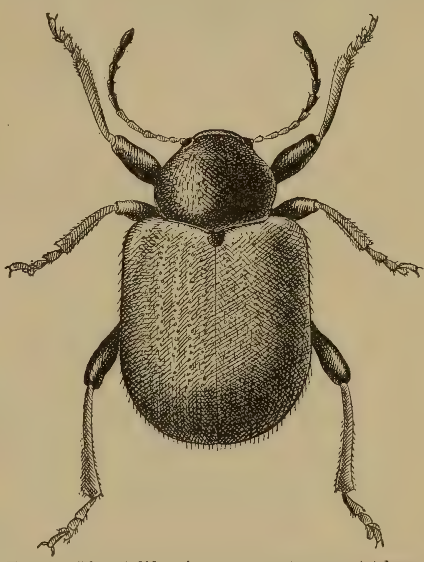


FIG. 2.—The California grape root-worm (*Adoxus obscurus*): Adult or beetle. Much enlarged. (Original.)

Closely related to *Fidia viticida* Walsh (fig. 10) is the California grape root-worm (*Adoxus obscurus* L.) (fig. 2), of which there are two varieties, namely, a black form, known as *A. obscurus,* and a bicolored form, known as *A. obscurus vitis.* Both varieties occur in this country and have been reported from several widely separated States and from Canada. It is found generally in Europe and throughout Siberia. At present it is becoming injurious to vineyards in California, infesting the European varieties of the cultivated grape. A valuable contribution to the knowledge of this insect was published by Mr. H. J. Quayle [a] in 1908. In habits this beetle is in most respects similar to the eastern grape root-worm, *Fidia viticida,* and the two pests can thus be combated with similar methods. It will, however, be necessary to take into consideration the local conditions

[a] Bul. 195, Cal. Agr. Exp. Sta., 1908.

and variations as to the habits of the beetles in order to accomplish effective results.

There are at present 6 species of the genus Fidia known to Boreal America and by including those occurring in Central America there are 14 known species. Of these, *Fidia viticida* Walsh and *Fidia longipes* Melsh. have been recorded as being injurious to the native varieties of the domesticated grape. *Fidia longipes* (fig. 3) is found generally throughout the Mississippi Valley and in the Eastern States. It is, however, less common than *F. viticida.* In Missouri and Kentucky it occurred in injurious numbers on the Concord and on Norton's Virginia varieties of grapes. The earlier stages of this beetle are not yet known.

FIG. 3.—The grapevine Fidia (*Fidia longipes*): Adult or beetle. Much enlarged. (Original.)

For characteristic distinction of the species of Fidia reference is made to the works of Lefevre, Jacoby, Horn, and Schæffer, as listed in the appended bibliography (p. 93).

BEETLES FREQUENTLY MISTAKEN FOR THE GRAPE ROOT-WORM BEETLE.

There are several different kinds of beetles injurious to the grapevine, and these when found in numbers are frequently mistaken for the grape root-worm beetles. It is essential that an insect pest should be properly determined before any successful control measure can be properly recommended. Although most leaf-eating beetles can be controlled with a poison spray, as used against the grape root-worm, there exists a marked difference in the time of appearance of

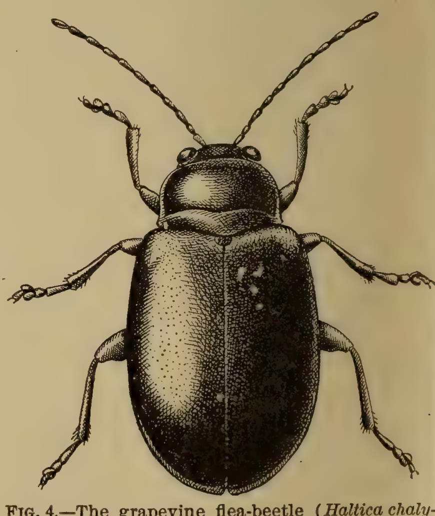


FIG. 4.—The grapevine flea-beetle (*Haltica chalybea*): Adult. Much enlarged. (Original.)

Fig. 1.—Five-year-old grapevine with normally developed root-system; enlarged portion showing root fibers. (Original.)

Fig. 2.—Four-year-old grapevine, showing result of feeding by larvæ of the grape root-worm. (Original.)

DESTRUCTION OF ROOT FIBERS BY LARVÆ.

the different pests, so that an application intended for one may not at all affect another. The descriptions with figures of the following beetles and of their more characteristic habits will aid the vineyardist in distinguishing the grape root-worm from other injurious species.

The grapevine flea-beetle (*Haltica chalybea* Ill.) (fig. 4), measuring about one-fifth of an inch in length, is readily recognized by its brilliant metallic color, which varies from steel blue to green. It is of a robust shape, with thickened thighs well adapted for jumping. With the opening of the buds of the grapevine in the spring the beetle generally makes its appearance. The larvæ, which are found in the early part of the summer, feed, like the adult, upon the leaves of the grape.

The rose-chafer (*Macrodactylus subspinosus* Fab.) (fig. 5) appears as a rule at the time of the blossom of the grape. It is a slender beetle about one-third of an inch long, with the body tapering a little toward each extremity. It is covered with a grayish-yellow down, which gives rise to its color. The pale reddish legs are long, at the joint armed with prominent spines, and terminate in very long black claws. The antennæ, or "feelers," are short and have at the end a laminated club-like structure. The beetle readily attracts attention because of its activity and great abundance wherever present. It preferably feeds upon the clusters of the blossom, and to some extent upon young grape-berries and leaves.

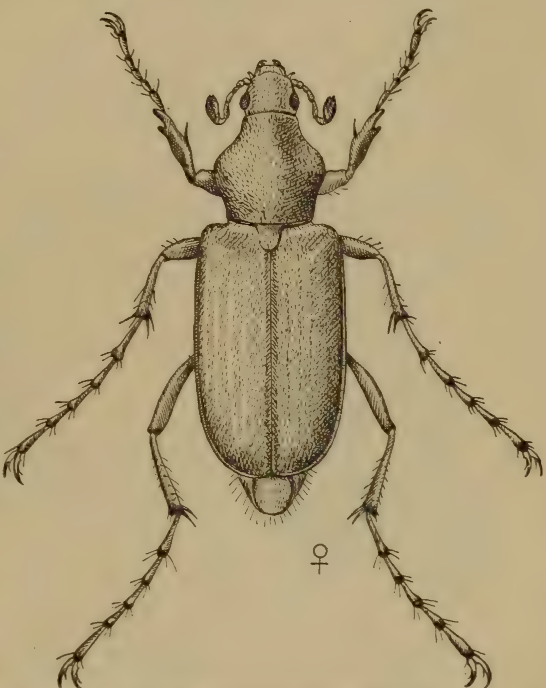


FIG. 5.—The rose-chafer (*Macrodactylus subspinosus*): Adult or beetle. Much enlarged. (Original.)

The red-headed Systena (*Systena frontalis* Fab.) (fig. 6) somewhat resembles the previously described beetle. It is, however, smaller, measuring about one-sixth of an inch in length, and is black in color except for a pale reddish area between the eyes. This beetle has of late become quite injurious to young grapevines, feeding upon the leaves to such an extent that it often kills the vines. The feeding marks of the beetles are quite characteristic, consisting of round patches eaten into the parenchyma from the upper surface of the leaves. It is a very shy little creature, and on the slightest disturbance jumps off and hides beneath the foliage. Young vineyards when infested should be promptly sprayed with a mixture of from 5 to 8 pounds of arsenate of lead to 100 gallons of water. This gives the plants a very good protection. The earlier stages of this insect are not known.

The grapevine Colaspis (*Colaspis brunnea* Fab.) (fig. 7) in its general appearance resembles the grape root-worm beetle. It is, however, slightly smaller, has no pubescence, and is of a pale yellowish color. It is nearly one-fifth of an inch long, with the body densely punctate. On the wing covers the deep punctures are arranged in double longitudinal rows or striæ. The beetle feeds upon the grape foliage in a manner more or less similar to that of the grape root-worm beetle.

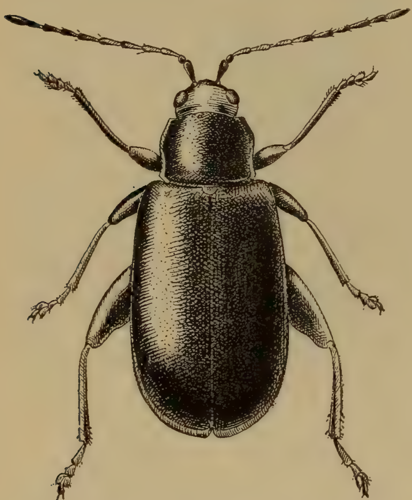


Fig. 6.—The redheaded Systena (*Systena frontalis*): Adult or beetle. Much enlarged. (Original.)

Fig. 7.—The grapevine Colaspis (*Colaspis brunnea*): Adult or beetle. Much enlarged. (Original.)

It is not within the scope of this paper to treat the various insect problems, such as those of the grape leafhopper (*Typhlocyba comes* Say), the grapeberry moth (*Polychrosis viteana* Clem.), the grape curculio (*Craponius inæqualis* Say), and others, which from time to time confront the vineyardist. These pests demand special treatment, and in cases of serious infestation an entomologist should be consulted. It has, however, been our observation that well cultivated and properly sprayed vineyards are less subject to the attacks of insects. Such infestations are very frequently the direct outcome of neglect in the general care of vineyards, as is more fully considered elsewhere in this bulletin.

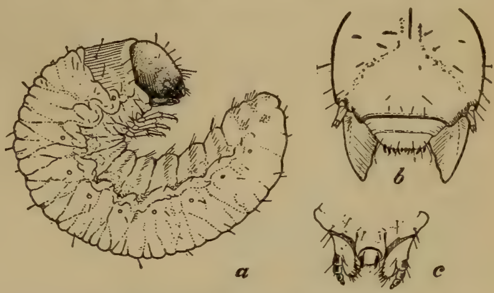


FIG. 8.—The grape root-worm (*Fidia viticida*). Larva: *a*, Side view of full-grown larva; *b*, front view of head; *c*, maxillæ and labium. Much enlarged. (Original.)

DESCRIPTION.

THE EGG.

(Pl. I, figs. 3–4.)

The eggs of the grape root-worm beetle are small yellowish-white objects, measuring 1.15 mm. in length and are about one-third as broad as long. In form the egg is cylindrical, with the two ends almost hemispherical. As the shell is very flexible and the eggs are generally laid crosswise on the canes, they often assume a slightly curved shape. Through the semitransparent shell the segmentation of the embryo can be seen, and later, as the young larva attains its full development, the head with the dark-colored mandibles becomes clearly visible. Prof. F. M. Webster observed the larva backing out from the eggshell in the process of hatching.

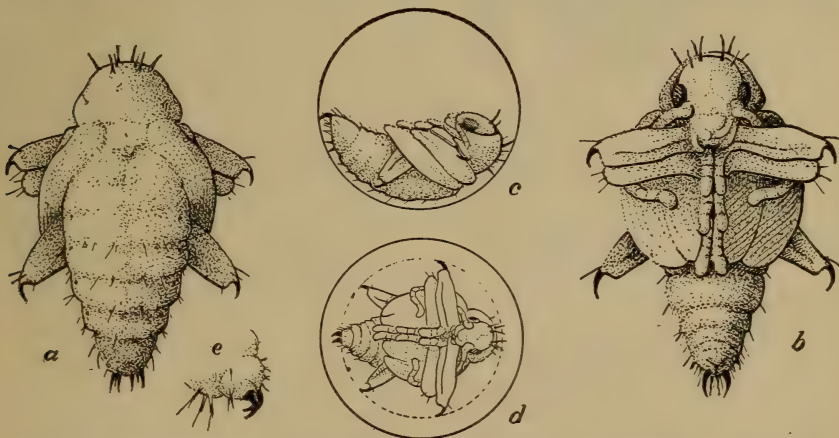


FIG. 9.—The grape root-worm. Pupa: *a*, Upper view; *b*, lower view; *c*, normal position of pupa in cell; *c*, *d*, showing the pupa supported by the spines in the cell; *e*, hind part of body, showing terminal spines. Much enlarged. (Original.)

THE LARVA.

(Pl. I, figs. 5–6; text fig. 8.)

The full-grown larva varies in length from 8 to 10 mm. It is whitish, with the head, thoracic shield, and spiracles pale brown.

The mandibles and the margin of the clypeus and areas around the antennæ are almost black. The anterior margin of the upper lip is armed with short and stout spines (fig. 8, *b*), and as the inner surface is reenforced by chitinous ridges extending inward, its function is probably that of a scraper. The setæ on the head and on the cervical shield are rather prominent; those on the sides and back of the body are less conspicuous. The ventral parts of the abdominal segments are armed with strong spines, which are particularly large on the fourth to the eighth segments. These project obliquely backward and are properly termed ambulatory setæ. The legs are slender and proportionately very small. Normally the larva assumes a curved position (fig. 8, *a*). The anterior portion of the body can be straightened out at will, but the hinder parts remain curved, which is characteristic of the larvæ of most underground beetles. The newly hatched larva is little over 1 mm. in length and of slender form; the legs are relatively large, and the setæ of the entire body are long and prominent.

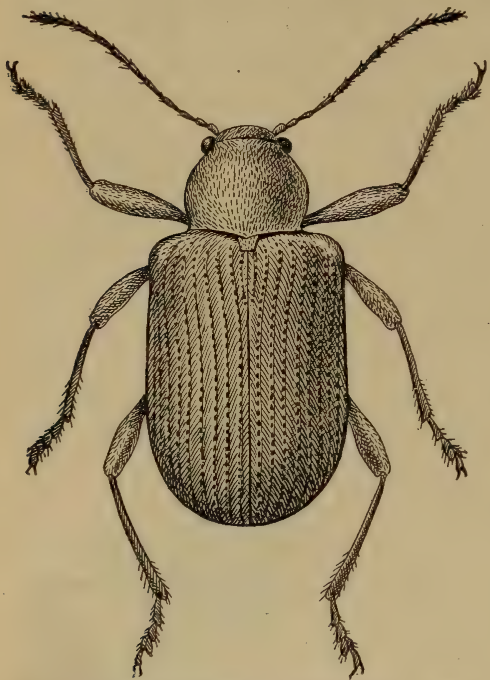


FIG. 10.—The grape root-worm: Adult or beetle. Much enlarged. (Original.)

THE PUPA.

(Pl. I, figs. 7–9; text fig. 9.)

The length of the pupa is from 8 to 10 mm. When newly transformed it is whitish, with a slightly pinkish tinge, which in a few days after pupation disappears and the pupa becomes white. The upper part of the head and anterior margin of the thorax are armed with large spines; each anterior and posterior femur is armed with one curved hooklike spine and two straight, more slender spines. The middle femora have only hairlike bristles. The posterior end of the abdomen carries two stout, flattened hooks, curved upward, and several pairs of spines and bristles (fig. 9, *c* and *d*). The pupa in the cell is supported by these larger spines and its body is not in touch with the moist walls of the cell. As these large and strongly chitinized spines do not occur in either the larval or the adult form of the insects, it is probable that their main function is to support the pupa in the cell.

THE ADULT OR BEETLE.

(Pl. I, figs. 1–2; text figs. 10, 11.)

The original description of the beetle as made by Walsh is given below:

Fidia viticida, new species. Chestnut rufous, punctured and densely covered with short grayish white prostrate hairs, so as to appear hoary. *Head* rather closely punctured, with a very fine longitudinal stria on the vertex. Clypeus and mandibles glabrous and black, the clypeus with a subterminal transverse row of punctures, armed with long golden hairs, the mandibles minutely punctured on their basal half. Palpi and antennæ honey-yellow verging on rufous, the antennæ $\frac{4}{5}$ as long as the body, with joint 4 fully $\frac{1}{2}$ longer than joint 3. *Thorax* finely and confluently punctured, about as long as wide, rather wider behind than before, the sides in a convex circular arc of not quite 60°, the males with the thorax rather longer and laterally less strongly curved than the females. Elytra punctato-striate, the striæ subobsolete, the punctures approximate, and rather large but not deep, the interstices flat and with close-set fine shallow punctures. *Legs* with the anterior tibiæ of the male suddenly crooked $\frac{4}{5}$ of the way to their tip; anterior tibiæ of the female as straight as the others. Length ♂ .24–.27 inch; ♀ .24–.28 inch.

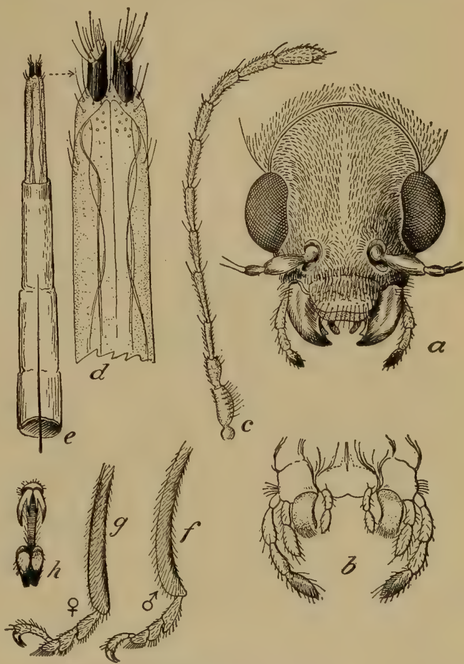


FIG. 11.—The grape root-worm: Structural parts of the adult or beetle—*a*, Front view of head, showing biting mouth parts; *b*, lower view of labium and maxillæ; *c*, antenna or "feeler;" *d*, terminal portion of the ovipositor; *e*, ovipositor with membranous portion extended; *f*, front leg of male beetle; *g*, front leg of female beetle; *h*, claws of tarsus. All parts greatly enlarged. (Original.)

The ovipositor of the female (fig. 11, *d*, *e*) consists of a more or less solid terminal portion and a membranous proximal part. Ordinarily it remains completely withdrawn within the abdominal cavity, where the terminal part lies within the membrane, which is folded into three parts. Meso-ventrally the membrane is supported by a slender chitinous rod (fig. 11, *e*). In the terminal portion are a pair of chitinous rods. Fully extended, the ovipositor is three times the length of the abdomen.

SEASONAL HISTORY.

The grape root-worm attains its growth during the feeding period of the larvæ. The pupal stage, following the long larval period, is a process of transformation, whereby all the internal organs, and to some extent the external parts, become reconstructed, resulting, with the throwing off of the pupal skin, in the appearance of the beetle. It is during this latter stage and in the early part of the summer that reproduction occurs.

The diagram (fig. 12) will, it is believed, greatly aid the reader in comprehending the development and the activity of the grape root-worm in its various stages throughout its life cycle. This illustration has been compiled from both field and rearing observations and represents the life of a single beetle under average conditions.

In the following consideration of the life history of the grape root-worm is presented the results of rearing experiments and field observations for the year 1909. In most respects that year was normal as regards climatic conditions and the insect developed as might be expected under average conditions. In view of the extreme variations in the development of the insect during 1907 and 1908, the records of observations for these years have been treated under the topic "Seasonal variations in the life history of the grape root-worm." The rearing and experimental methods relating to the tables of the life-history work are described separately on pages 44–50.

THE ADULT OR BEETLE.

THE PROCESS AND TIME OF EMERGENCE.

Prior to its emergence the beetle spends several days in the pupal cell and at the time of the shedding of the pupal skin is of a light turbid yellowish cast, and is comparatively soft and for a time helpless. On an average the beetles remain 4 days in the cell, while the parts of the body harden. In Table XV (p. 38) are given 25 observations on the length of time the beetles remain in the cell after transformation. In one instance a beetle remained in the cell 7 days. The minimum length of time was 2 days. Dead beetles have been found in cells, both in the breeding cages and in the ground in vineyards. This occurrence, however, has not been found sufficiently common to cause any material reduction in the number of insects.

The time required by the beetle in passing through the soil to the surface varies considerably with the distance to be covered and the texture and moisture of the soil. It has been possible to make only a few observations on the process of emerging. These were made in breeding cages with glass sides, in which the beetles have worked their way out to the edge of the soil next to the glass. One beetle which left the cell July 6 emerged July 9. On its way upward it had to dig around a flat pebble, and as a result passed through 3½ inches of soil. Another beetle left the cell July 5 and emerged July 6, having penetrated the soil for a distance of 1 inch. A third beetle left the cell July 16 and emerged July 19, in which time it worked through 2 inches of soil. In the process of digging, the beetles make use of the mandibles and to some extent also of the legs. The cells become partly filled with earth by material being pushed behind and beneath the beetle. In this process the channel is refilled and only a small hole is left on the surface to indicate where the beetle emerged (Pl.

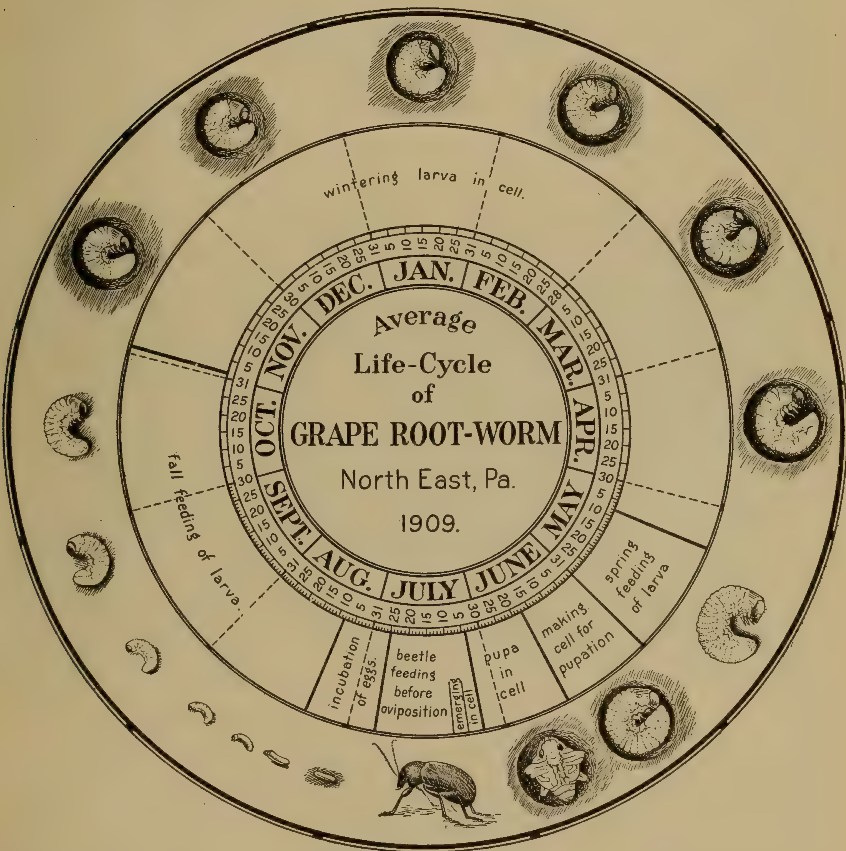


FIG. 12.—Diagram showing time and development of a single individual of the grape root-worm under average conditions, as observed in 1909, at North East, Pa. (Original.)

I, fig. 10). In vineyards where the ground remains undisturbed such openings can be readily found during the emergence period of the beetle.

In 1909 the first beetles observed in the field were collected by the senior author June 28, and, since daily observations were made of vineyard conditions, this record probably represents the earliest occurrence of the beetle for the season. In the breeding cages the first beetle emerged July 1, which shows a fairly uniform emergence of beetles in captivity as compared with their emergence in the field. The results of the emergence experiments are given in Table I.

TABLE I.—*Date of the emergence of 398 grape root-worm beetles (Fidia viticida) from the ground, as observed in the breeding cages in the spring and early part of the summer of 1909 at North East, Pa.*

Date.	Number of beetles.	Date.	Number of beetles.	Date.	Number of beetles.	Date.	Number of beetles.
July 1	5	July 9	36	July 17	8	July 27	4
July 2	9	July 10	39	July 18	4	July 29	1
July 3	16	July 11	19	July 19	5	July 30	2
July 4	11	July 12	36	July 20	2	Aug. 5	1
July 5	15	July 13	22	July 22	6	Aug. 9	1
July 6	27	July 14	16	July 23	1		
July 7	34	July 15	26	July 24	5		
July 8	31	July 16	14	July 25	2		
Total	148	Total	208	Total	33	Total	9

In figure 13 the curve shows more graphically the relative emergence of these beetles. It will be noted from this curve that after

FIG. 13.—Curve showing time and relative emergence of beetles of the grape root-worm from the ground in rearing cages at North East, Pa., 1909. (Original.)

the first emergence the beetles continued to appear in rapidly increasing numbers, reaching a maximum July 10. The decrease in the number of beetles emerging after this date was more gradual, and emergence continued until late in the season. In the cages the last beetle emerged August 9, while in the field a single beetle was still found in the cell August 14. From July 1 to July 5, inclusive, 14.1 per cent had emerged; from July 6 to July 16, 75.4 per cent had emerged; and the remaining 10.5 per cent emerged later. Thus the great majority of over 75 per cent emerged during a period of 10 days, and the maximum of emergence took place about 2 weeks after the first beetle had been observed in the field.

VARIATION IN THE TIME OF EMERGENCE.

The variation found in the time of emergence of beetles in different vineyards and even in different sections of the same vineyard is due to various factors, such as temperature, moisture, porosity and texture of the soil, etc.

Since larvæ are found more abundantly in the looser porous soils than in the heavy, compact clay soils, and since the former soils are warmer, it is but natural that the insect should emerge earlier under these conditions. This fact is confirmed by observations presented in figure 14, which shows the relative emergence of beetles from three grades of soil. For these experiments a number of larvæ were collected in the early spring from different localities in the vicinity of North East, Pa. They were confined in large earthen pots (fig. 22) with the same kinds of soil in which they had been collected. Since these larvæ were supplied with a sufficient amount of food and the

FIG. 14.—Curves showing variations in time of emergence of beetles of the grape root-worm from different kinds of soil. From rearing experiments during 1909 at North East, Pa. (Original.)

pots were placed in the ground in the open, it is believed that their normal conditions had been changed but slightly. The emergence of beetles from the sandy and gravelly soil was seven days earlier than the emergence from the clay soil.

In the vicinity of North East, Pa., the authors have observed that the emergence of the beetle in vineyards situated on the hills is one week later than the emergence in vineyards in the valley. This delay is not merely confined to the time of emergence of the beetles, but has been observed in practically all the different stages of the insect, as can be verified from the various tables of field observations.

FEEDING BEFORE AND AFTER EGG DEPOSITION.

At the time of emergence from the ground the beetle seems to possess a keen appetite. It readily finds its way to the grape foliage, and generally feeds upon the first leaf that it encounters. The leaves of the lower shoots are frequently found badly mutilated as a result of this first feeding. The voracity with which newly emerged beetles feed is indicated in the poison-spray experiments described on page 65. Fifty per cent of newly emerged beetles were killed the first day, against 10 per cent of older beetles, both sets being subjected to identical conditions.

The feeding of the beetle is confined mainly to the upper surface of the leaves; the parenchyma is devoured, leaving characteristic chainlike feeding marks, as shown in Plate II. With individual beetles the length of time of feeding previous to egg deposition varies considerably. In Tables II and III is given the record of 16 individual females, showing a feeding period before oviposition varying from 9 to 24 days, with an average of 15.9 days.

TABLE II.—*Oviposition, feeding, and length of life of individual male and female beetles of Fidia viticida in captivity during the summer of 1909 at North East, Pa.*

Number of experiment	1.	2.	3.	4.	5.	6.
Date of emergence of beetles	June 30	June 30	June 30	June 30	July 2	July 2
Mated	July 8	July 8	July 8–9	July 14	July 13	....
First oviposition	July 22	July 21	July 15	July 21	July 15	July 19
Eggs	31	17	26	15	17	35
Second oviposition	July 25	July 26	July 16	....	July 28	July 26
Eggs	31	6	19	....	14	36
Third oviposition	July 26	....	July 27	....	Aug. 3	July 29
Eggs	40	....	14	....	5	31
Fourth oviposition	July 28	....	July 29	....	Aug. 8	July 31
Eggs	25	....	61	....	4	14
Fifth oviposition	....	....	....	....	....	Aug. 4
Eggs	....	....	....	....	....	14
Sixth oviposition	....	....	....	....	....	Aug. 7
Eggs	....	....	....	....	....	23
Seventh oviposition	....	....	....	....	....	....
Eggs	....	....	....	....	....	....
Eighth oviposition	....	....	....	....	....	....
Eggs	....	....	....	....	....	....
Ninth oviposition	....	....	....	....	....	....
Eggs	....	....	....	....	....	....
Death of male	Aug. 8	Aug. 26	Aug. 19	July 23	Aug. 25	....
Death of female	Aug. 1	Aug. 2	Aug. 3	July 23	Aug. 9	Aug. 31
Days of feeding before oviposition	22.0	21.0	15.0	21.0	13.0	17.0
Times of oviposition	4.0	2.0	4.0	1.0	4.0	6.0
Eggs per cluster:						
Minimum	25.0	6.0	14.0	15.0	4.0	14.0
Average	31.8	11.5	30.0	15.0	10.0	25.5
Maximum	40.0	17.0	61.0	15.0	17.0	36.0
Total number of eggs	127.0	23.0	120.0	15.0	40.0	153.0
Length of life of male	39.0	57.0	50.0	23.0	54.0	....
Length of life of female	31.0	32.0	33.0	23.0	38.0	60.0

TABLE II.—*Oviposition, feeding, and length of life of individual male and female beetles of Fidia viticida in captivity during the summer of 1909 at North East, Pa.*—Cont'd.

Number of experiment	7.	8.	9.	10.	11.	12.
Date of emergence of beetles	July 3	July 9	July 10	July 10	July 11	July 12
Mated	July 14	July 12 to 15	July 14	July 14	July 22	July 28
First oviposition	July 16	July 22	July 19	July 22	July 27	Aug. 3
Eggs	14	25	19	23	22	35
Second oviposition	....	July 25	July 20	July 26	July 29	....
Eggs	....	51	35	48	15	....
Third oviposition	....	July 28	....	July 27	Aug. 3	....
Eggs	....	43	....	26	28	....
Fourth oviposition	....	July 30	....	Aug. 3	Aug. 5	....
Eggs	....	33	....	43	25	....
Fifth oviposition	....	Aug. 2	....	Aug. 6	Aug. 8	....
Eggs	....	28	....	24	11	....
Sixth oviposition	....	Aug. 5	....	....	Aug. 9	....
Eggs	....	21	....	....	11	....
Seventh oviposition	....	Aug. 7	....	....	....	....
Eggs	....	18	....	....	....	....
Eighth oviposition	....	Aug. 8	....	....	....	....
Eggs	....	15	....	....	....	....
Ninth oviposition	....	Aug. 13	....	....	....	....
Eggs	....	29	....	....	....	....
Death of male	Aug. 25	Aug. 10	July 23	Aug. 14	Sept. 9	Aug. 14
Death of female	Aug. 23	Aug. 23	July 24	Aug. 26	Aug. 22	Aug. 6
Days of feeding before oviposition	13.0	13.0	9.0	12.0	16.0	22.0
Times of oviposition	1.0	9.0	2.0	5.0	6.0	1.0
Eggs per cluster:						
Minimum	14.0	15.0	19.0	23.0	11.0	35.0
Average	14.0	29.2	27.0	32.8	18.6	35.0
Maximum	14.0	51.0	35.0	48.0	28.0	35.0
Total number of eggs	14.0	263.0	54.0	164.0	112.0	35.0
Length of life of male	53.0	32.0	13.0	35.0	60.0	33.0
Length of life of female	51.0	45.0	14.0	47.0	42.0	25.0

Number of experiment	13.	14.	15.	16.	Totals.	Average.
Date of emergence of beetles	July 12	July 27	July 27	July 30		
Mated	July 27	....	Aug. 6	....	....	....
First oviposition	July 28	Aug. 6	Aug. 7	Aug. 23	....	....
Eggs	25	57	20	35	416	26.0
Second oviposition	Aug. 1	Aug. 8	Aug. 8	Aug. 26	....	....
Eggs	22	43	22	20	362	27.8
Third oviposition	Aug. 3	Aug. 9	Aug. 13	Sept. 10	....	....
Eggs	35	25	4	29	280	25.5
Fourth oviposition	Aug. 5	Aug. 13	Aug. 18	Sept. 14	....	....
Eggs	19	8	39	23	294	26.7
Fifth oviposition	Aug. 7	Aug. 14	Aug. 23	....	....	....
Eggs	16	37	28	....	158	22.6
Sixth oviposition	Aug. 11	Aug. 17	....	....	....	....
Eggs	19	46	....	....	120	24.0
Seventh oviposition	Aug. 14	Aug. 19	....	....	....	....
Eggs	18	16	....	....	52	17.3
Eighth oviposition	Aug. 19	Aug. 20	....	....	....	....
Eggs	23	19	....	....	57	19.0
Ninth oviposition	Aug. 23	....	....	....	....	....
Eggs	23	....	....	....	52	15.7
Death of male	....	Aug. 28	Aug. 14	Sept. 22	....	....
Death of female	Aug. 25	Aug. 26	Aug. 27	Aug. 15	....	....
Days of feeding before oviposition	16.0	10.0	11.0	24.0	255	15.9
Times of oviposition	9.0	8.0	5.0	4.0	71	4.4
Eggs per cluster:						
Minimum	16.0	8.0	4.0	20.0	....	....
Average	22.2	31.4	22.6	26.7	383.3	24.0
Maximum	35.0	57.0	39.0	35.0	....	....
Total number of eggs	200.0	251.0	113.0	117.0	1,791	112.0
Length of life of male	....	32.0	18.0	54.0	553	39.1
Length of life of female	44.0	30.0	31.0	16.0	562	35.1

TABLE III.—*Summary of oviposition experiments, recorded in Table II, showing the final average, maximum, and minimum, of egg deposition by individual female beetles in captivity, at North East, Pa., 1909.*

Observations.	Average.	Maximum.	Minimum.
Number of days previous to first oviposition	15.9	24	9
Number of times of oviposition	4.4	9	1
Number of days between ovipositions	3.6	15	1
Number of eggs per cluster	24.0	61	4
Number of eggs per female	112.0	263	14

In Table V (p. 30), giving records of experiments with a large number of beetles in stock jars, where only the minimum length of time could be verified, this feeding period is shown to have covered from 9 to 10 days. Feeding is continued for almost the entire length of life of the beetle, and it has undoubtedly a direct bearing upon the number of eggs deposited.

MATING AND ITS BEARING UPON EGG DEPOSITION.

Mating of beetles has been observed a few days after their emergence. It has been found to take place several times before the first egg deposition, the day previous to oviposition, and also after each oviposition. Repeated mating, however, is not essential in bringing about further egg depositions, as shown in one instance under observation (Table II, jar No. 13). In this jar the male and the female beetles were confined together shortly after emerging. Mating took place July 27, 28, and 30. The male beetle escaped August 5, yet oviposition by the same female occurred on August 7, 11, 14, 19, and 23 without further mating.

PROCESS OF EGG DEPOSITION.

As the time of egg deposition approaches, the female beetles cease feeding for a day or two and become sluggish and somewhat inactive. They generally seek the shady places and are at this period to be found on the canes of the vines, where they are less easily detected.

The eggs are deposited almost entirely under the loose bark on the canes and trunk; very rarely, however, they are placed on other parts of the vine. The female inserts the eggs beneath the loose bark by means of the protrusible ovipositor (fig. 11, *e*) and places them side by side in a cluster of a single layer. An adhesive substance, secreted by the female, glues the eggs together, and the entire mass is fastened either to the cane or to the inner surface of the loose bark (Pl. I, figs. 3, 4). Individual female beetles have been observed to move along the canes in search of suitable places for egg deposition. In this process the hind end of the body touches the cane, and as the insect slowly passes along the ovipositor is inserted into the cracks or crevices, apparently testing the fitness of these places for egg deposition. A female beetle is shown in Plate I, figure 1, photographed in the act of oviposition.

VARIATION IN THE NUMBER OF EGGS PER CLUSTER.

Under average conditions the eggs for each oviposition are all laid in a single cluster. In this respect exceptions occur when the female is disturbed in the act of oviposition or when the space is too small to hold all the eggs. On the other hand, it has been frequently found that eggs have been laid side by side by different females, so that from the appearance of the cluster separate depositions could not be told apart. In the breeding experiments clusters containing from 30 to 35 eggs have been found quite frequently, and these figures represent, approximately, the average number of eggs per cluster. Table II gives the egg deposition of 16 female beetles. As here there had been interference to some extent, and the beetles had been confined in captivity, the average number of 24 eggs per cluster was comparatively low. The maximum number of eggs in one cluster was 61 and the minimum 4 (Table III). In the rearing cages the period for each separate oviposition occasionally extended over from 1 to 2 days, rarely 3 days; normally, however, the eggs were all laid at once and in a single cluster.

NUMBER OF SEPARATE OVIPOSITIONS BY INDIVIDUAL FEMALES.

Different female beetles have displayed considerable diversity in the number of times of oviposition. In the experimental work 8 individuals failed to deposit any eggs; others, as recorded in Table II, oviposited from 1 to 9 times, or, on an average, 4 or 5 times. Similarly, the length of time between each oviposition is variable. An average of 4 days elapsed between each oviposition. Often the interval has been only 1 day, while in the other extreme in one case the interval was 15 days. (See Table IV.)

TABLE IV.—*Number of days between ovipositions of the grape root-worm as observed during 1909 in breeding cages at North East, Pa. (Supplementary to Table II.)*

No. of experiment.	Periods between ovipositions.								Total.	Average per female.
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.		
1	3	1	2						6	2.0
2	5								5	5.0
3	1	11	2						14	4.7
4										
5	13	6	5						24	8.0
6	7	3	2	4	3				19	3.8
7										
8	3	3	2	3	3	2	1	5	22	2.7
9	4								4	4.0
10	4	1	7	3					15	3.7
11	2	5	2	3	1				13	2.6
12										
13	4	2	2	2	4	3	5	4	26	3.2
14	2	1	4	1	3	2	1		14	2.0
15	1	5	5	5					16	4.0
16	3	15	4						22	7.3
Total	52	53	37	21	14	7	7	9	200	53.0
Average	4.0	4.8	3.4	3.0	2.8	2.3	2.3	4.5		4.07

NUMBER OF EGGS DEPOSITED BY INDIVIDUAL FEMALE BEETLES.

The total number of eggs laid per female seems to depend upon the vitality of the individual insect, and undoubtedly also upon the amount of feeding by the adult. In the experiments of Table II the average was 112 eggs per female, with a maximum of 263 and a minimum of 14 eggs. In Table V is presented the results of the so-called "stock-jar" experiments, in which several beetles were confined.

TABLE V.—*Egg deposition of the grape root-worm by about 57 female beetles in eight stock jars, as observed in 1909 at North East, Pa.; with a summary of the length of life of the beetles for each stock jar.*

Stock jars.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	Total number of eggs.
Number of beetles.	25.	21.	5.	22.	16.	12.	7.	6.	
Date of the emergence.	July 9.	July 10.	July 11.	July 12.	July 13.	July 16.	July 19.	July 22.	
Date of oviposition:									
July 19	85								85
July 20		105							105
July 21		33	13						46
July 22	107	44	23	38	25				237
July 23	70	21							91
July 25	64				36				100
July 26	96		21	68	33				218
July 28	94	60	27		45				226
July 29	43	39	25		74	41	31		253
July 30	81			23					104
July 31	22		29		13		35	10	109
Aug. 1	121					39	3		163
Aug. 3				35	36		143	26	240
Aug. 4							26	16	42
Aug. 5	28			52	14			22	116
Aug. 6	60				28		70		158
Aug. 7	35				38	23	66	77	239
Aug. 8	33	10		152	29		36	22	282
Aug. 9					34				34
Aug. 11	17							38	55
Aug. 13					16	10	18	12	56
Aug. 14		16			22	37			75
Aug. 19				19			23		42
Aug. 23				21			21		42
Aug. 27								23	23
Total oviposition	956	328	138	408	443	150	472	246	3,141
Eggs per female	76.5	31.2	55.2	37.1	55.3	25.0	134.9	82.0	55.1

LENGTH OF LIFE OF BEETLES.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	
Maximum number of days	50	48	23	47	53	13	46	53	
Average number of days	21.6	20.3	12.0	15.9	23.5	5.0	28.7	20.2	
Minimum number of days	6	5	4	3	2	3	6	1	

The number of female beetles for each jar has been estimated to be at least half of the total number placed therein. The average number of eggs per female for each separate experiment varied considerably. In jar 7 there were approximately 135 eggs per female, in jar 6 only 25 eggs per female, or a final average for the eight jars of only 55 eggs per female. In considering the average egg deposition in the breeding cages there were found to be about 75 eggs per female.

THE OVIPOSITION PERIOD FOR THE SEASON OF 1909.

The oviposition period and the number of eggs deposited for the entire season is directly influenced by the time of emergence and occurrence of the beetles. In Table VI is given the total egg deposition of beetles in captivity.

TABLE VI.—*Records of the total egg deposition of the grape root-worm in breeding cages at North East, Pa., during 1909.*

Date.	Eggs.	Date.	Eggs.	Date.	Eggs.	Date.	Eggs.
July 8	29	July 26	360	Aug. 6	291	Aug. 18	39
July 13	83	July 27	62	Aug. 7	353	Aug. 19	81
July 15	104	July 28	333	Aug. 8	397	Aug. 20	19
July 16	153	July 29	379	Aug. 9	102	Aug. 23	163
July 18	43	July 30	137	Aug. 10	19	Aug. 26	20
July 19	155	July 31	123	Aug. 11	74	Aug. 27	23
July 20	149	Aug. 1	185	Aug. 12	29	Sept. 3	40
July 21	88	Aug. 2	28	Aug. 13	101	Sept. 10	29
July 22	427	Aug. 3	421	Aug. 14	152	Sept. 12	22
July 23	121	Aug. 4	71	Aug. 16	26	Sept. 14	23
July 25	225	Aug. 5	223	Aug. 17	46	Sept. 20	15
Total	1,577	Total	2,322	Total	1,590	Total	474

Total number of eggs: 5,963.

With the exception of a few early records, which were obtained from beetles collected in the field June 30, these records represent the total oviposition by the greater proportion of the beetles emerging in breeding cages (listed in Table I), and for their entire length of life. As the date of the emergence of these beetles was normal and simultaneous with the occurrence of beetles under natural conditions in the field, it is thought that this record of egg deposition may closely approximate oviposition in vineyards. In considering the relative number of eggs laid at different dates, it will be found (Table VI; fig. 15) that previous to July 22, 13.5 per cent were deposited; from July 22 to August 8, 71.4 per cent, and after August 8, 15.1 per cent. Previously it has been shown how the time of emergence of the beetle varied, as a result of the development of the insect under different conditions. Thus oviposition in the same sections of the grape belt must differ under similar variations. The extreme of such variations has been especially marked in vineyards located on the hill as compared with those in the valley. In Table XI is shown the time of hatching of eggs in the two named localities. On the hill the eggs were one week later in hatching, mainly as the result of later deposition.

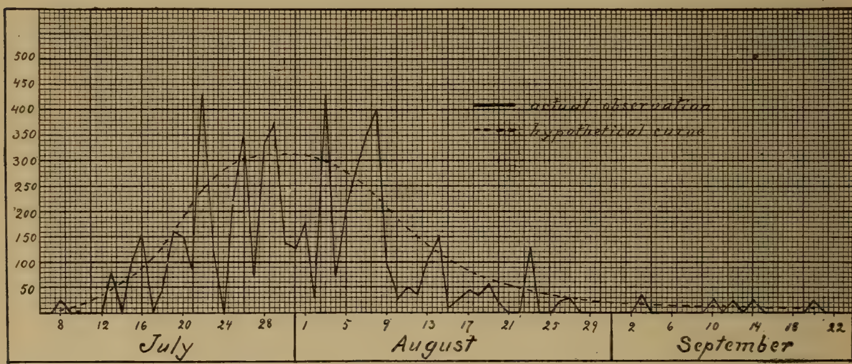


FIG. 15.—Curve showing time of egg deposition and relative abundance of eggs laid in rearing cages by beetles of the grape root-worm at North East, Pa., during 1909. (Original.)

LONGEVITY OF MALE AND FEMALE BEETLES.

On an average the beetles have lived in captivity one month. In Table VII will be found a full account of the length of life of individual male and female beetles.

TABLE VII.—*Length of life of individual male and female beetles of the grape root-worm as recorded in breeding cages at North East, Pa., during 1909.*

No.	Sex.	Date.		Days.		No.	Sex.	Date.		Days.	
		Emergence.	Died.	Male.	Female.			Emergence.	Died.	Male.	Female.
1	♂	June 30	Aug. 4	35	......	24	♀	July 10	Aug. 11	......	32
2	♀	...do....	July 22	......	22	25	♂	...do....	Aug. 6	27	......
3	♂	...do....	July 26	26	......	26	♀	...do....	Aug. 4	......	25
4	♀	...do....	July 27	......	27	27	♂	...do....	Aug. 14	35	......
5	♂	...do....	July 22	22	......	28	♀	...do....	Aug. 26	......	47
6	♀	...do....	July 21	......	21	29	♂	...do....	Aug. 23	44	......
7	♂	...do....	Aug. 19	50	......	30	♀	...do....	Aug. 24	......	45
8	♀	...do....	Aug. 3	......	34	31	♂	July 11	Aug. 22	42	......
9	♂	...do....	Aug. 8	39	......	32	♀	...do....	Sept. 9	......	60
10	♀	...do....	Aug. 1	......	32	33	♂	July 12	Aug. 9	28	......
11	♂	...do....	Aug. 26	57	......	34	♀	...do....	...do....	......	28
12	♀	...do....	Aug. 2	......	33	35	♂	...do....	Aug. 5	24	......
13	♂	...do....	July 22	22	......	36	♀	...do....	Aug. 25	......	44
14	♀	...do....	July 23	......	23	37	♂	...do....	Aug. 6	25	......
15	♂	July 2	Aug. 25	54	......	38	♀	...do....	Aug. 26	......	45
16	♀	...do....	Aug. 9	......	38	39	♂	June 15	Aug. 25	41	......
17	♂	...do....	Escaped.	......	......	40	♀	...do....	...do....	......	41
18	♀	...do....	Aug. 31	......	60	41	♂	July 27	July 28	1	......
19	♂	July 3	July 23	20	......	42	♀	...do....	Aug. 26	......	30
20	♀	...do....	July 24	......	21	43	♂	...do....	Aug. 14	18	......
21	♂	July 9	Aug. 10	32	......	44	♀	...do....	Aug. 27	......	31
22	♀	...do....	Aug. 23	......	45	45	♂	July 30	Aug. 15	16	......
23	♂	July 10	Aug. 27	48	......	46	♀	...do....	Sept. 22	......	54

The summary of these records (Table VIII) shows that the female beetles on an average, not individually, survived the males by 4 days.

TABLE VIII.—*Summary of the length of life of individual male and female beetles of Table VII.*

Sex.	Average.	Maximum.	Minimum.
	Days.	*Days.*	*Days.*
Male	32.1	54	1
Female	36.4	60	21

The maximum length of life for the males was 54 days, while that for the females was 60 days. In Table V is given further a summary of the length of life of the beetles in the stock jars, where no separate record has been made as to life of male and female individuals.

THE EGG.

INCUBATION PERIOD OF THE EGG.

The time necessary for the hatching of the eggs depends largely upon the prevailing temperature and probably also upon moisture conditions. Experiments to test the effective limits of these influences have not been made, but the results of these factors have been in a general way well marked as is evident from the difference in the time of hatching of individual egg clusters throughout the season (see Table IX). In different sections of vineyards the hatching probably varies slightly, since some eggs are located in well shaded places, while others are so situated as to receive more heat from the sunlight. In the middle of the hatching period eggs which were kept in an open outdoor shelter hatched, on an average, in 12 days. The rate for hatching for the entire egg period is shown in Table IX.

TABLE IX.—*Incubation period of eggs of the grape root-worm as observed in 1909 at North East, Pa.*

No. of observation.	Date. Laid.	Date. Hatched.	Days.	No. of observation.	Date. Laid.	Date. Hatched.	Days.
1	July 15	July 29	14	49	Aug. 7	Aug. 23	16
2	...do....	July 30	15	50	Aug. 8	Aug. 20	12
3	July 16	...do....	14	51	...do....	Aug. 21	13
4	July 18	July 31	13	52	...do....	Aug. 22	14
5	...do....	Aug. 1	14	53	...do....	Aug. 23	15
6	July 19	...do....	13	54	...do....	Aug. 24	16
7	July 20	...do....	12	55	Aug. 9	...do....	15
8	...do....	Aug. 2	13	56	...do....	Aug. 25	16
9	July 21	...do....	12	57	Aug. 10	...do....	15
10	...do....	Aug. 3	13	58	...do.....	Aug. 26	16
11	July 22	Aug. 2	11	59	...do....	Aug. 27	17
12	...do....	Aug. 3	12	60	Aug. 14	Aug. 26	12
13	July 23	Aug. 4	12	61	...do....	Aug. 27	13
14	July 25	Aug. 6	12	62	...do....	Aug. 28	14
15	July 26	...do....	11	63	...do....	Aug. 29	15
16	...do....	Aug. 7	12	64	...do....	Aug. 31	17
17	July 27	...do....	11	65	Aug. 16	...do	15
18	July 28	Aug. 8	11	66	...do	Sept. 1	16
19	July 29	...do....	10	67	Aug. 17	...do....	15
20	...do....	Aug. 9	11	68	...do....	Sept. 2	16
21	...do....	Aug. 10	12	69	...do....	Sept. 4	18
22	July 30	Aug. 9	10	70	...do....	Sept. 5	19
23	...do....	Aug. 10	11	71	Aug. 18	Sept. 4	17
24	...do....	Aug. 11	12	72	...do....	Sept. 5	18
25	...do....	Aug. 12	13	73	...do....	Sept. 6	19
26	July 31	Aug. 11	11	74	...do....	Sept. 7	20
27	...do....	Aug. 12	12	75	...do....	Sept. 10	23
28	Aug. 1	...do....	11	76	Aug. 19	Sept. 3	25
29	...do....	Aug. 13	12	77	...do....	Sept. 4	16
30	Aug. 2	...do....	11	78	...do....	Sept. 6	18
31	Aug. 3	...do....	10	79	...do....	Sept. 7	19
32	...do....	Aug. 14	11	80	...do....	Sept. 8	20
33	...do....	Aug. 15	12	81	...do....	Sept. 9	21
34	...do....	Aug. 16	13	82	...do	Sept. 10	22
35	Aug. 4	Aug. 17	13	83	...do	Sept. 11	23
36	Aug. 5	Aug. 16	11	84	...do....	Sept. 12	24
37	...do....	Aug. 17	12	85	Aug. 20	Sept. 6	17
38	...do....	Aug. 18	13	86	...do....	Sept. 7	18
39	...do....	Aug. 19	14	87	...do....	Sept. 8	19
40	Aug. 6	Aug. 18	12	88	...do....	Sept. 9	20
41	...do....	Aug. 19	13	89	Aug. 26	Sept. 18	23
42	...do....	Aug. 20	14	90	...do....	Sept. 19	24
43	...do....	Aug. 21	15	91	Sept. 3	Sterile.	....
44	Aug. 7	Aug. 18	11	92	Sept. 10	Sterile.	....
45	...do....	Aug. 19	12	93	Sept. 12	Sterile.	....
46	...do....	Aug. 20	13	94	Sept. 13	Sterile.	....
47	...do....	Aug. 21	14	95	Sept. 14	Sterile.	....
48	...do....	Aug. 22	15	96	Sept. 20	Sterile.	....

TABLE X.—*Summary of Table IX; time of incubation of grape root-worm eggs for 1909.*

Incubation.	Average.	Maximum.	Minimum.
	Days.	*Days.*	*Days.*
For the entire egg period	14.67	24	10
For the maximum egg period, July 22–Aug. 8, inclusive	12.3	16	10

Eggs laid at approximately the same date by the same female varied in the time of hatching to the extent of several days. The embryological development becomes particularly prolonged later in the season with the advent of colder weather. All the eggs laid during the month of September failed to hatch.

The rate of hatching of eggs in the field has been recorded in Table XI.

TABLE XI.—*Field observations on the hatching of eggs of the grape root-worm in the valley and on the hill in the vicinity of North East, Pa., 1909.*

In the valley.			On the hill.		
Date.	Number of clusters counted.	Percentage of clusters hatched.	Date.	Number of clusters counted.	Percentage of clusters hatched.
July 30	41	39	July 30	48	10
Aug. 4	70	42	Aug. 13	56	40
Aug. 12	67	70	Aug. 19	76	60
Aug. 19	90	91	Aug. 26	66	77
Aug. 26	103	97	Sept. 2	97	81
Sept. 2	78	100	Sept. 9	98	92
			Sept. 16	87	100

THE LARVA.

VITALITY OF THE NEWLY HATCHED LARVA.

On hatching, the minute larva drops to the ground and makes its way to the roots of the vine through cracks and crevices in the soil and by burrowing. In this struggle to reach the food supply there is probably always a high percentage that perishes, for the number of eggs deposited is much larger than the number of larvæ found later in the ground.

The power of the young larva to exist for a time without food, however, is remarkable. In the breeding of the insect a number of newly hatched larvæ, confined in a glass tube, were kept alive for 8 days without food or moisture. Interesting experiments showing the burrowing and traveling powers of the young grub were carried out by Dr. E. P. Felt in 1902. This gentleman found that one larva had traveled a distance of over 47 feet in 7 hours, or an average of 6 feet an hour. In another experiment he found that 14 young larvæ out of 40 penetrated through loose earth in a glass tube 17 inches long in a period of 4 days. This tube was one-half inch in diameter and bent so that 4 inches were vertical. In our breeding cages young larvæ were found to feed upon the humus of the soil before reaching the root fibers; therefore it is not surprising that many larvæ do penetrate to the roots, even under unfavorable conditions, and that they are found in vineyards in compact clay soil.

FEEDING AND DEVELOPMENT OF THE LARVA BEFORE WINTERING.

During the summer and until late fall the larvæ feed extensively, and on an average attain three-fourths the full size and frequently full growth before wintering.

The young larva feeds mainly upon the finer roots and root fibers of the grapevine. Later it attacks the larger roots, devouring the bark in longitudinal furrows, as shown in Plate III. Sometimes the feeding may even extend to the underground portion of the stem. Most of the larvæ are found within a distance of from 2 to 3 feet of the crown of the vine, and at a depth varying with the root system of the vines and the character of the soil.

The rate of growth of the larva varies under different conditions. The time of hatching, the abundance of food, and the ease with which food can be obtained are determining factors. As a rule the larvæ are found more abundantly in loose, porous soils, and especially on exposed ridges in the vineyards. (Table XII; fig. 14.)

TABLE XII.—*Occurrence of larvæ of the grape root-worm in different soils. Summary of field diggings for 1907, 1908, and 1909, at North East, Pa.*

Year.	Date of digging.	Total number of larvæ.	Number of vines examined.	Soil.	Number of larvæ per vine.
1907	May 13–June 8	831	66	Gravel	12
	May 31	1	7	Clay	0.1
1908	May 18–June 9	96	14	Gravel	6
	June 12	3	3	Clay	1
1909	May 24–June 25	539	88	Silt [a]	6
	May 19–June 25	439	83	Gravel	5
	May 27–July 10	102	37	Loam	3
	June 1–July 10	20	54	Clay	0.4

[a] Very light porous soil.

From rearing and field observations we have found that the larvæ are less abundant and slightly retarded in their development in clay soils. This is natural in that the larvæ can not move about to obtain food in this soil so readily as in soils of looser texture.

The growth of some larvæ is sometimes delayed to such an extent as to hinder them from transforming at the normal period in the spring. Hence these belated larvæ remain an additional year in the ground and transform in the spring of the second year. The causes of delay in the development and the percentage of belated larvæ have been described in detail on pages 41–44.

WINTERING OF THE LARVA IN AN EARTHEN CELL.

As the time for hibernation approaches the grubs penetrate deeper into the ground, generally slightly below the roots of the vines. An earthen cell is made in which the larva spends the winter. It was observed in the field in the fall of 1909 that the 2-year-old larvæ, referred to above, were the first to hibernate. Some of these were already in the wintering cells by the middle of August, when most of the larvæ of the new brood were still extremely small or had not yet hatched. In Table XIII is shown the relative occurrence of larvæ in wintering cells in the different vineyards. The actual percentage is higher than given, because in the process of digging many cells were broken, and thus escaped being noticed.

TABLE XIII.—*Percentage of hibernating larvæ of the grape root-worm as found in vineyards during the fall of 1909 at North East, Pa.*

Curtis vineyard, in the valley.		Algren vineyard, in the valley.		Young vineyard, on the hill.	
Date of digging.	Percentage of larvæ in cells.	Date of digging.	Percentage of larvæ in cells.	Date of digging.	Percentage of larvæ in cells.
Oct. 5....	5	Oct. 4....	0	Oct. 12...	0
Oct. 12...	20	Oct. 14...	0	Oct. 20...	3
Oct. 19...	12	Oct. 19...	14	Oct. 28...	16
Oct. 28...	83	Oct. 25...	36	Nov. 12..	33

SPRING FEEDING OF THE LARVA.

In the spring, with normally developed larvæ, comparatively little feeding takes place. In the early part of May, 1909, the larvæ in the rearing cages were still in their wintering cells, and the condition in the field in most places did not permit the larvæ to become active previous to that time. Since occasional pupal cells were found on May 24 in the field (Table XIV) and continued to appear in rapidly increasing numbers, the time of spring feeding may, on an average, have lasted 20 to 25 days.

TABLE XIV.—*Appearance of larvæ of the grape root-worm in cells previous to pupation at North East, Pa., 1909.*

Date of digging.	Soil condition.	Total number of larvæ.	Number of larvæ in cells.	Percentage of larvæ in cells.
May 19...	Gravel.....	230	....	....
May 24...	Sandy.....	35	3	8.6
May 25...	.....do.....	140	37	2.8
Do....	Loam......	33	7	21.2
May 26...	Gravel.....	32	2	6.2
May 27...	Clay.......	47	4	8.5
May 29...	Silt........	79	23	29.1
June 1...	Clay.......	6	....	....
June 2...	Gravel.....	7	2	2.8
June 3...	Silt........	63	25	39.0
June 4...	Gravel.....	54	10	18.5

TIME AND MAKING OF THE PUPAL CELL.

The pupal cells are found from 2 to 3 inches below the surface of the ground. Like the wintering cells, they are made by a peculiar rolling and twisting motion of the larva, whereby the cavity is enlarged, the earth becomes packed together, and the inside smoothly finished. The cell is quite spacious and would readily accommodate a larva twice the size of the owner. Usually 15 days are required to complete the pupal cell. As recorded in Table XVI, the average length of time spent by the larvæ in the cell is 21 days, which includes the post-larval stage described below. Should the cell be disturbed or destroyed some time before the post-larval period, a new one is readily made, and, as a rule, within a shorter time than was required for the making of the first cell. As recorded in Table XV, individual No. 21, a larva made the second cell and pupated within 9 days.

TABLE XV.—*Observations on the transformations and habits of the pupa and the beetle of the grape root-worm in the soil, from breeding experiments at North East, Pa., 1909.*

Number of individual.	Date.				Days.		
	Making of cell.	Pupation.	Transformed to beetle.	Left the cell.	Making cell.	Pupal stage.	Beetle in cell.
1	May —	June 17	June 30	July 6		13	6
2	May —	...do...	July 1	(Died)		14	
3	May —	...do...	July 2	...do...		15	
4	May —	June 15	June 30	July 5		15	5
5	May —	June 20	July 7			17	
6	May —	June 19	July 9			20	
7	May —	June 21	July 10	July 14		19	4
8	May 30	...do...	...do...	...do...	22	19	4
9	...do...	June 20	July 2	(Died)	21	12	
10	May —	June 21	July 9	July 13		18	4
11	May 30	June 24	...do...	July 14	25	15	5
12	May —	June 20	...do...	July 13		19	4
13	May —	June 21	July 10	...do...		19	3
14	May —	...do...	...do...	July 14		19	4
15	May —	...do...	July 9	July 13		18	4
16	May 30	June 20	...do...	July 16	21	19	7
17	...do...	June 18	July 7	July 13	19	19	6
18	...do...	June 21	July 10	...do...	22	19	3
19	...do...	...do...	July 9	...do...	22	18	4
20	June 7	...do...	...do...		14	18	
21	...do...	...do...	July 6	July 13	9	20	7
22	May 30	June 16	July 12	July 16	25	18	4
23	June 7	June 24	July 11		14	20	
24	June 8	June 21	July 13	July 16	14	21	3
25	May 26	June 22	...do...	(Died)	31	17	
26	...do...	June 26	July 11	July 14	28	18	3
27	...do...	June 23	...do...	...do...	28	18	3
28	...do...	...do...	...do...	...do...	28	18	3
29		June 25	July 12	...do...		17	2
30	May 30	...do...	July 14	July 18	26	19	4
31	...do...	June 2	July 23		33	21	
32	...do...	June 22	July 10		23	18	
33	...do...	June 23	July 12		24	19	
34	June 4	June 25	July 11	July 17	21	16	6
35		June 26	July 14			18	
36		June 25	July 15	July 17		20	2
37		June 29	July 17			18	
38		June 21	July 8			17	
39	May 31	June 10			10		
40	June 5	June 23	July 11	July 15	18	18	4
41	June 8	...do...			15		
Total					513	696	104

TABLE XVI.—*The making of the pupal cell, the pupal period, the beetle in the cell; summary of Table XV.*

	Average.	Maximum.	Minimum.
	Days.	*Days.*	*Days.*
The making of the pupal cell	21.4	33	9
Pupal stage	17.8	21	12
Beetle in cell	4.1	7	2

THE POST-LARVAL STAGE.

During the post-larval stage the grub undergoes marked structural changes and is in this condition extremely delicate and helpless. The body is slightly shortened, and the curved grublike appearance is modified to a more cylindrical form. To some extent the legs become shorter and remain practically motionless. The white color changes to a light pinkish tint, which is especially marked toward the extremities. Should the cell be destroyed during this period the larva is incapable of making a new one, and in many instances, as has frequently been observed in the breeding experiment, the larva fails to pupate.

THE PUPA.

THE PROCESS OF PUPATION.

Pupation is the result of the changes brought about during the post-larval stage. In the process of pupation the larval skin splits on the back of the thorax and on the head, and the skin is ruptured along the median line and in front along the V-shaped suture toward the mouth (fig. 8, *b*). As the pupa frees itself from the larval skin it is of a rather elongated form. The appendages are short, and the skin on these parts is wrinkled in a circular manner. The light pink color is particularly marked on portions around the spines, head, prothorax, the points of the legs, and on the hind end of the body. The pupa is at this stage very restless, turning the abdomen in a circular motion, which, together with a contracting motion, brings about the expansion of the appendages and the assuming of the normal shape of the pupæ. Unlike many pupæ of beetles of this group, the larval skin is completely freed from the pupa. Within a short time the pupa becomes whiter in color and the prominent spines turn darker as they harden.

POSITION OF THE PUPA IN THE CELL.

Within the cell the pupa is continually moving, often changing its position and constantly turning the abdomen in a circular manner. Normally the pupa lies on its back, and the soft body of the tender creature is kept from close contact with the moist walls of the cell by the spines on the appendages and on the back of the body (fig. 9). This function of the spines is undoubtedly of great importance in the development of the pupa, since this is the critical period of the insect, when the organs and in fact all the parts of the insect are reconstructed in the formation of the adult or beetle. The pupa is completely helpless when removed from the cell and is incapable of making a new one, and if left on the surface of the ground or covered up with earth it almost invariably perishes.

TIME OF PUPATION IN THE FIELD AND IN BREEDING CAGES.

In the field during the summer of 1909 the first pupæ were found June 11, while in the breeding cages the first pupa was found June 15. The time of pupation is indicated in Table XVII, showing the relative occurrence of the pupæ in the field.

TABLE XVII.—*Time of transformation of larvæ and pupæ of the grape root-worm in the field, as observed in the vicinity of North East, Pa., 1909.*

Vineyard.	Date examined.	Number of vines examined.	Number of larvæ.	Number of pupæ.	Number of beetles in cells.
J. D. Curtis's vineyard, porous silt.	June 12	....	286	32	....
	June 21	7	6	47	....
	June 25	6	2	54	2
	June 30	6	2	4	24
	July 6	6	....	....	4
	July 10	6	....	....	....
G. E. Pierce's vineyard, gravel soil.	June 11	....	101	49	....
	June 21	6	5	13	....
	June 25	6	5	12	....
	June 30	6	....	....	3
	July 6	7	....	....	2
	July 10	6	....	....	....
Vineyard, loamy soil.	June 23	6	3	24	....
	June 25	6	1	5	....
	June 30	6	1	17	2
	July 7	6	1	2	2
	July 10	6	....	1	1
	July 17	6	....	....	....
Whitman's vineyard, clay soil.	June 23	6	1	6	....
	June 25	6	1	5	....
	June 30	6	1	2	....
	July 7	6	1	....	1
	July 10	6	....	1	....
	July 17	6	....	....	1
	July 26	6	....	....	....

It is possible to establish the time of pupation by knowing the time of emergence of the beetle and the length of time of the pupal stage. Judging by the late emergence of the beetles, August 9, and by the finding of beetles in cells in the field August 14, pupæ must have occurred up to the end of July. Based upon these records the curve of figure 23 has been constructed.

DURATION OF THE PUPAL PERIOD.

The pupal stage on an average lasts 17 days (see Tables XV and XVI). The maximum length of time observed was 21 days and the minimum 12 days.

LIFE CYCLE OF THE GRAPE ROOT-WORM AS DETERMINED BY REARING.

Several attempts were made to rear this insect from eggs, and to carry it through the different stages to complete the life cycle. In the course of these experiments many failures occurred. The mortality in certain experiments was high; in other instances a large percentage became materially delayed in development and the larvæ wintered a second season, and only a small number completed the life cycle within one year. (See Table XX.) The records from these latter observations are given in Table XVIII, with dates of hatching in 1908 and the dates of reaching maturity the following year.

TABLE XVIII.—*Complete life cycle of 19 grape root-worms at North East, Pa., reared from eggs laid during 1908; adults emerged in 1909.*

Number of individuals.	Date of Hatching of eggs, 1908.	Date of Emergence of beetles, 1909.	Number of days for the life cycle.
1	July 16	July 9	358
1	...do.....	July 10	359
1	...do....	July 13	362
1	...do....	July 15	364
1	...do....	July 17	366
4	July 20	July 7	352
1	...do....	July 8	353
4	...do....	July 10	355
2	...do....	July 11	356
1	...do....	July 30	375
1	July 25	July 26	366
1	...do....	July 27	367
19	....	....	6,810

SUMMARY.

	Days.
Average........................	358.4
Maximum........................	375
Minimum........................	352

SEASONAL VARIATIONS IN THE LIFE HISTORY OF THE GRAPE ROOT-WORM.

In comparing the records for the time of emergence of the beetle for the three consecutive years of 1907, 1908, and 1909 a marked difference in the date of emergence will be found (fig. 16). This variation is partly due to the relative lateness of the spring and partly to the climatic conditions prevailing during the entire development of the insect in the ground.

The climatic conditions for the years 1906 to 1909, inclusive, have been strikingly varied and, as will be seen, the life of the insect for these years has been affected accordingly. The mean temperature for 1906 was 1 degree above normal and the precipitation averaged about 1 inch below normal, August and September being particularly dry and hot. Frost occurred June 11 and 12 and snow on October 10, 11, and 12. The year 1907 was marked with an abnormally low temperature, a late spring, and an early fall, with a rather high precipitation for the summer months. The month of May was the coldest on record during a period of eighteen years. In 1908, on the contrary, the mean temperature was above normal and the summer was marked by two periods of severe drought, the dry conditions being especially felt during the end of August. In most respects 1909 (fig. 17) was nearer the average.

Although 1906 was a favorable season, during which the larvæ attained a normal growth, yet owing to the late and cold spring of 1907 the emergence of the insect was very materially delayed and limited to a very short period (see fig. 16). The first beetle in the field was observed July 11. In the spring of 1908, on collecting larvæ in different vineyards two distinct sizes were found, as possibly due to climatic conditions of previous seasons. The larger larvæ were full grown, while the smaller varied from one-third to three-fourths grown. In the rearing cages the full grown larvæ transformed normally and without further feeding. Of the smaller larvæ few matured at the normal time, many were quite belated, while quite a number wintered, thus spending two years as larvæ in the ground. As a result of the early season of 1908 the beetles commenced to emerge by June 16. The emergence extended over a long period;

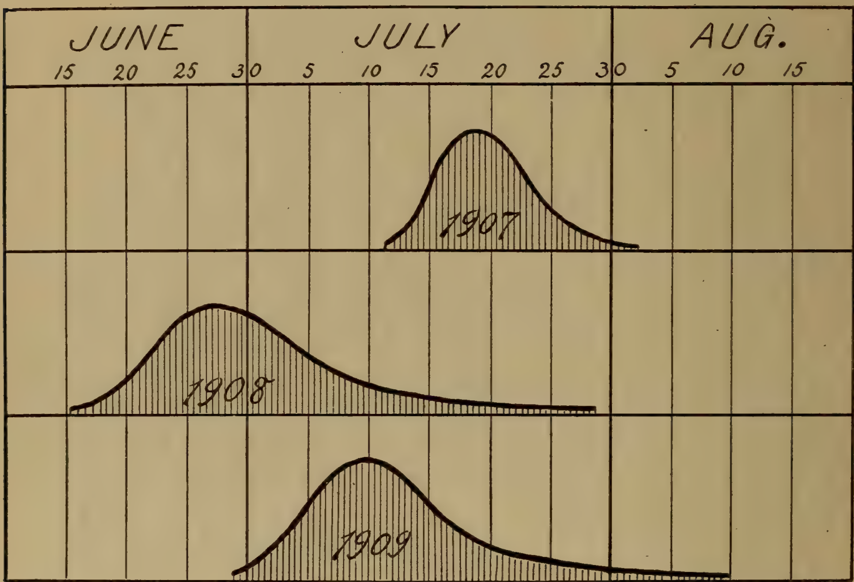


FIG. 16.—Diagram showing variation in time of emergence of beetles of the grape root-worm during 1907, 1908, and 1909 at North East, Pa. (Original.)

the latest beetles to emerge appeared in the rearing cages July 28. This longer emergence period was partly due to the delay in the development of larvæ that hatched in 1907. In the spring of 1909 the larvæ were again of a more uniform size as a result of the long season of 1908, and the emergence in 1909, as recorded in figure 16, was about normal. On examining larvæ in the field in the early fall of 1909 data were obtained as to the prevailing number of 1-year and 2-year old larvæ (Table XIX). At the dates of these observations only a few of the new-brood larvæ had attained one-half their growth while many of the eggs had not yet hatched, and since the 1908 brood larvæ were full grown the two broods could then be readily told apart.

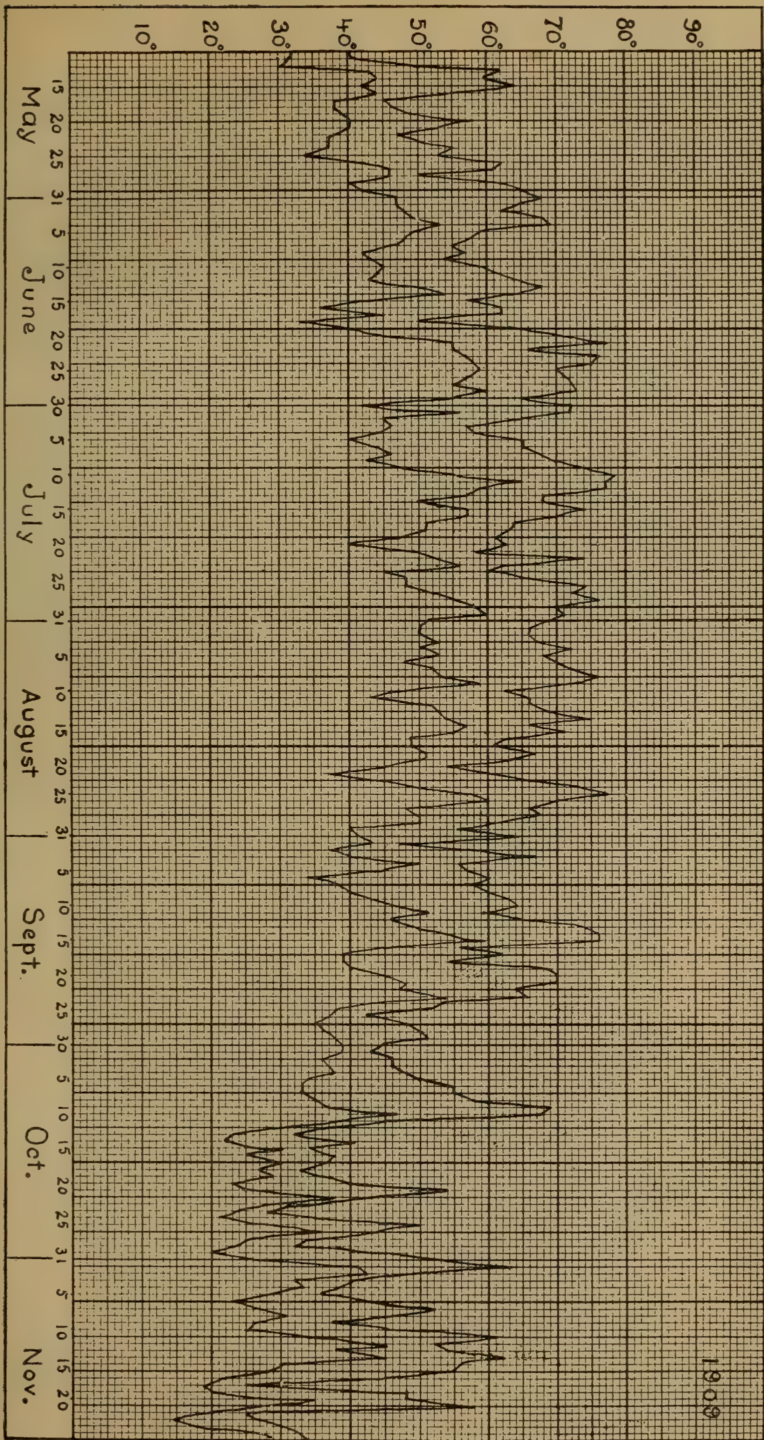


Fig. 17.—Temperature curves showing the daily records of the maximum and minimum temperature during the breeding period of 1909 at North East, Pa. (Original.)

TABLE XIX.—*Percentage of 2-year-old larvæ of the grape root-worm as recorded in vineyards in the vicinity of North East, Pa., in the fall of 1909.*

Vineyard in silt soil in the valley.				Vineyard on loamy soil in the valley.				Vineyard on gravelly loam on the hill.			
Date of digging.	Number of vines examined.	Total number of larvæ.	Percentage of old larvæ.	Date of digging.	Number of vines examined.	Total number of larvæ.	Percentage of old larvæ.	Date of digging.	Number of vines examined.	Total number of larvæ.	Percentage of old larvæ.
Aug. 17 to Oct. 12	32	328	3.0	Aug. 16 to Sept. 20	18	449	0.66	Sept. 2 to Oct. 7	11	517	5.0

The percentages of twice-wintering larvæ in Table XIX represent only records of early observations when a number of larvæ had not yet been hatched. It is of interest to note that the percentage of 2-year-old larvæ was largest in vineyards located on the hill, owing to the prevailing shorter season on the hill as compared with the season in the valley. The time of transformation of the insects in other stages has similarly been affected by the climatic conditions of the past three years.

In Table XX is shown the relative number of maturing insects and twice-wintering larvæ which were reared from eggs deposited at known dates in 1908.

TABLE XX.—*The relative occurrence of transforming and twice-wintering larvæ of the grape root-worm reared from eggs laid in cages in 1908, at North East, Pa.*

Date of hatching 1908.	Number of beetles emerging, 1909.	Number of larvæ wintering, 1909.
July 16	5	12
July 20	12	0
July 25	2	0
July 28	0	3
Total	19	15

In the rearing experiments other factors beside climatic conditions have influenced the results and no direct conclusion should be drawn from these observations beyond the point of establishing the fact that under unfavorable conditions individual insects of this species do remain two years in the ground before maturing.

REARING AND EXPERIMENTAL METHODS.

The underground habits of the larvæ of the grape root-worm have made the rearing of this insect comparatively difficult, and certain obstacles have been overcome only by persistent and continued experimenting. The rearing work in most cases has been planned

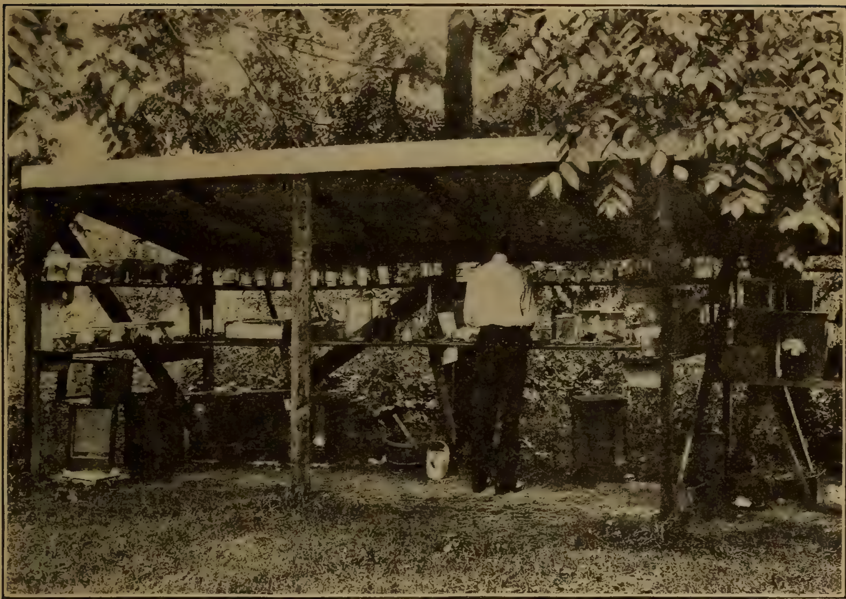


FIG. 18.—Portion of the outdoor rearing shelter used in the rearing of insects at North East, Pa., during 1909. (Original.)

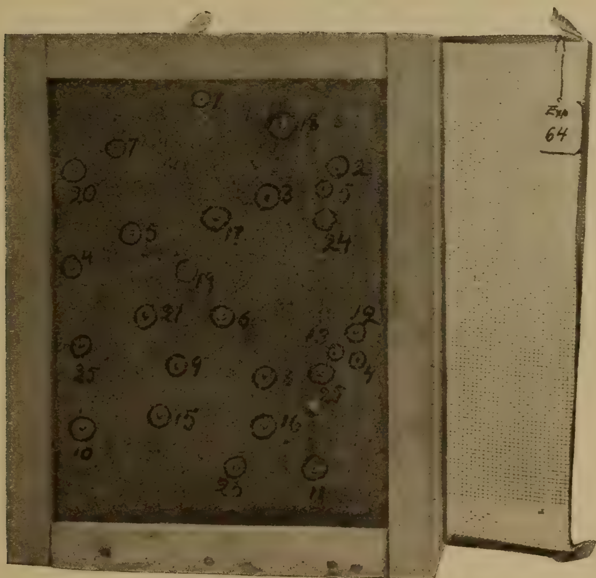


FIG. 19.—Wooden-frame box with glass bottom and wire-screen cover used in studying the pupal stage of the grape root-worm beetle. (Original.)

on a large scale, so that variations would be minimized and the final averages would represent approximately normal conditions. The numerous separate experiments have involved the handling of a large bulk of rearing material, which, together with the simulation of normal conditions, has to some extent necessitated special rearing devices and methods of handling. The experiments have been con-

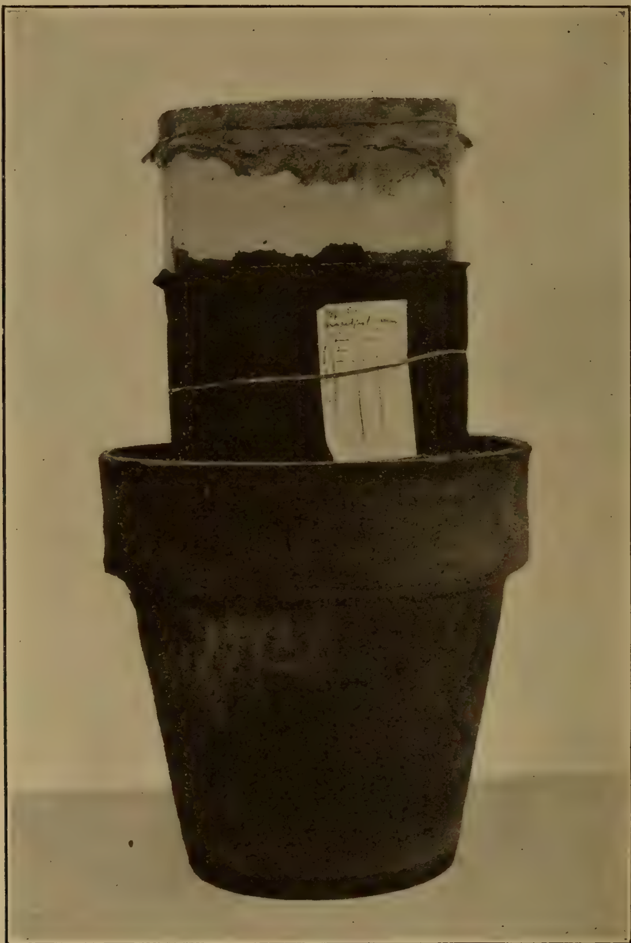


FIG. 20.—Earthen pot with glass cylinder used in rearing the grape root-worm. (Original.)

ducted either in the field or under an open breeding shelter, a portion of which is shown in figure 18. This consisted of a temporary structure of light wooden framework covered with waterproof canvas.

Most of the rearing material was obtained in the spring, some time previous to the transformation of the larvæ. During the past two years of the investigation the insects were to some extent reared from eggs laid in the cages, and these larvæ, together with larvæ of the previous year, were carried through the winter in rearing cages.

The pupal records have been obtained from experiments in medium-sized wooden boxes, having glass bottom, 9 inches long, 8 inches wide, and 5 inches high (fig. 19). Each box contained 2 to 3 inches of earth, and in order to duplicate outside weather conditions as nearly as possible the soil in these boxes was permitted to become almost dry during dry periods and during rainy periods water was proportionately added. To exclude the light from below, the boxes were placed upon burlap. Previous to the emergence of the beetles a wire screen cover was placed over each box. The shallow layer of soil caused many larvæ to penetrate to the bottom of the cages, where they appeared next to the glass; and as the pupal cells, made of earth packed together, were next to the glass the activity of the insect inside could be readily observed. By means of a glass and porcelain blue pencil a number was fixed next to each cell, and by using this number a detailed record could be kept from the time the cell was made to the time the adult emerged. In the study of the underground habits of the insect the device shown in figure 20 proved to be useful. The glass cylinder in the earthen pot was about half filled with soil, and to exclude the light the lower portion of the cylinder was wrapped with black paper. Several cells were made next to the glass, and on emerging the beetles were observed in the process of making their exit through the soil.

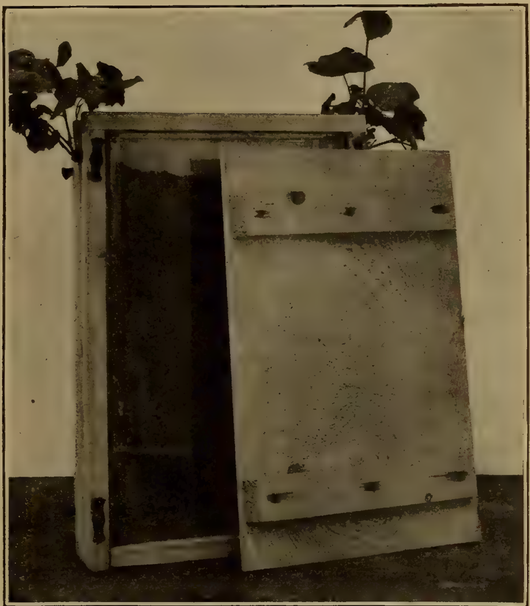


FIG. 21.—Rearing cage with glass sides used in the study of the larva of the grape root-worm beetle. (Original.)

Cages similar to the one shown in figure 21 were convenient for the study of the habits of the larva, and they were particularly useful in experiments extending over periods of one and two years. In width these cages varied from 1 to $2\frac{1}{2}$ inches, and were of a uniform height of 20 inches. The two larger sides consisted of plate glass with outer wooden shutters on either side which could be removed for the examination of the contents.

The emergence records of Table I, as shown by curve in figure 13, are the results of about 15 separate experiments with larvæ transforming in large earthen pots filled with soil. Since the time of emergence of the beetles and their relative occurrence has a direct bearing upon the time of application of poison sprays against this pest, special attention and care were exercised in preparing these experiments. In the early spring approximately 1,000 larvæ were collected in different vineyards in the vicinity of North East, Pa. In many instances soil from different localities, which varied from loose sandy soils to heavy clay, was transferred with the larvæ to the rearing pots (fig. 22). Provision for the spring feeding of the larvæ was made by planting young grapevines in the pots. Finally the pots were placed in the ground in the open field and were left undisturbed for the rest of the season. Before the beetles commenced to appear wire screen covers were placed over each pot, so that a complete daily record could be kept of the number of beetles emerging from each separate pot.

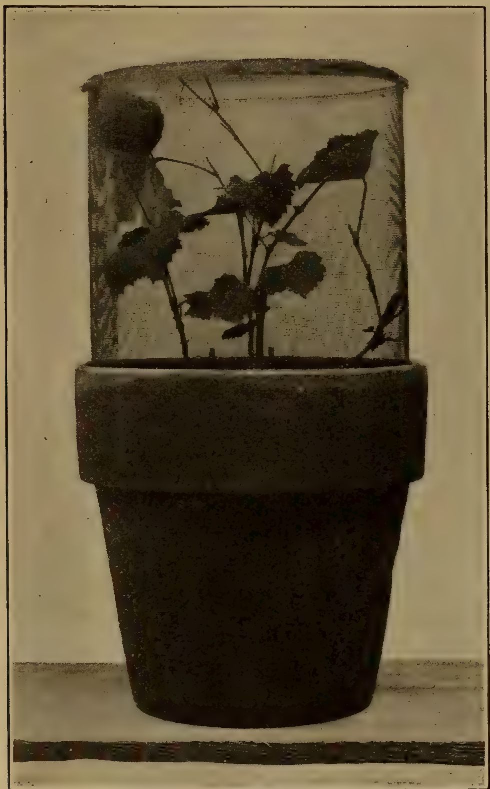


FIG. 22.—Earthen pot with wire-screen cover used in rearing the grape root-worm. (Original.)

By preserving the beetles from the above-mentioned experiments, rearing material of known source and age was obtained for further experiments. The daily catch of beetles throughout the emergence period was transferred to so-called "stock jars," from which insects were taken as needed for miscellaneous experiments. The "stock jars" shown in the rearing shelter (fig. 18) consisted of large-sized glass jars covered with thin cloth. A layer of moist sand was placed in each jar, which made it easier for the insects to move about and made the conditions more natural. Grape foliage, constituting the food of the beetles, was supplied daily, and to prevent unhealthy conditions in the cages the old leaves were always removed. For oviposition short pieces of grapevine cane were placed with the beetles, and as egg depositions progressed these canes were removed daily and replaced by fresh ones. In determining the number of eggs deposited, the loose bark had to be peeled off the pieces of cane and the eggs in each cluster carefully counted. In determining the egg deposition of individual females and the length of life of male and female beetles, pairs when found in copulation in the stock jars were

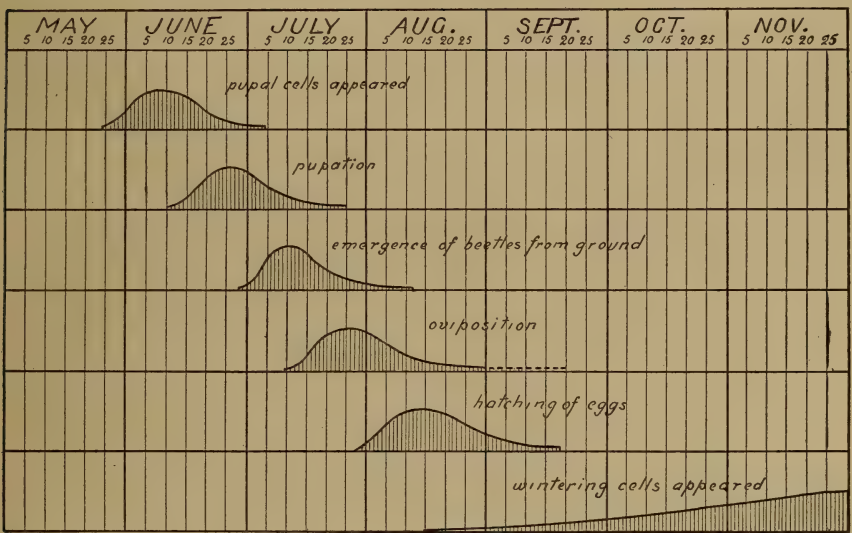


FIG. 23.—Diagram illustrating seasonal history of the grape root-worm as observed during 1909 at North East, Pa. (Original.)

isolated previous to the earliest egg deposition. The observations on the habits of these individual beetles are given in Table II.

Since the greater portion of the beetles from the emergence cages was used in obtaining the egg records, and since these insects oviposited undisturbed during the entire season, it is believed that the records in figure 15 represent the relative occurrence of eggs in the field.

Eggs used in determining the length of time of incubation were kept in glass tumblers under the outdoor breeding shelter.

In conjunction with the rearing work, field observations were constantly made, and in certain instances collections of the insect in its different stages were regularly made in the same localities for a given length of time. Thus it has been possible to check the rearing observations with field conditions, and whenever differences have occurred corrections in the summary (fig. 23) have been made to approximate field conditions.

SUMMARY OF LIFE-HISTORY STUDIES OF THE GRAPE ROOT-WORM.

The life history of the beetle (see fig. 12, p. 23) may be briefly summarized as follows: The grape root-worm produces only one generation a year; the larva feeds on the roots of the grapevine, and in this stage the insect is found in the ground for the greater part of the year. In early June the full-grown larva makes an earthen cell a few inches below the surface of the ground, within which it pupates about the middle of June; the pupal stage lasts generally twenty days, and the beetle or adult begins to emerge from the ground in late June or early July, while a few belated beetles continue to appear in the early part of August. On an average the beetle feeds for from 10 to 13 days on the grape foliage before ovipositing. The eggs are laid beneath the loose bark on the canes of the vines, and hatch on an average in 12 days; the young larva drops to the ground and soon finds its way to the roots of the vine; generally the larva becomes three-fourths grown and sometimes attains its full growth in the fall. Previous to wintering it penetrates deeper into the ground, below the roots, and there constructs an earthen cell in which it passes the winter.

The diagram (fig. 23) shows the relative occurrence and the time of transformation of the grape root-worm in its various stages. It has been prepared from field observations and rearing records of 1909 and is a summary graphically presenting the life-history studies.

Local variations in the times of development of the different stages of the insect, as described in preceding pages, may be brought about by various factors, such as differences in the texture of the soil, relative abundance of food, and altitude and exposure of vineyards. The seasonal variations, as shown by the difference in the time of emergence of beetles during 1907, 1908, and 1909, and also by the occurrence of larvæ that remained two winters in the soil, are the direct results of climatic influences. The insect has a strong tendency, however, to develop normally, even under adverse conditions.

NATURAL ENEMIES.

PREDACEOUS INSECTS.

Several predaceous insects have been found feeding upon the larvæ of the grape root-worm. During the process of digging for larvæ, both in the spring and fall, various species of carabid beetles and their larvæ have been found in the ground. These insects are entirely predaceous and probably feed upon the grubs of the grape root-worm whenever the latter come within their reach. Dr. E. P. Felt recorded

Staphylinus vulpinus Nordm. as probably predatory on the larvæ. In the spring of 1909 in one instance a "June-bug" larva (*Lachnosterna* sp.) was found by the junior writer feeding upon a larva of the grape root-worm beetle. When first discovered the grape root-worm was already half devoured, and while the operation was being watched the remaining portion was completely eaten.

The eggs of the grape root-worm are subject to the attacks of a number of different predaceous insects. Professor Webster observed in Ohio a small brown ant (*Lasius brunneus* Latr. var. *alienus*) and three species of mites (*Tyroglyphus* [*Rhizoglyphus*] *phylloxeræ* [Riley], *Heteropus* [*Pediculoides*] *ventricosus* Newport, and the third, resembling *Hoplophora* [*Phthiracarus*] *arctata* Riley), feeding upon the eggs. Mr. P. R. Jones, of this Bureau, in 1907, at North East, Pa., found a coccinellid larva (*Hippodamia convergens* Guér.), and a malacoderm larva (family Telephoridæ) feeding upon the eggs of the grape root-worm. The determinations of these coleopterous larvæ were made by Mr. E. A. Schwarz, of this Bureau. The junior author in 1909, at North East, Pa., collected a small ant, determined by Mr. Th. Pergande, of this Bureau, as *Cremastogaster lineolata* Say, var. ?, which carried off eggs from a cluster on a grape cane. The larvæ of a lace-wing fly (*Chrysopa* sp.) have been observed from time to time extracting the egg contents by means of their pointed, tubelike mandibles, which are peculiarly well fitted for the purpose.

PARASITIC INSECTS.

Two minute hymenopterous egg parasites, *Fidiobia flavipes* Ashm. and *Lathromeris* (*Brachysticha*) *fidiæ* (Ashm.), were reared from eggs of the grape root-worm in Ohio by Professor Webster. The late Professor Slingerland recorded *Fidiobia flavipes* in the Lake Erie section in 1900, and later, during the present investigation by the Bureau of Entomology at North East, Pa., this minute egg parasite has been constantly noticed by different members of the staff. *Lathromeris fidiæ* (Ashm.) has been only once observed at North East, Pa., as recorded on pages 56–57. The two parasites mentioned above were described by the late Dr. William H. Ashmead[a] in 1894 from specimens reared by Prof. F. M. Webster. The original description of Fidiobia is given herewith:

Fidiobia flavipes sp. n. Female, length, 0.6 mm. Black, polished; legs and antennæ yellow; thorax without distinct furrows, smooth, with only slight indications of furrows posteriorly, but not sharply defined; wings hyaline, veinless; abdomen oblong, sessile, the first segment wider than long, the second very large, occupying most of the remaining surface, the following being usually retracted with it, and thus making the abdomen appear truncated at apex.

---

[a] Cinti. Soc. Nat. Hist., vol. 17, 1894, pp. 170–172.

LIFE HISTORY OF FIDIOBIA FLAVIPES ASHM.

During the summer of 1909 the junior author had opportunity to rear *Fidiobia flavipes* Ashm. (fig. 24) and to make some observations relative to its habits and occurrence in the Lake Erie grape belt.

The parasitized root-worm eggs can be readily recognized in that they assume a brownish-yellow cast and become gradually darker with the development of the parasite. The grape root-worm eggs when first deposited are whitish, but soon take on a yellowish cast. In view of the semitransparent eggshell it is possible to observe the development of the different stages.

Parasitized eggs were obtained in the vineyards July 13, from which adults issued on August 3. These adults were then placed in a vial August 4, with fresh eggs which had been laid in breeding cages the previous day. On August 7 an irregular area could be distinguished in the center of each egg, indicating a breaking up of the yolk tissue. On August 11 the parasitized eggs were already of a dark yellowish-brown cast. In one extremity of the egg there began to appear an empty space and the larva could be distinguished feeding toward the opposite end. On August 14 most of the parasite larvæ pupated. Two or three days after pupation the eyes could be distinguished in the form of black spots, and a few days previous to the time of the emergence of the adults the entire pupa assumed a dark color. The minute hymenopterous flies emerged August 28, 29, and 30.

FIG. 24.—*Fidiobia flavipes*, an egg-parasite of the grape root-worm: Adult and enlarged antenna. Very greatly enlarged. (Original.)

In summarizing these data, we get 10 days for the egg and larval stages, 14 to 15 days for the pupal stage, or a total of 24 to 26 days for the whole life cycle. It is possible to recognize parasitized eggs 3 or 4 days after they become infested. Adult insects lived from 5 to 7 days in a test tube without food.

To determine the development of parasites from root-worm eggs of different ages and also to test in a general way the resistance of eggs of different ages to parasitism, the following experiments were carried out as summed up in Tables XXI and XXII:

TABLE XXI.—*Parasitism of grape root-worm eggs by Fidiobia flavipes at North East, Pa., 1909, the eggs ranging in age from 1 to 9 days.*

Observation.	Grape root-worm eggs.		Hatched.	Parasitized.
	Oviposition.	Normally hatching.		
1	July 30	Aug. 11	×	....
a2	July 31	Aug. 12	×	×
3	Aug. 1	Aug. 13	....	×
4	Aug. 3	Aug. 14	....	×
5	Aug. 4	Aug. 17	....	×
6	Aug. 5	...do.....	....	×
7	Aug. 6	Aug. 21	....	×
8	Aug. 7	Aug. 24	....	×
9	Aug. 8	Aug. 26	....	×

[a] Parasites placed with the host August 9. New parasites emerged September 10 to 12. Thirty-two to thirty-four days to complete the life cycle. Experiment No. 2 consisted of 15 root-worm eggs, of which 13 became parasitized and 2 eggs developed root-worms normally. Eggs within two to three days of hatching escaped parasitism.

TABLE XXII.—*Parasitism of eggs of the grape root-worm by Fidiobia flavipes, at North East, Pa., 1909, eggs varying in age from fresh to 10 days old.*

Number of observation.	Root-worm eggs.		Number of eggs.	Emerging root-worm larvæ.	Hatching of parasites.
	Oviposition.	Normally hatching.			
1	July 25	Aug. 6	15	15	....
2	July 26	Aug. 7	20	20	....
3	July 28	Aug. 8	38	....	37
4	July 30	Aug. 10	13	....	12
5	Aug. 1	Aug. 11	18	....	18
6	Aug. 2	Aug. 13	19	....	19
7	Aug. 4	Aug. 14	22	....	21

Parasites placed with host August 4, having emerged August 3. New adults emerged August 30 to September 3. Twenty-seven to thirty-one days to complete the life cycle. Root-worm eggs within two to three days of hatching escaped parasitism.

For each experiment egg clusters of the grape root-worm, each of a given age, ranging from 1 to 10 days, were subjected to the parasites. The insects with the host were confined in large-size glass vials, which were covered with fine cloth. In Table XXI it is probable that the parasites oviposited shortly after being confined with the host, since they had emerged a few days previous to their confinement with fresh eggs. In the first experiment (Table XXI) the parasites were confined three days with the hosts. The two experiments of Tables XXI and XXII are practically identical, the second being made to check the results with those of the first one. The records for the normal hatching of the eggs are from another set of records, since such data could not be obtained from parasitized eggs. The results of either experiment show that the parasites did not affect eggs which were within two or perhaps three days of hatching. There was no marked difference in the time of the development of the parasites from eggs of different ages.

The percentage of parasitized eggs in the field varied considerably in different sections of the grape belt, as well as in parts of the same vineyard. It was always highest where eggs were most numerous. This was especially brought out in the different sections in the experimental vineyards, where the sprayed areas were but slightly infested with root-worms.

Thus, Davidson's vineyard, consisting of 12 acres, located half a mile north of the city, showed in 1908 the following results:

	Per cent parasitized.	Average number of eggs per vine.
Unsprayed young Concord vines	18	268. 8
Sprayed young Concord vines	9. 5	12. 4
Unsprayed old Concord vines	13. 2	319. 2
Sprayed old Concord vines	20	23. 6
Unsprayed Niagara vines	35	56. 0
Sprayed Niagara vines	Free.	1. 2

The Porter vineyard, located a few miles east of the town and containing 10 acres of old Concord vines, gave the following results:

Unsprayed plat had 14.7 per cent parasitized eggs.
Sprayed plat had 5.5 per cent parasitized eggs.

By comparing the records taken during August from three different vineyards located within a radius of from 2 to 3 miles east of N rth East, Pa., Algren's vineyard on August 4 showed 2 per cent of parasitized eggs; Young's vineyard, August 24, showed 16 per cent; and Wheeler's vineyard, August 27, 96 per cent.

A marked increase of parasitism was observed with the advancement of the season. The records given below, obtained by H. B. Weiss, from Mr. Young's vineyard, illustrate this fact:

	Per cent.
July 30	5
August 13	10
August 19	14
August 26	16
September 2	20

Similar records from other vineyards were not as uniform as those just given, but since the percentage varies with the amount of eggs present, no great uniformity can be expected unless the eggs are found more or less evenly distributed in the vineyards.

By breeding the parasites two full generations and a partial third were produced. Infested eggs were obtained in the field July 13, from which adults emerged August 3. These were placed with fresh eggs August 4, and new adults issued August 28. The third generation developing from these adults was much delayed by cold weather, but at the time of concluding the field work for the season on November 22 the adults were about to emerge.

The diagram (fig. 25) shows the relation of the three generations of parasites as observed in the breeding cages to the time of oviposition and the time of hatching of the host eggs. With the data in hand it is not possible to determine the period covered by each generation. The records only show the appearance of the first adults for the three generations. A few conclusions can, however, be drawn from the above diagram. Adult parasites must have existed in vineyards at the time of earliest oviposition of the grape root-worm. Adults producing the second generation appeared before the greater portion of the root-worm eggs had hatched, and since eggs could become parasitized within two days of hatching, the second generation is apt to infest more eggs than either the first or the third generation. In fact, the third generation appeared so late that it only reached a very few belated eggs.

Fidiobia flavipes is an important factor in the control of the grape root-worm. Professor Webster, who for several years studied the

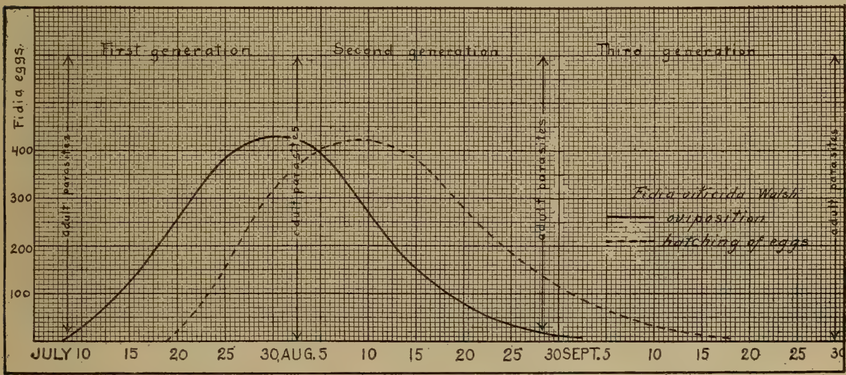


FIG. 25.—Diagram showing the relation between the three generations of the Fidiobia parasite and the relative occurrence of eggs of the grape root-worm at North East, Pa., during 1909. (Original.)

grape root-worm in Ohio, reported in 1896 that the decrease in numbers of the beetle was largely due to this and other parasites. Though the data on hand for North East, Pa., for the years 1907, 1908, and 1909 are not sufficient to show any increase in occurrence, it is our impression, from extensive observations, that the insect is becoming more and more numerous.

A DIPTEROUS PARASITE.

Along with *Fidiobia flavipes* there occurs another grape root-worm egg parasite (fig. 26), which is at present only known in the larval stage. It is supposed to be a dipterous insect, in view of the resemblance of the larva to dipterous forms. It was first observed by the senior author and Mr. P. R. Jones, of the Bureau of Entomology, who in 1907, at North East, Pa., collected several parasitized egg clusters.

During the summer of 1909 parasitized eggs were in evidence in the field from July 20 to August 30, and were found locally quite abundant, though less so than *Fidiobia flavipes*. Professor Webster informed the junior writer that he had found a similar parasite in Ohio in 1896. Table XXIII shows the relative occurrence of para-

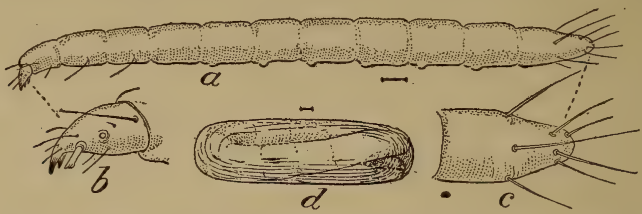


FIG. 26.—Larva of an undetermined insect parasite of the eggs of the grape root-worm. (Original.)

sitized eggs as observed at various stages in different localities during 1909 at North East, Pa.

TABLE XXIII.—*Percentage of eggs of the grape root-worm parasitized by a dipterous insect, as observed in vineyards in the vicinity of North East, Pa., 1909.*

Date.	Vineyard.	Per cent.
July 20	Davidson.....	1
July 22	Porter.........	1
July 24	Mosher	3
Aug. 4	Algren.........	7
Aug. 12	.....do.........	22
Aug. 19	.....do.........	12
Aug. 26	.....do.........	14

It will be noted that there is an increase in the occurrence of the parasite toward the end of the season, as was observed with Fidiobia.

Root-worm eggs parasitized by this insect are in their early stages opaque-white in color. Later the eggshell becomes semitransparent and iridescent. The larva of the parasite when full-grown is almost twice the length of the host and lies folded within the egg. The whitish larvæ are very active on emerging from the hosts. They were found to penetrate several inches in the soil in glass jars. Though the larva is quite common, all attempts to rear the insect to obtain the adult or fly have so far proved fruitless.

DOUBLE PARASITISM.

August 30, 1909, a cluster of 115 root-worm eggs was collected, which were infested by the dipterous parasite. The egg along the border of the cluster, unlike the rest, a few days later assumed a pink color, but at the same time showed the iridescence characteristic of this parasite. Dipterous larvæ emerged September 3 from the eggs of the central portion of the cluster. From the eggs along the border of the cluster a hymenopterous fly (*Lathromeris fidiæ* Ashm.) (fig. 27) emerged. The host had been confined indoors during the winter, thus bringing out the hymenopterous parasite on February 2. It is probable that the root-worm eggs were first parasitized by the dipterous insect and that later the eggs along the margin of the cluster were parasitized a second time by *Lathromeris fidiæ*. The dipterous and the hymenopterous insects are undoubtedly both primary parasites.[a]

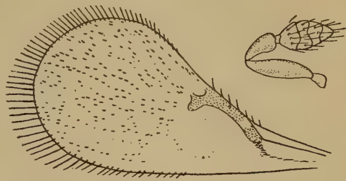


FIG. 27.—*Lathromeris fidiæ*, an egg-parasite of the grape root-worm: Antenna and fore wing. Very greatly enlarged. (Original.)

VINEYARD CONDITIONS IN THE LAKE ERIE VALLEY.

Before entering upon a discussion of methods of control undertaken against the grape root-worm during this investigation it may be well to consider some of the changes which have occurred in vineyard conditions throughout the Lake Erie valley since the advent of this pest.

In 1900, when the grape root-worm first appeared in injurious numbers in the Lake Erie valley, the grape industry was just emerging from a period of depression which had caused, for several years previous, an almost complete cessation in planting of new vineyards. The period of low prices had resulted in indifferent care, amounting in some cases to positive neglect, thus creating a condition very favorable to the increase of this pest. Furthermore, the fact that practically all vineyards had been for several years in bearing and had a well established root system permitted the insect to become thoroughly disseminated through them before the unsuspecting owners were aware of its presence in numbers sufficient to affect the vigor of their vines. The tendency of most vineyardists at that time was to pull out declining vineyards rather than to go to the expense of fighting insect foes. Thus it happened that a combination of circumstances conspired to favor a general spread of the insect without creating widespread alarm.

With the steady rise in the value of grapes since 1900, however, this condition has been reversed. Thousands of acres of new vineyards have been planted, and the more progressive vineyardists are commencing to appreciate fully what an enormous amount of injury has been done to their old vineyards, and are greatly alarmed at the rapidity with which many young vineyards are falling a prey to this pest.

The maximum crop yield for the Lake Erie grape belt occurred in 1900, and amounted to 8,000 carloads of fruit. At that time there

[a] The authors are indebted to Mr. A. A. Girault, of the office of the state entomologist of Illinois, for the determination of the above-named parasites.

were about 30,000 acres of vineyards in bearing. Since 1900 fully 10,000 acres of bearing vines have been added to this area, yet the yield for 1908 was only a little more than one-half that of 1900.

The figures given below are taken from the Chautauqua Grape Belt, a newspaper which is largely devoted to the grape interests of that region and every year publishes carefully gathered statistics on grape production.

Grape production from 1900 to 1909.

Yield for—	Carloads.
1900	8,000
1901	6,669
1902	5,062
1903	2,954
1904	7,479
1905	5,365
1906	5,465
1907	5,186
1908	4,232
1909	7,561

These figures denote a steady decline in crop yield traceable to a variety of causes, namely, depletion of soil, lack of proper cultivation, adverse weather conditions, and lack of proper fertilization. There are thousands of acres of vineyard throughout the belt that have borne many crops and have never received a pound of fertilizer. It is doubtful, however, if all of these factors combined could of themselves have resulted in such unfavorable vineyard conditions as have been brought about by the ravages of the grape root-worm. We make this statement advisedly after several seasons of careful study of the habits and depredations of the pest.

The table presents certain points of interest. Thus, in 1903 there was an especially light crop of 2,954 carloads followed by a large crop in 1904. About the same conditions prevailed during the respective years 1908 and 1909. It should be borne in mind that a considerable percentage of the phenomenal increase during the years 1904 and 1909 must be credited to the greater vigor of the plants following the light crops of the preceding years and to extremely favorable weather conditions.

In the early history of this infestation, as previously mentioned, practically all of the vineyards of the belt contained old vines with a well-established root system able to withstand for several seasons even a heavy infestation of the larvæ before a marked decrease in yield was noticeable. With the extensive planting of new vineyards since the thorough dissemination of this pest its swift and deadly work has become more apparent. Numerous instances have come to our notice where young vineyards bearing the second or third season's crop have been so severely injured that hundreds of vines died outright in a single season, while the rest were so weakened that they had to be cut back so severely that in the following season they were unable to produce more than from 15 to 25 per cent of a normal crop. Persons not thoroughly familiar with the habits of the pest have frequently charged this death and weakened condition to a variety of causes, such as winter killing, deep plowing, overbearing of young vines, etc. In practically every case of this kind coming under our observation we have found overwhelming evidence of injury wrought upon the roots by the larvæ of this pest. There is no doubt that the overbearing of young vines which possess a limited root system and then become subject to a heavy infestation of grape root-worm larvæ will serve to greatly weaken the vine, and that severe winter weather following this heavy infestation of larvæ, and consequent weakening of the vine, will accelerate the death of the vine during the winter. Yet these are but secondary evils to which the vines, primarily weakened by injury from the insect during the growing season, finally succumb. This is also true of drought conditions occurring in August and September. During the drought which occurred in these months in 1906 numerous cases came under our notice where young vines bearing a heavy crop of fruit and having made a heavy growth of vine early in the season were so badly injured by larvæ hatching from eggs deposited in July that they were unable to mature the fruit, which actually shriveled on the vine by the last week in August. Other injured vines which carried through their crop died during the following winter. It is the rapid decline in yield of large numbers of vines in young vineyards throughout the whole grape belt and the steady though less perceptible shrinkage in yield of the other vineyards that make it impossible for the increased planting of recent years to more than hold its own with the crop production of the period previous to the general infestation of vineyards by this pest, and it will require the greatest care and watchfulness on the part of those planting new vineyards to carry their young bearing vines through that critical period when they are producing their first two or three crops and at the same time establishing a root system sufficient to continue the production of successive profitable crops.

REMEDIAL MEASURES FOR THE CONTROL OF THE GRAPE ROOT-WORM.

EVOLUTION OF PREVENTIVE MEASURES.

Although the occurrence of this insect in numbers sufficient to cause great damage to the foliage of grapevines was brought to the attention of Walsh in 1866, no remedial measures were suggested by him. The first record of an attempt to control the pest was made in 1870 by C. V. Riley, who relates an instance where a vineyardist, having observed that the beetles have the habit of falling from the foliage to the ground when the vines are jarred and that they have a tendency to "play possum," and also that they were readily devoured by his chickens, was able to destroy many of them in his vineyard by having a boy drive his flock of chickens through the vineyard while he shook the beetle-infested vines in front of them.

In 1872 Kridelbaugh suggested handpicking of the beetles from the vines and also the use of an arsenical spray.

Not until 1895, however, when Professor Webster made his investigation of the pest in Ohio, were methods for its control seriously considered. During his investigation Professor Webster conducted experiments with salt, kainit, tobacco, kerosene emulsion, and carbon bisulphid against the larvæ in the soil, all of which appear to have given indifferent results. The carbon bisulphid, although partially effective, was likely to injure the roots of the vines and was also too expensive to be practicable. He also used kerosene emulsion against the adults, both on the foliage and after they had fallen to the ground. Pyrethrum in solution was used in the same manner, but with very indifferent results. Arsenical sprays were applied to the foliage in an attempt to poison the beetles, using London purple and Paris green, 4 ounces to 50 gallons of water, and arsenate of lead, 1 pound to 150 gallons of water. Although there was evidence that some beetles were destroyed by the use of these arsenicals, the results were far from conclusive. Later experiments in Ohio with arsenicals against the pest gave more encouraging results, yet the practice of spraying as a method of control never became general. Therefore in 1900, when the insect appeared in destructive numbers in the vineyards of Chautauqua County, N. Y., it was again the subject of experimentation by both the late Prof. M. V. Slingerland, of Cornell University Agricultural Experiment Station, and by Prof. E. P. Felt, of the New York State Museum to determine effective methods of control.

During the early part of the investigation it was shown that early in June the larvæ come near the surface of the soil to make the pupal cells in which they transform to beetles, and that thorough stirring of the first 3 or 4 inches of the soil, especially beneath the trellis, will expose and destroy a large number of the pupæ. On account of the somewhat unsatisfactory and inconclusive results obtained with arsenical sprays in former years in Ohio, Doctor Felt gave considerable attention to the perfecting of a device for collecting the beetles by jarring them into troughlike receptacles containing kerosene oil which could be operated either by hand or by horsepower where large areas of vineyard have to be treated. That large numbers of the beetles can be captured and destroyed by this method is demonstrated in Doctor Felt's reports of his experiments published by the New York State Museum. (See Bibliography, p. 93.)

Experiments with arsenical sprays against the pest during the early part of the New York investigations, although giving more encouraging results than those obtained in Ohio, were not so conclusive as could have been desired. By persistent experiment with improved spraying apparatus and increased strength of arsenicals, and thorough and heavy applications where desirable, Professor Slingerland was able toward the end of his investigations to secure results with poison sprays which showed that in the hands of the thorough vineyardist very effective results could be obtained.

Unfortunately these field experiments with arsenicals were not conducted for a number of consecutive seasons on the same blocks of vineyards. This makes it impossible to determine the cumulative

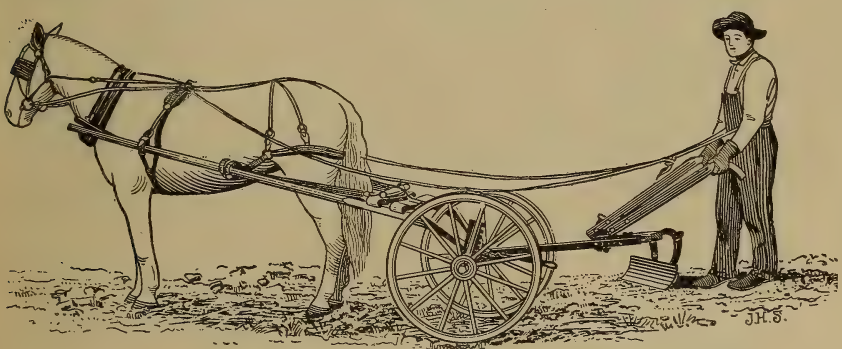


FIG. 28.—Horse hoe used in removing the soil from beneath the trellis in vineyards. (Original.)

benefits of the treatments in preventing infestation on the sprayed portion as compared with the injury wrought by the insect on the untreated portion of the vineyard.

CULTURAL METHODS FOR THE DESTRUCTION OF PUPÆ.

Prior to the appearance of the grape root-worm in destructive numbers in the Lake Erie grape belt about the first cultural operation of the season performed by vineyardists was to remove the soil from beneath the trellis with a horse hoe (fig. 28) to a depth of 3 or 4 inches. This operation removed all of this layer of soil beneath the trellis with the exception of a few inches directly around the base of the vine which was removed later with a hand hoe. Almost immediately following these operations a furrow was thrown back under the trellis with a 1-horse plow, and the remaining space between the rows of grapes was stirred with a gang-plow and followed by several cultivations during the season. With the discovery that the grape root-worm larva has the habit of coming near the surface of the soil to make its pupal cell, this plan of cultivation has been somewhat modified. In order to encourage the larva to come still higher above the roots of the vine to pupate than it would have done under ordinary cultural methods it has become customary to throw up a ridge of soil beneath the trellis at the last cultivation of the preceding summer (see Pl. V, fig. 2). Observations have shown that it is highly desirable that this ridge be formed under the trellis late in the summer rather than in the early spring, since in the former case the soil becomes of a uniform compactness by the time the larvæ are ready to migrate nearer to the surface to pupate; whereas, if the ridge is formed in the spring a layer of trash and leaves accumulating under the trellis during the winter is sandwiched in this ridge, and in no case in our examinations have we found pupal cells above this layer of trash. In the operation of horse hoeing this spring-formed ridge away from the vines it frequently happens that only the layer above the trash is thrown away, hence the pupæ, which are all beneath the trash, are undisturbed.

Undoubtedly this modification in the plan of early cultivation of vineyards is an important aid in the destruction of this pest at a time when it is in its most critical stage of development. Instances have come directly under our observation where we have seen great numbers of the pupæ exposed to the air and sunlight or become the immediate prey of birds and predaceous insects. The operation is probably of greater value in sandy and loose gravelly soils than in stiff clay soils, for in the former the earthen cells fall apart quite readily with the disturbance of the soil, leaving the pupæ exposed; whereas in the clay the soil is more likely to turn over in lumps, leaving many of the cells intact. In addition to this, in soils of a sandy or gravelly nature the loose earth around the vines may be removed by the horse hoe to a much greater depth and more pupæ disturbed than in the case of stiff clay soils, where it frequently happens that the operation of horse hoeing amounts to little more than a scraping of the weeds from the surface of the ground, especially if the season be a dry one. In fact, the drying out of the soil is the chief drawback to placing reliance on this operation as a means of controlling this pest.

It not infrequently happens that a dry period may occur along the Lake Erie Valley during the month of June which renders it difficult to make horse hoeing as thorough and as timely as it should be to derive the greatest benefit from this operation in the destruction of the pupæ. In the summer of 1907 when the development of the pupæ was unusually late the operation of horse hoeing was postponed by some vineyardists until the last of June and early July in order to perform it at a time when the maximum number of the insects were in the pupal stage, and considerable complaint was forthcoming

RIDGE OF SOIL UNDER TRELLIS.

Fig. 1.—Vineyard view in the spring, showing ridge of undisturbed soil under the trellis. Fig. 2.—Vineyard view, showing ridge of soil under trellis as formed at the last cultivation of the preceding summer. North East, Pa. (Original.)

from large vineyardists concerning the undesirability of suspending horse hoeing until so late a date. In 1907 we saw many hundreds of acres of vineyard in the condition shown in Plate V, figure 1, in which cultivation had been suspended to await the development of the pupæ. Under normal conditions this cultivation would have been performed several weeks earlier, and since early and thorough tillage is essential to good vineyard management, it is not well to place entire reliance on this operation to control the pest. Nevertheless it is an operation that should be utilized whenever soil and moisture conditions will permit, and these are most favorable in sandy and gravelly soils and in seasons of moderate rainfall during the month of June. The most beneficial results from this operation are obtained by horse hoeing as deeply as possible without scraping the roots, followed by thorough and deep hand hoeing around the crown of the vine, at which point by far the greater number of pupæ are to be found.

During this investigation we have never felt warranted in placing entire dependence upon this method of destroying pupæ to control this pest, but have regarded it as a valuable supplementary aid obtained by a slight modification of general vineyard practice at no additional expense to the vineyardist and that other means must be employed to destroy the beetles developing from pupæ which escape destruction by this method. Since we were unable to find vineyardists with heavily infested vines who were willing to allow us to conduct an experiment covering several acres for several consecutive seasons, depending entirely on the destruction of pupæ by cultivation, it is impossible to present definite data as to the exact value of this treatment.

EFFECT OF POISON SPRAYS ON THE BEETLE IN THE FIELD.

The use of poison sprays against the beetles of the grape root-worm after they have emerged from the soil and commenced to feed upon the foliage of grapevines has been recommended by many entomologists since the insect has become of economic importance as a vineyard pest.

Extensive experiments with arsenicals were made by Webster in Ohio in 1895, and also by Slingerland and Felt in Chautauqua County, N. Y., in a number of field experiments conducted during the seasons from 1902 to 1906.

Although in many of these experiments the results obtained indicated a considerable degree of benefit from the use of arsenical poisons, especially in those made by Slingerland from 1904 to 1906, there has always been an element of doubt as to the value of arsenical sprays applied to the vines as a direct and rapid killing agent of the beetles. The inference has been drawn by some experimenters that the beneficial effects of poison sprays are due rather to a distaste on the part of the beetles for poisoned foliage, and their consequent abandonment of sprayed foliage and migration to unsprayed areas, than to the direct killing effect of the poison. This view is supported to some extent by cage experiments which showed that in many cases when confined in cages the beetles fed but slightly upon sprayed foliage and the death rate was not as rapid as might be wished. In addition to this, beetles thus confined with poisoned vines have in feeding indicated a preference for unsprayed areas, all of which left reasonable cause for doubt as to the direct efficiency of arsenicals as a killing agent.

During our investigation of this pest, covering the seasons of 1907, 1908, and 1909, we have observed this tendency of the beetles to feed more freely upon the unpoisoned than upon poisoned foliage, both in the open vineyard and in cages, yet we have no direct evidence of wholesale migration of the beetles from sprayed areas.

CAGE EXPERIMENTS WITH POISON SPRAYS AGAINST THE BEETLES.

On July 13, 1907, 100 beetles recently emerged from the soil were divided into two lots of 50 each and placed in cages; one cage contained sprayed foliage collected from a vineyard recently sprayed, the other unsprayed foliage. The beetles in the cage containing the unsprayed foliage fed freely upon the leaves soon after they were placed in the cage, whereas those placed in the cage containing the sprayed foliage did but little feeding during the first 3 days. During the next 3 days there was evidence of an increased amount of feeding. At the end of the 6 days, 25 of the beetles feeding on the sprayed foliage had died as against 6 dead beetles out of the 50 feeding on the unsprayed foliage. At this date (July 19) the experiment terminated on account of the withering of the sprayed foliage, and the impossibility of obtaining additional recently sprayed foliage.

Another cage experiment to observe the feeding of beetles upon poisoned and unpoisoned foliage was undertaken during the summer of 1909. This experiment was made upon young grapevines growing in large flower pots and covered with a wire screen (see fig. 22). Thus the freshness of foliage was assured throughout the experiment and the limited area of the plant permitted close observation of what took place. Three plants growing in pots were used in this experiment. The plants in two of the pots were sprayed very thoroughly, care being taken to cover the entire upper surface of all of the leaves with a poisoned spray, which consisted of Bordeaux mixture with 3 pounds arsenate of lead to 50 gallons of the mixture, the proportions used in field experiments. The plant in the third pot was unsprayed. An additional object of this experiment was to observe the readiness with which beetles that had just emerged from the soil and had not had a previous opportunity of feeding on unsprayed foliage would feed on poisoned foliage as compared with beetles which were taken from vineyards and which had fed to some extent upon unsprayed vines. Accordingly 30 beetles, on emerging July 8, from soil inclosed with wire screens, were placed on a sprayed plant in pot I. Thirty more beetles collected in a vineyard, June 30, and fed on unsprayed leaves until July 8, were placed (July 8) in pot II, also containing a sprayed plant. At the same date 15 beetles which had just emerged were placed on an unsprayed plant in pot III.

Table XXIV shows the death rate of the beetles in these three cages.

TABLE XXIV.—*Experiments with poison sprays against grape root-worm beetles feeding on vines in confinement at North East, Pa., in 1909.*

Pot I.		Pot II.		Pot III.	
30 beetles emerged from soil July 8, and at once removed to sprayed vine.		30 beetles taken on vines in the field June 30 and placed on sprayed vine July 8.		15 beetles emerged from soil July 8, and removed at once to unsprayed vine.	
Number of dead beetles.	Date.	Number of dead beetles.	Date.	Number of dead beetles.	Date.
16	July 9	3	July 9	1	July 15
12	July 10	10	July 10	1	July 27
2	July 11	13	July 11	1	July 29
		2	July 12	1	July 31
		1	July 13	7	Aug. 14
		1	July 17	3	Aug. 15
				1	Aug. 28
30	....	30	....	15	Total.

It was observed that the beetles just emerged from the soil and which had been placed in pot I without having had an opportunity to come in contact with unsprayed foliage fed as readily and indiscriminately on the poisoned leaves as did those placed on the unsprayed plant in pot III. The beetles placed on the other sprayed plant in pot II, which had had 8 or 10 days of feeding on unsprayed leaves, fed less upon the sprayed foliage, especially for the first 24 hours. A glance at the table will show that 50 per cent of the beetles in pot I died in 24 hours as against 10 per cent in pot II. On the fourth day all beetles in pot I had died and also 85 per cent of those in pot II, whereas it was not until the eighth day of the experiment that the first dead beetle was found in pot III, and 73 per cent of the beetles remained alive on this plant for more than a month.

FIELD EXPERIMENTS WITH POISON SPRAYS AGAINST THE BEETLES.

The most striking evidence of the value of a poison spray as a direct killing agent of the beetles, however, was obtained by us in a field experiment conducted at North East, Pa., June 30, 1909. At this date our attention was called by Mr. Frank Pierce to the presence of large numbers of grape root-worm beetles feeding upon a block of several acres of vines planted that spring. These vines had been planted on land from which the vines of the greater portion of an unproductive vineyard had been removed early the same spring. The owner, not being aware at the time that these vines had been

Fig. 29.—Young grapevine, unsprayed, showing extensive feeding by beetles of the grape root-worm. North East, Pa., 1909. (Compare with fig. 30.) (Original.)

rendered unproductive by infestation by the grape root-worm, decided to replant the area immediately with young vines. After removing the old vines the ground was plowed and planted to the young vines and the space between these vines was sown to peas. Thus the soil was left uncultivated during the period between early May, when the peas were sown, and July 1. Consequently the root-worm larvæ which had infested the roots of the old vines were permitted to perform their transformations undisturbed. On June 28, when Mr. Pierce harvested the peas growing between the rows of grapevines, he observed some grape root-worm beetles feeding upon foliage of the young vines. By June 30, when our attention was called to the infestation, the leaves of many of the plants were badly riddled by the beetles (see fig. 29). At our suggestion Mr. Pierce sprayed part of these young vines quite thoroughly, using Bordeaux mixture and 3 pounds arsenate of lead to 50 gallons of the mixture. This application was made with a hand spray pump mounted on a grape wagon, and the spray was directed at the plants by a man following behind the wagon and carrying an extension rod with two nozzles at the end and connected with the spray pump by a long lead of hose. In this way 4 rows of vines could be treated from the wagon. The vines were sprayed on the afternoon of June 30. It should also be stated that the portion of the old vineyard not removed in the spring and adjoining the young vines was treated at the same time. On the afternoon of July 1 an examination was made of the effect of the treatment of the previous day. Only a few beetles were found on the young vines as compared with the large numbers present previous to the application of the poison spray. Close examination of the soil beneath the vines disclosed the presence of a large number of dead beetles. Eighteen dead beetles were found beneath one vine, and under a number of others from 3 to 10 dead beetles were found. In addition to this we observed that a small brown ant was very actively removing evidence of the direct effect of the poison by tearing to pieces the dead beetles and often dragging away the whole body of the beetle. Wing-covers, heads, and legs of several beetles were to be seen beneath a single vine, and in several cases ants were observed to attack the beetles before they were quite dead.

A visit was also made to the old trellised vines adjoining them, anticipating evidence of a wholesale migration of beetles from the young vines to the denser foliage of the old vines. Such, however, was not the case; although there was evidence of considerable feeding at an earlier date, few beetles were now observed on the vines. Several dead beetles were found beneath these old vines, and fragments of beetles and their wing-covers were also observed. A few days later a second application of Bordeaux mixture and arsenate of lead was made on these vines to take care of later emerging beetles. On a visit to these young vines July 10 not more than 4 live beetles were observed, although more than an hour was spent in the block, and not a single dead beetle was found on the ground beneath the vines, although fragments of their bodies were in evidence. If this timely application of a poison spray had not been made, the young vines would have been seriously injured by the feeding of the beetles; for it not infrequently happens that the beetles, where they are numerous and the foliage limited, as in this case, riddle the foliage and tear it into shreds until it has the appearance of being singed by fire.

In view of the results described above, there can be no doubt as to the value of a poison as a direct and effective killing agent of the beetles in the open field. It is quite possible, moreover, that the rapid removal of dead bodies by ants and other agencies and the close search required to find them on account of the fact that their color is the same as that of the soil, and also by the fact that they were distributed over a large area on the foliage of full-grown vines, have resulted in the failure of other workers to find a sufficient number of dead bodies of beetles in sprayed vineyards to warrant them in feeling that this method of control is as effective as might be desired.

COMPARATIVE EFFECTIVENESS OF ARSENATE OF LEAD AND ARSENITE OF LIME.

In our field work with arsenical sprays, planned for a period of two or three seasons, arsenate of lead was the insecticide used throughout the experiments. Since, however, many vineyardists were using arsenite of lime when this investigation commenced, it was deemed advisable to make a test of its efficiency as an insecticide against the grape root-worm beetle as compared with arsenate of lead.

In the summer of 1907 a test of these two insecticides was made in two vineyards in different parts of the township of North East. One vineyard of about 8 acres belonging to Mr. W. S. Wheeler was divided into three plats. Two plats of about 3 acres each were sprayed, one with Bordeaux mixture and arsenate of lead and the other with Bordeaux mixture and arsenite of lime. The third plat of about 2 acres running through the middle of the block was left unsprayed. Two spray applications were made on these plats at the same dates, July 9 and July 27, with a gasoline-engine power sprayer (Pl. X, fig. 2). The spray was applied at a pressure of about 100 pounds, and about 100 gallons of the liquid were used per acre. The formula used on the plat sprayed with arsenite of lime was, copper sulphate, 5 pounds; lime, 6 pounds; resin-fishoil soap, 2 pounds, and 1 quart arsenite of lime made according to Kedzie's formula (containing 4 ounces of white arsenic) to 50 gallons of water. The resin-fishoil soap was added to increase the mixture's property of adhering to the foliage. The formula used on the plat sprayed with arsenate of lead was, copper sulphate, 5 pounds; lime, 5 pounds; arsenate of lead, 3 pounds; and water, 50 gallons. The effect of these treatments in preventing egg deposition is shown by a count of the egg clusters on 25 vines in each of the three plats. It should be stated in addition that at the time of making the count of egg deposition there was evidence of a great deal more feeding by beetles on the foliage on the plat treated with arsenite of lime than upon the foliage of the plat sprayed with arsenate of lead. (For results, see Table XXV.)

TABLE XXV.—*Relative value of arsenite of lime and arsenate of lead as insecticides, as shown by egg depositions at North East, Pa., 1907.*

VINEYARD OF W. S. WHEELER.

Date of application.	Formula.	Size of clusters. Large.	Medium.	Small.	Total clusters.	Estimated number of eggs.	Number of vines.	Number of canes.	Eggs per vine.	Eggs per cane.	Date examined.
1907.											
	Unsprayed	37	102	151	290	6,420	25	50	256.8	128.4	Aug. 14
July 8	5-6-2-50+1 quart Kedzie	27	98	132	257	5,610	25	65	224.4	86.3	Do.
July 27	5-5-3-50	3	14	47	64	1,040	25	51	41.6	20.39	Do.

VINEYARD OF W. E. GRAY.

Date of application.	Formula.	Large.	Medium.	Small.	Total clusters.	Estimated number of eggs.	Number of vines.	Number of canes.	Eggs per vine.	Eggs per cane.	Date examined.
	Unsprayed	28	119	139	286	6,360	25	75	254.4	84.8	Aug. 17
July 6, July 25	Prepared Bordeaux: 1 qt. arsenite lime, 2 qts. fishoil soap, 50 gals. water	21	107	155	283	5,810	25	63	232.4	92.22	Do.
July 6, July 25	Prepared Bordeaux: 3 lbs. arsenate of lead, 50 gals. water	11	49	78	136	2,800	25	58	112.0	48.27	Do.

The vines on all these plats were quite thrifty and were carrying a heavy foliage.

The second experiment for comparing the value of these two poisons against the grape root-worm beetle was made on a 12-acre vineyard belonging to Mr. W. E. Gray, North East, Pa. The vineyard was divided into three plats, 5 acres on the east side, 2 acres through the middle of the block, and 5 acres on the west side. In this experiment a commercial brand of prepared Bordeaux mixture was used. The poison ingredients of the spray, however, were the same as in the experiments on the vineyard of Mr. Wheeler. The plat on the east side of the vineyard was sprayed with a mixture of 2 gallons prepared Bordeaux mixture, 1 quart of arsenite of lime, Kedzie formula, 2 quarts of fishoil soap, and 50 gallons of water. The plat on the east side of the vineyard was sprayed with a mixture of 2 gallons of prepared Bordeaux mixture, 3 pounds of arsenate of lead, and 50 gallons of water. The 2 acres through the middle of the vineyard were left unsprayed. As in all of our other spray experiments, the foliage in the untreated plat showed much more feeding by the beetles at the time of taking the records of egg deposition. A greater amount of feeding by the beetles was also apparent on the foliage treated with arsenite of lime than upon that treated with arsenate of lead. The results of these experiments are set forth in

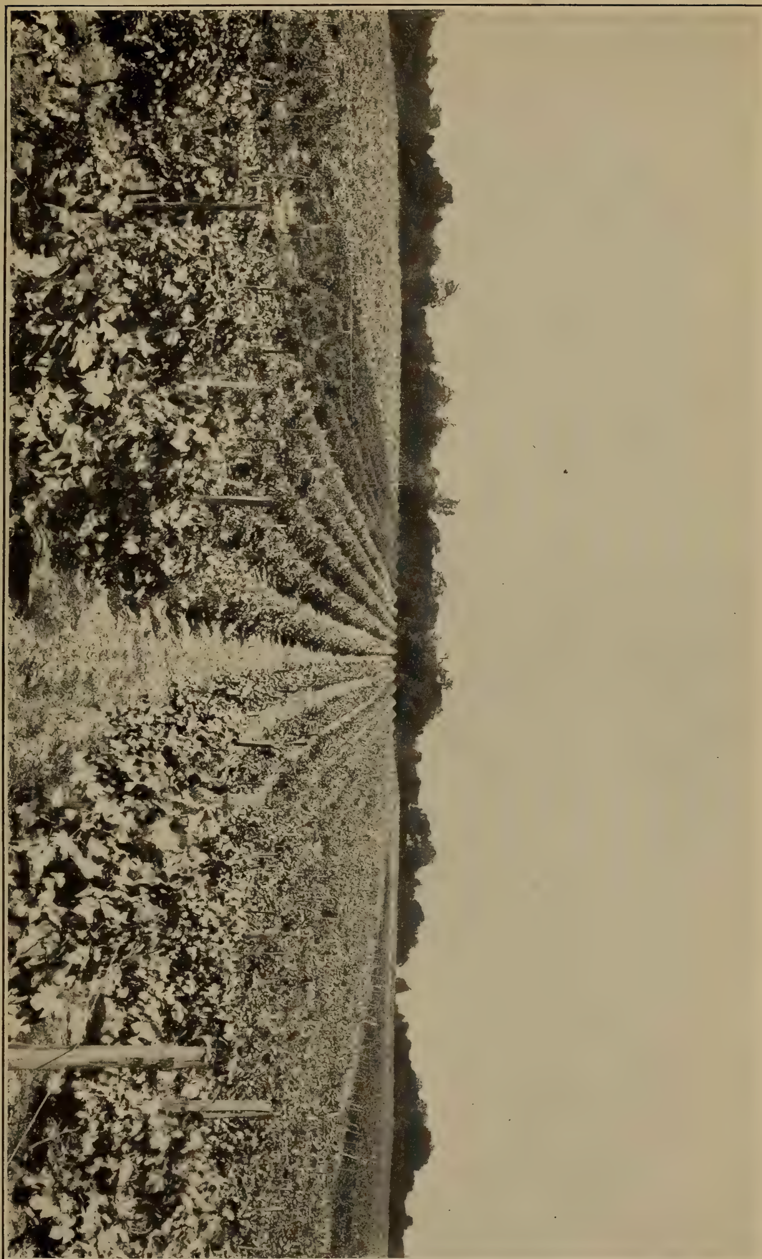
Table XXV and indicate a much greater efficiency from the arsenate of lead application than from the application of arsenite of lime.

Vineyardists throughout Erie County have practically abandoned the use of arsenite of lime as a poison spray against the grape root-worm beetle, and arsenate of lead is now used almost exclusively.

RESULTS OF VINEYARD EXPERIMENTS WITH POISON SPRAYS.

The field experiments of this investigation were carried on during the three consecutive seasons of 1907, 1908, and 1909, and in view of results obtained by spraying by the senior author during his single season of cooperative work with the late Prof. M. V. Slingerland the remedial measures tried out were almost entirely along the line of spray applications, it being his belief that the most effective results could be obtained by this method of combat. Some of the principal points upon which information was desired were the effect of poison sprays in ridding the vines of the grape root-worm beetles, the effect of this application in preventing egg deposition by beetles, the relative effect of this treatment on vines of different ages and different stages of infestation, the determination of the immediate seasonal benefit to the vines by prevention of egg deposition, and the cumulative benefit both in vigor of vines and crop yield obtained by following up a line of treatment for several consecutive seasons.

A brief survey of vineyard conditions in the townships of North East, Pa., during the late summer of 1906 enabled us to make a selection of vineyard areas in the various stages of infestation and decline best suited to the working out of these problems. A block of vineyard owned by Mr. Roscoe Davidson, of North East, was selected for the experiment to determine the effect of poison applications. The conditions existing in this vineyard were well suited to the plan of experiment. The area was about 12 acres, thus making it possible to secure results of commercial value. The vineyard (Pl. VI) is situated on a northern slope and is divided into four blocks or sections. The soil is of a loose gravelly texture. The lower northern section consists of young Concord vines about 7 years planted, the two sections immediately above are made up of vines about 20 years planted and are referred to as old Concords, and the south section consists of a block of 7-year-old Niagara vines referred to in these experiments as young Niagaras. At the time the experiment was undertaken the whole block showed a uniformly heavy infestation of larvæ on the roots of the vines. With the exception of the section of young Concords, however, the vines had not yet reached the stage of serious decline and were still producing fairly profitable crops. With the young Concords the case was different. Our attention had been called to these vines late in the summer of 1906 at the time when the fruit was commencing to color.



GENERAL VIEW OF MR. ROSCOE DAVIDSON'S VINEYARD AT NORTH EAST, PA., WHERE SPRAYING EXPERIMENTS AGAINST THE GRAPE ROOT-WORM WERE CONDUCTED DURING 1907, 1908, AND 1909. THE DARK AREA IS THE UNSPRAYED PLAT. (ORIGINAL.)

So serious was the injury of the larvæ to the roots at this date that the large crop of fruit which some of these vines were carrying was actually shriveling up and dropping to the ground. By the following spring many of these vines had either died outright or were in a very weakened condition. Plate IV, figure 2, gives an example of the manner in which the fibers had been removed from the roots of many of these young vines by the larvæ of the root-worm, and shows the limited growth of new canes as a result of the infestation which rendered the vine incapable of producing a crop of fruit during the coming season. Thus the variety of conditions existing in this vineyard was such as to enable us to work out several features of the problem on the same block, namely, the effect of a poison-spray application on vines of different varieties, of different ages, and in different stages of injury, all growing side by side under practically the same conditions. All of the vineyard was subjected to the same treatment in regard to cultivating, fertilizing, and spraying, with the exception of six rows running through the center of the block (Pl. VI) which cut through all four of the sections mentioned above. These six rows were reserved as a check and from these the spraying alone was withheld.

Below are given all of the data relating to the experiment conducted on this vineyard during the seasons of 1907, 1908, and 1909, together with the results obtained.

As the time for the emergence of the beetles from the soil drew near daily visits were made to this vineyard during the latter end of June and early July, 1907. On July 15 an occasional beetle was found feeding on foliage near the ground. All preparations had been made for spraying as soon as the first beetles appeared, and the first application was made at this date. The sprayer used was a gasoline-engine power outfit constructed especially for vineyard work (Pl. X, fig. 2). The regular Bordeaux formula, 5–5–50, was used, and to this 3 pounds of arsenate of lead were added, this latter ingredient being the active poison agent of the spray. A pressure of about 100 pounds was maintained throughout the application, and about 100 gallons of spray mixture were applied per acre. Fixed nozzles were used of the eddy chamber type.

On July 23 a second application was made, the same formula being used and the same pressure maintained.

During the season of 1908–9 the same spray formula, machinery, and nozzle arrangement were used and the same pressure maintained. The only varying factor was the dates of application, which varied each season with the date of emergence of the beetles. To facilitate comparison, the dates of application, effect of spray on egg deposition, prevalence of larvæ at roots, and crop yield as compared with the unsprayed check are tabulated for the three seasons. (Tables XXVI, XXVII, and XXVIII.)

TABLE XXVI.—*Effect of poison spray against the grape root-worm as shown by relative occurrence of eggs in sprayed and unsprayed plats in Davidson vineyard for 1907, 1908, and 1909, North East, Pa.*

CHECK (UNSPRAYED) PLAT—YOUNG CONCORD VINES.

Date of application.	When examined.	Number of egg clusters found.				Estimated number of eggs.	Number of vines.	Number of canes.	Average number of eggs.	
		Large.	Medium.	Small.	Total.				Per vine.	Per cane.
	Aug. 2, 1907	92	163	246	501	11,950	25	55	478	217.2
	July 13, 1908	31	109	190	330	6,720	25	29	268.8	231.7
	July 19, 1909	41	41	74	156	4,020	25	35	160.8	114.8

SPRAYED PLAT—YOUNG CONCORD VINES.

Formula: 5 lbs. blue vitriol (copper sulphate), 5 lbs. lime, 3 lbs. arsenate of lead, 50 gallons water.

Date of application.	When examined.	Large.	Medium.	Small.	Total.	Estimated number of eggs.	Number of vines.	Number of canes.	Per vine.	Per cane.
July 15, July 23	Aug. 2, 1907	7	10	22	39	870	25	66	34.8	13.8
June 22, June 30	July 13, 1908	0	5	16	21	310	25	41	12.4	7.5
July 2, July 14	July 19, 1909	1	7	12	20	380	25	47	15.2	8.8

CHECK (UNSPRAYED) PLAT—OLD CONCORD VINES.

Date of application.	When examined.	Large.	Medium.	Small.	Total.	Estimated number of eggs.	Number of vines.	Number of canes.	Per vine.	Per cane.
	Aug. 2, 1907	52	136	213	401	8,810	25	69	352.4	127.6
	July 13, 1908	47	139	146	332	7,980	25	71	319.2	112.3
	July 19, 1909	35	57	91	183	4,370	25	68	174.8	64.2

SPRAYED PLAT—OLD CONCORD VINES.

Formula same as above (5–5–3–50).

Date of application.	When examined.	Large.	Medium.	Small.	Total.	Estimated number of eggs.	Number of vines.	Number of canes.	Per vine.	Per cane.
July 15, July 23	Aug. 2, 1907	4	13	13	30	720	25	72	28.8	10.0
June 22, June 30	July 13, 1908	2	13	10	25	590	25	64	23.6	9.2
July 2, July 14	July 19, 1909	0	7	7	14	280	25	81	11.2	3.4

CHECK (UNSPRAYED) PLAT—YOUNG NIAGARA VINES.

Date of application.	When examined.	Large.	Medium.	Small.	Total.	Estimated number of eggs.	Number of vines.	Number of canes.	Per vine.	Per cane.
	Aug. 6, 1907	32	74	77	183	4,590	25	49	183.6	93.6
	July 15, 1908	11	18	31	60	1,400	25	34	56.0	41.4
	July 19, 1909	3	9	15	27	570	25	51	9.6	4.7

SPRAYED PLAT—YOUNG NIAGARA VINES.

Formula same as above (5–5–3–50).

Date of application.	When examined.	Large.	Medium.	Small.	Total.	Estimated number of eggs.	Number of vines.	Number of canes.	Per vine.	Per cane.
July 15, July 23	Aug. 6, 1907	0	2	1	3	70	25	35	2.8	2.0
June 22, June 30	July 15, 1908	0	1	0	1	30	25	36	1.2	.69
July 2, July 14	July 19, 1909	1	4	7	12	240	25	51	9.6	4.7

TABLE XXVII.—*Effect of poison spray against the grape root-worm as shown by occurrence of larvæ at roots of vines in sprayed and unsprayed plats in Davidson vineyard in 1907, 1908, and 1909, at North East, Pa.*

Date of examination.	Number of vines.	Variety and age of vines.	Number of larvæ. Unsprayed plat.	Sprayed plat.
DIGGINGS MADE IN SUMMER OF 1907.				
September 5, 1907	1	Young Concord	92	6
Do.	1	Old Concord	91	1
Do.	1	Young Niagara	6	0
DIGGINGS MADE IN SUMMER OF 1908.				
August 26, 1908	10	Young Concord	214	40
August 25, 1908	5	Old Concord	86	4
Do.	5	Young Niagara	58	5
DIGGINGS MADE IN SUMMER OF 1909.				
September 8-9, 1909	5	Young Concord	39	0
September 10-15, 1909	5	Old Concord	13	0
September 11-15, 1909	5	Young Niagara	17	0

TABLE XXVIII.—*Davidson vineyard. Effect of spray applications on the crop yield for the seasons 1908 and 1909 at North East, Pa.*

Year.	Variety and age of vines.	Treatment.	Plat area.	Plat yield.	Value per basket.	Value per acre.	Spray benefit per acre.
FOR SEASON OF 1908.							
			Acre.	*Lb. baskets*	*Cents.*		
1908	Young Concord	Sprayed	½	101.8	13	$26.26	$5.20
1908	do	Unsprayed	½	81.8	13	21.06	
1908	Old Concord	Sprayed	¾	502.0	13	86.97	8.06
1908	do	Unsprayed	¾	455.0	13	78.91	
1908	Young Niagara	Sprayed	⅓	231.4	9	62.37	21.87
1908	do	Unsprayed	⅓	150.4	9	40.50	
FOR SEASON OF 1909.							
1909	Young Concord	Sprayed	½	435.8	11	$95.70	$47.96
1909	do	Unsprayed	½	217.0	11	47.74	
1909	Old Concord	Sprayed	¾	1,039.0	11	152.35	39.70
1909	do	Unsprayed	¾	836.0	11	112.65	
1909	Young Niagara	Sprayed	⅓	158.2	28	132.72	61.32
1909	do	Unsprayed	⅓	85.0	28	71.40	

The effect of the spray on egg deposition was obtained by stripping all of the loose bark from 25 consecutive vines in the sprayed portion and also in the check rows, making an actual count of the number of egg clusters deposited on an equal number of consecutive vines in the sprayed and unsprayed plats. This has proved to be one of the best ways to determine the immediate direct effect of spray applications. These examinations were made at a time, determined by careful observation, when the maximum number of eggs had been deposited, and before but few larvæ had hatched from the earliest deposited eggs.

All of the bark was carefully stripped from the vine and a count made of the egg clusters found. The number of eggs in these clusters may vary from 3 or 4 to 75 or even 100. Since it was impossible to make an actual count of the individual eggs, the clusters were classified, as the count was made during the examination of the vines, as *large* when they contained approximately 50 eggs or more, *medium* when they contained about 30 eggs, and *small* when they contained about 10 eggs. In this manner we obtained the estimated number of eggs per vine given in the Table XXVI dealing with egg deposition. A simple enumeration of the number of egg clusters deposited per vine regardless of the number of eggs which they contained would have given but an inadequate idea of the total number of larvæ which might infest the roots of these vines. The number of canes per vine is also given to indicate the size of the vine, since the limit of the area upon which the beetles could deposit eggs would have some influence on the number of clusters deposited.

The prevalence of larvæ at the roots of vines in sprayed and unsprayed plats was determined by making careful diggings at the roots of a given number of vines in both the sprayed and the unsprayed plats (Table XXVII). During these diggings the difference in the number of root fibers thrown out by vines in the sprayed and unsprayed plats was very noticeable. On May 13, 1908, after the vineyard had received the protection of one season's treatment with poison spray the root systems of several vines were examined in the block of young Concords. It was found that the roots of many of the vines in the unsprayed plat were almost entirely devoid of new root fibers, and that the large roots were badly channeled and pitted by the feeding of the larvæ of the grape root-worm, whereas the roots of vines examined in the sprayed portion of this vineyard showed that they had thrown out large masses of new fibrous roots during the growing season as a result of the protection the spraying had afforded them in the prevention of the deposition of eggs by the beetles. Plate IV, figure 1, will illustrate this luxuriant growth of new root fibers on roots of sprayed treated vines, practically all of which were produced during the growing season of 1907, as compared with the lack of them on the unsprayed vines (Pl. IV, fig. 2). These illustrations also indicate the recuperative power of badly injured grape vines when protection from the larvæ is afforded; for in the spring of 1907, previous to the protection of the vines by the poison spray, the roots of the vines in the sprayed plat were as devoid of root fibers as were those in the unsprayed plat, as was shown by diggings made in the spring of 1907.

Fig. 1.—Retarded growth of vines in the unsprayed plat. (Original.)

Fig. 2.—Vigorous growth of vines in the sprayed plat. (Original.)

VIEWS OF EXPERIMENTAL PLATS IN MR. ROSCOE DAVIDSON'S VINEYARD AT NORTH EAST, PA.

In addition to the above-described methods of comparing the effect of the treatment of this vineyard with a poison spray, an accurate count of the number of baskets of grapes picked from equal areas in the sprayed and unsprayed plats was made and their cash value for each season recorded. This data, covering the seasons 1907, 1908, and 1909, is presented in Table XXVIII.

Plate VII, figure 1, shows the light growth of the vines in the unsprayed plat as compared with Plate VII, figure 2, showing the heavy growth in the sprayed plat after three years' treatment.

RESULTS OF VINEYARD RENOVATION EXPERIMENTS.

At the time this investigation was commenced the feeling was quite common among vineyardists of North East, Pa., that it would be useless to attempt to restore to their former productivity some of the vineyards very badly injured by the root-worm, and that it would be cheaper to tear out these old vines and replant the ground to new vines. In view of the fact that our survey had shown that many young vineyards just coming into bearing were also declining very rapidly under attacks of the pest, and that a run-down condition of old vines was very common throughout the entire grape belt, it was deemed desirable to investigate as to what could be done in the way of renovating a badly run-down vineyard.

RENOVATION EXPERIMENT ON AN OLD VINEYARD.

During the fall of 1906 our attention had been called to the condition of 10 acres of old vineyard which in previous years had possessed the reputation of being very productive but had suddenly shown a rapid decrease in yield and also in growth of vine. The yield of this vineyard, which in 1905 was 6,597.5 pounds of fruit per acre, declined in 1906 to 1,697 pounds per acre, showing a decrease of 4,900.5 pounds and barely covering operating expenses. When visited by us in the fall of 1906 the foliage of these vines was found to be riddled by the beetles of the grape root-worm, the cane growth was stunted, and many vines simply threw out tufts of puny shoots near the lower wire of the trellis. The roots were almost devoid of fibers and badly scarred by the feeding of grape root-worm larvæ, and the fruit hung in scraggy clusters of undersized berries—in short, this vineyard had all the appearance of being in the last stages of production as a result of grape root-worm injury. In the spring of 1907 it was decided to undertake an experiment in this vineyard to determine if by ridding the vines of this pest, the vineyard could be restored to its former condition of profitable production. At this point it should be stated that the vineyard had received in previous years only indifferent cultivation and practically no fertilizing or spraying. The importance of these operations was recognized at the outset of the experiment and arrangements were made to give the vines thorough cultivation and liberal fertilizing in addition to thorough spraying with a poison and a fungicide; in fact, to treat the vineyard according to the most approved methods of vineyard management.

That spring when the vineyard was pruned many of the badly weakened vines were cut back to the ground and others to the lower wire of the trellis. Even on the most vigorous vines, not more than one to three fruit-bearing canes were left, it being thought desirable to concentrate the remaining energies of the weakened vines and force the vegetative growth rather than attempt to produce fruit of an inferior quality such as was borne by the vines during the season of 1906. In order that some light might be thrown on the effect of different kinds and amounts of fertilizer used in restoring these injured vines it was decided to divide the vineyard into seven plats of one acre each and the following kinds and amounts of fertilizer were applied:

Plat I. Barnyard manure, 7 wagon loads.

Plat II. Complete high grade commercial fertilizer, 1,000 pounds.

Plat III. Complete high grade commercial fertilizer, 1,000 pounds plus 100 pounds sodium nitrate.

Plat IV. Sodium nitrate, 400 pounds.

Plat V. High grade commercial fertilizer, 1,000 pounds.

Plat VI. High grade commercial fertilizer, 500 pounds.

Plat VII. No fertilizer; no spraying.

The brand of fertilizer used in 1907–8 analyzed available phosphoric acid, 11.28 per cent; potash, 5.89 per cent; nitrogen, 3.41 per cent. In 1909 a brand of fertilizer was used analyzing phosphoric acid, 8 per cent; potash, 8 per cent; nitrogen, 5 per cent. The plats commenced on the west side of the vineyard and ran eastward. Plats I, V, VI, and VII included seven rows measuring approximately one acre in area. Plats II, III, and IV contained 14 rows each, but all the data here given are reduced to a 7-row or 1-acre basis for convenience in comparison. The ground on which this vineyard is planted is quite level and is of a stony loam on the west side grading to an almost stoneless clay on the east side where it has been somewhat enriched by wash from a slight elevation lying immediately south, which doubtless is responsible for the greater productivity of plats 5, 6, and 7, at the beginning of the experiment.

The barnyard manure was spread broadcast over the rows of Plat I during the month of April. The commercial fertilizer was distributed on the other plats in two equal applications, the first being made May 21, when active growth of the vines commenced. The second application was made June 18, about one month later.

All of the fertilizer was applied with a broadcast fertilizer distributor and immediately followed by a spring-tooth cultivator.

The ground was plowed early in May and received three thorough cultivations during the summer. It should be observed at this point that this is by no means an attempt to solve the problem of vineyard fertilization, which belongs to the province of the horticulturist, and that the results obtained on these plats are presented without comment upon this feature of the experiment, leaving the reader to draw his own conclusions.

With the appearance of the first beetles all of the plats except the check plat received a thorough spraying with Bordeaux mixture and arsenate of lead, using the following formula: Copper sulphate, 4 pounds; quicklime, 4 pounds; arsenate of lead, 3 pounds. A second spraying with the same ingredients was made ten days to two weeks later. (See exact dates on Table XXIX, showing egg deposition.)

TABLE XXIX.—*Effect of poison spray against the grape root-worm as shown by relative occurrence of eggs on sprayed and unsprayed plats of the Porter vineyard during 1907, 1908, and 1909, at North East, Pa.*

UNSPRAYED PLAT.

Year	When examined.	Number of egg clusters found.				Estimated number of eggs.	Number of vines.	Number of canes.	Average number of eggs.		Date of spray application.
		Large.	Medium.	Small.	Total.				Per vine.	Per cane.	
1907..	Aug. 12, 1907	97	150	238	485	11,730	25	76	469.2	154.37	....
1908..	July 22, 1908	45	91	78	214	5,760	25	76	230.4	78.9	....
1909..	July 21, 1909	37	56	94	187	4,470	25	97	178.8	46.08	....

SPRAYED PLAT.

Formula: 4 lbs. blue vitriol (copper sulphate), 4 lbs. lime, 3 lbs. arsenate of lead, 50 gallons water.

Year	When examined.	Large.	Medium.	Small.	Total.	Estimated number of eggs.	Number of vines.	Number of canes.	Per vine.	Per cane.	Date of spray application.
1907..	Aug. 13, 1907	1	21	34	56	1,440	25	56	57.6	25.7	{July 13 July 22
1908..	July 22, 1908	0	10	4	14	340	25	58	13.6	5.8	{June 24 July 2
1909..	July 21, 1909	3	8	7	18	460	25	117	18.4	3.9	{July 5 July 16

The spray applications were made with a gasoline-engine spraying outfit specially mounted for vineyard work (Pl. X, fig. 2) having an arrangement of fixed nozzles, three on each side, the two lower of which throw the spray on the side of the vines as the machine passes through the rows. The upper nozzle reaches out over the top of the row throwing the spray downward so that it covers the new growth at the top of the trellis. This downward direction of the spray to cover the new growth at the top of the trellis is highly desirable since the beetles exhibit a tendency to feed more freely on this new growth, especially after the lower leaves have been coated with a poison spray. A pressure of from 100 to 125 pounds was maintained throughout the operation, using about 100 gallons of spray liquid per acre. With this spraying outfit it is possible to cover from 8 to 10 acres of vineyard per day.

METHODS OF OBTAINING AND RECORDING RESULTS.

As in the preceding field experiment, the results of the spray application were determined by counting the number of egg clusters deposited on the vines by the grape root-worm beetles at a time when the maximum number of eggs were to be found upon the vines. All of the bark was removed from 25 consecutive vines in the unsprayed plat and also in the adjoining sprayed plat. The results of these examinations are given in Table XXIX for the three seasons 1907, 1908, and 1909. Table XXX indicates the effect on the larvæ of spraying as shown by the number of larvæ found at the roots of the vines by carefully removing the soil from the base of the vine for a distance of 3 or 4 feet from the trunk of the vine and to a depth of a foot or 16 inches, going several inches below the second whorl of roots.

TABLE XXX.—*Effect of poison spray against the grape root-worm as shown by relative occurrence of larvæ at roots of vines in sprayed and unsprayed plats of Porter vineyard, at North East, Pa., in 1907, 1908, and 1909.*

Date of examination.	Number of vines.	Variety and age of vines.	Number of larvæ.	
			Unsprayed plat.	Sprayed plat.
April and May	40	20-year Concord	76	
September 25, 1907	5	do	92	
May 27-28, 1908	10	do	100	21
June 19, 1909	12	do	67	7
September 25, 1909	5	do	115	19

When the crop was ready to harvest, the final effect of the season's treatment was obtained for each plat. Table XXXI indicates the plat number, area, fertilizer applied, number of crates or baskets of grapes, net weight of fruit, value per pound or basket, cash value per acre, cost of spraying and fertilizing, and value of crop less cost of treatment.

The data in Table XXXI, giving the results of the treatment from 1907 to 1909, inclusive, show a great increase in crop yield of this vineyard as a result of thorough spraying and heavy fertilization. This experiment proves conclusively that if energetic measures are taken with vineyards rendered practically unprofitable as a result of grape root-worm injury they may be made to yield very profitable crops.

TABLE XXXI.—*Crop yield of plats in renovation experiments for 1907, 1908, and 1909, at North East, Pa.*

Plat number.	Plat area.	Kind of fertilizer used.	Number of 8-pound baskets per acre.	Net weight of fruit in pounds per acre.	Average value of fruit per 8-pound basket for 1907, 1908, 1909.	Value of fruit per acre.	Cost of two spraying applications per acre.	Cost of fertilizer and application per acre.	Value of fruit less cost of spraying and fertilizing per acre.
		FOR SEASON OF 1907.							
	Acre.				*Cents.*				
I	1	Barnyard manure	129	968	12½	$16.11	$4.00	$22.00	−$9.89
II	1	Commercial fertilizer, 1,000 pounds.	198	1,485	12½	24.75	4.00	18.50	2.25
III	1	Commercial fertilizer, 1,000 pounds; sodium nitrate, 100 pounds.	211	1,590	12½	26.37	4.00	21.00	1.37
IV	1	Sodium nitrate, 400 pounds	194	1,460	12½	24.25	4.00	10.50	9.75
V	1	Commercial fertilizer, 1,000 pounds.	308	2,310	12½	38.50	4.00	18.50	16.00
VI	1	Commercial fertilizer, 500 pounds.	255	1,917	12½	31.87	4.00	9.50	18.37
VII	1	No fertilizer; no spraying	263	1,975	12½	32.87	....	....	32.87
		FOR SEASON OF 1908.							
	Acre.				*Cents.*				
I	1	Barnyard manure	427	2,606	12½	$53.37	$4.00	$22.00	$27.37
II	1	Commercial fertilizer, 1,000 pounds.	482	2,921	12½	60.25	4.00	18.50	37.75
III	1	Commercial fertilizer, 1,000 pounds; sodium nitrate, 100 pounds.	590	3,542	12½	73.75	4.00	21.00	48.75
IV	1	Sodium nitrate, 400 pounds	649	3,912	12½	81.12	4.00	10.50	66.62
V	1	Commercial fertilizer, 1,000 pounds.	681	4,153	12½	85.12	4.00	18.50	62.62
VI	1	Commercial fertilizer, 500 pounds.	630	4,022	12½	78.75	4.00	9.50	65.25
VII	1	No fertilizer; no spraying	535	3,369	12½	66.87	....	....	66.86
		FOR SEASON OF 1909.							
	Acre.				*Cents.*				
I	1	Barnyard manure	1,188	9,049	12½	$148.50	$4.00	$22.00	$122.50
II	1	Commercial fertilizer, 1,000 pounds.	1,282	9,898	12½	160.26	4.00	18.50	137.76
III	1	Commercial fertilizer, 1,000 pounds; sodium nitrate, 100 pounds.	1,184	9,146	12½	148.00	4.00	21.00	123.00
IV	1	Sodium nitrate, 400 pounds	1,037	8,372	12½	129.62	4.00	10.50	115.12
V	1	Commercial fertilizer, 1,000 pounds.	1,171	9,090	12½	146.37	4.00	18.50	123.87
VI	1	Commercial fertilizer, 500 pounds.	1,260	9,580	12½	157.50	4.00	9.50	144.00
VII	1	No fertilizer; no spraying	855	6,412	12½	106.87	....	....	106.87

In examining the yields for the various plats it will be observed that in the first year of the experiment plats I, II, III, and IV fell considerably below the unsprayed and unfertilized plat. This condition is due in a great measure to the fact that vines in plats V, VI, and VII were in a somewhat more thrifty condition at the outset of the experiment. The soil in these plats grades to a clay loam and has been enriched somewhat by the wash from an elevation immediately south of them. While the untreated plat shows great improvement in yield simply as a result of thorough cultivation, yet the annual increase in yield on this plat was much less than that upon the treated plats in the same soil.

In addition to this increase in crop yield there was noted a great improvement in the quality of the fruit both in size of berries and of clusters. Plate IX, figure 2, gives a comparison of the size and compactness of fruit on a vine in the sprayed portion as compared with fruit on a vine in the unsprayed portion shown in Plate IX, figure 1.

It was also found that the fruit in the sprayed plats remained firm and that there was practically no loss from shelling of the berries, whereas the fruit and stems in the unsprayed plat were badly mildewed and there was a great deal of shelling of berries. This benefit is derived from the fungicidal effect of the Bordeaux mixture. This increase in crop yield has also been accompanied by a marked improvement in the vigor of the vines throughout this vineyard. Practically all of the vines are now in a condition to produce a full crop of fruit, and there is no reason why this vineyard should not continue to produce as profitable crops as it did previous to its infestation, provided it is subjected to treatment similar to that which it has received during this investigation.

Plate VIII affords a comparison of the growth of vine at the beginning and at the end of the experiment, the upper figure showing the vineyard at the beginning of the experiment, and the lower figure after three years' treatment.

RENOVATION EXPERIMENT ON A YOUNG VINEYARD.

About the year 1900 there was a heavy planting of new vineyards throughout the Lake Erie grape belt. Scarcely had these young vines come into bearing when the owners noticed a rapid decline both in their crop yield and in vigor of vines. Close observation indicated that this decline was due largely to injury by the grape root-worm, and that the decline of these young vines was even more rapid than in the case of older, well-established vines. In many vineyards it was found that young vines had been killed outright in a single season.

VIEWS OF THE PORTER EXPERIMENTAL VINEYARD, SHOWING COMPARATIVE GROWTH OF THE VINES IN 1907 AT THE BEGINNING OF THE EXPERIMENT (UPPER FIGURE), AND IN 1909 AT THE END OF THE EXPERIMENT (LOWER FIGURE), NORTH EAST, PA. (ORIGINAL.)

Fig. 1.—Average condition of berries in the untreated plat, North East, Pa., 1909. (Original.)

Fig. 2.—Average condition of berries in the treated plats, North East, Pa., 1909. (Original.)

CONDITION OF FRUIT ON VINES IN PLATS OF THE PORTER EXPERIMENTAL VINEYARD.

During the summer of 1907 our attention was called to the condition of a young vineyard near North East, Pa., belonging to Mr. H. E. Mosher, which for the first three years of bearing had maintained a very thrifty condition. The soil of this vineyard had been well cultivated and heavily fertilized with barnyard manure, yet in spite of this favorable treatment the crop yield in 1907 decreased to an alarming extent, amounting only to about one-eighth of the value of the yield for the previous season.

This vineyard is about 5 acres in extent. The crop value in 1904, first year bearing, was $127.51; in 1905 it was $410.77; in 1906 it was $435.72, but in 1907 it was only $55.92

There is every reason to believe that the grape root-worm was directly responsible for the sudden decline of these vines, for when the roots of many of the vines, which were practically dead, were examined by us they were found to be entirely devoid of fibrous roots, and the whiplike larger roots and the crowns of the vines were badly furrowed and scarred as a result of feeding by the full-grown larvæ (Pl. III). From one section of this vineyard, about 2½ acres in area, containing 1,584 vines, 563 dead vines were removed in the spring of 1908. In addition to this, about 50 per cent of the remaining vines were cut back either to the ground or to the lower wire of the trellis, thus greatly limiting their fruit production for the coming season. So discouraged was the owner with the condition of this vineyard that he was at the point of pulling out all of the vines and replanting it anew. At our request, however, he permitted us to plan a renovation experiment on this section to determine if the vines could be restored to a thrifty condition and again produce profitable crops. This experiment was commenced in the spring of 1908. The remaining vines were severely cut back, as mentioned above, and new vines planted in the place of those which had been removed. The vines were heavily fertilized with a high-grade fertilizer. In this case, owing to the limited root area, as a result of the feeding by the larvæ, it was deemed desirable to sprinkle the fertilizer by hand about the base of the vines instead of scattering it broadcast over the whole area between the rows. Twelve rows received an application of 400 pounds of nitrate of soda and 24 rows received an application of high-grade commercial fertilizer at the rate of 2,000 pounds per acre. This fertilizer was distributed in two applications; the first on May 21, when active growth was well started, and the second about a month later.

With the appearance of the first beetles, June 23, 1908, the vines were sprayed thoroughly with Bordeaux mixture and arsenate of lead, using 4 pounds of copper sulphate, 4 pounds of stone lime, and 3 pounds of arsenate of lead to 50 gallons of water. On July 2, 1908, a second application was made, using the same formula as for the first application. The spray was applied with a traction sprayer at a pressure of about 100 pounds, and about 100 gallons of fluid were used per acre, covering the vines quite thoroughly with a fine spray. The whole 5 acres were included in each of these two spray applications. As a result of this treatment most of the vines made quite a vigorous growth of wood, which gave a good supply of bearing canes for next season. Owing to the severity with which these vines were cut back in the spring, the cash value of the crop from the 5 acres was $31.02.

The treatment given this section of vineyard in 1908 was duplicated during the summer of 1909. The same amount of fertilizer was applied, and two applications of spray were made, the first application June 29, the second July 8. As a result of the second season's treatment the vines have taken on a healthy appearance and made a vigorous growth of new canes. The number of grape root-worm beetles has been reduced to a minimum, as shown by the small amount of feeding on the foliage and by the number of egg clusters deposited. An examination made on July 24 showed but nine egg clusters on 25 sprayed vines as against 73 egg clusters on the same number of unsprayed vines. Diggings made in search of larvæ showed a similar condition. Only three larvæ were found about the roots of five sprayed vines as against 55 larvæ found about the roots of five untreated vines. The crop value for the season of 1909 for the 5 acres was $213.92 as against $31.02 for the season of 1908. The vineyard has made sufficient growth of vines during the season to enable the owner to put up enough bearing canes to produce a full crop for 1910.

The additional cost of the operations of spraying and fertilizing for the seasons of 1908 and 1909, over and above ordinary vineyard management, amounted to $135, itemized as follows:

Nitrate of soda, 1,000 pounds	$25.00
Complete fertilizer, 2 tons	70.00
Spray material and labor, $4 per acre	40.00

The success of this attempt to restore this 5 acres of vineyard to its former state of productivity can not be better summarized than by presenting the following figures showing net weight of fruit and the crop value for the years 1904 to 1909, inclusive:

	Pounds.	Value.
1904	11,630	$127.51
1905	23,705	410.77
1906	21,130	435.72
1907	3,195	55.92
1908	4,390	31.02
1909	19,935	213.92

The owner of this vineyard is greatly pleased with the results obtained by the treatment described above and is satisfied that a continuation of these methods will in another season restore his vineyard to its full bearing capacity of 1905. It might be added that previous to this experiment Mr. Mosher was very skeptical regarding the possibility that this pest could work such havoc in vineyards and also as to the value or necessity of a spray treatment. During this experiment, however, he has become a thorough convert, and is satisfied that the intelligent use of a poison spray has been the chief factor in the restoration of his vines.

SPRAYS.

ARSENICAL POISONS.

Arsenic in some form or other is usually the active killing agent used against insects which secure their food by chewing upon the foliage or fruit of plants, and since the grape root-worm beetles belong to the category of chewing insects the direct killing agent (or stomach poison) applied to grapevines is the arsenical poison which the spray mixture contains.

There are several forms of arsenicals used as insecticides. Those that have been most commonly used in the past are Paris green and arsenite of lime. Arsenite of lime is a common home-prepared insecticide made by boiling together, for about 20 minutes, 1 pound of white arsenic with 4 pounds of sal-soda crystals in 1 gallon of water. This is known as the Kedzie formula; and when used with water, milk of lime made by slaking 2 or 3 pounds of good stone lime must always be added to 50 gallons of the mixture; for the boiling of the sal-soda with the arsenic is simply to put all of the arsenic into solution in order that all of it may unite with the lime to form arsenite of lime. When used with Bordeaux mixture this addition of lime is not necessary.

Another arsenical poison and the one which has largely displaced both Paris green and arsenite of lime as a stomach poison for use on foliage is arsenate of lead. In properly made arsenate of lead less than 1 per cent soluble arsenic is present, whereas in Paris green and arsenite of lime a much higher percentage of arsenic may be soluble or exist in a weakly combined state, and since it is this soluble arsenic which is injurious to foliage a much higher strength of the arsenate of lead can be used without danger of injuring the foliage. In addition to having this advantage the lead base makes the arsenate of lead much more adhesive to the foliage than either Paris green or arsenite of lime. The chief element in favor of the two latter arsenicals is that they are somewhat cheaper than arsenate of lead. However, within the past few years the increased consumption of arsenate of lead for spraying purposes and the sharper competition among manufacturers to secure the trade have been the means of considerably lowering its cost to the consumer and the matter of price should no longer be a bar to its use.

COMBINING INSECTICIDES WITH FUNGICIDES.

Since the use of a fungicidal spray for grapevines is highly desirable and frequently absolutely necessary to hold in check fungous diseases such as mildew and black-rot, and since some of the applications for these fungous diseases and the insect pest may be made at the same date, it has become customary to combine the two treatments by adding poison in the form of arsenate of lead to Bordeaux mixture, the fungicide used against the fungous diseases.

The formula recommended for this combined treatment is as follows:

	Pounds.
Copper sulphate (blue vitriol)	5
Fresh stone lime	5
Arsenate of lead	3
Water	50

When Paris green or arsenite of lime are the arsenicals used, 4 ounces of the former, or 1 quart of the latter prepared according to Kedzie's formula, may be added to 50 gallons of Bordeaux mixture. For reasons given above the use of arsenate of lead in preference to either of these other arsenicals is strongly urged. We here include detailed directions for making Bordeaux mixture which are given by Mr. C. L. Shear, of the Bureau of Plant Industry, in Farmers' Bulletin 284, treating of fungous diseases of the grape.

PREPARATION OF BORDEAUX MIXTURE.

Failure to secure satisfactory results from the use of Bordeaux mixture is frequently due to lack of proper care and thoroughness in its preparation, or to the use of poor material. All ready-made preparations of Bordeaux mixture in the form of a paste or a dust should be avoided, as the chemical constitutents do not properly combine in these conditions. A definite chemical compound is desired, and this can only be produced in proper form and condition by carefully following the directions given below:

Stock solution.—In order to carry on the work with the greatest convenience and economy, a considerable quantity of copper sulphate and of lime should be ready for immediate use. The copper and the lime may be prepared and kept most conveniently in the following manner:

Copper sulphate solution.—Take 100 pounds of copper sulphate (bluestone), place it in a gunny sack, and suspend it in a 50-gallon barrel of water. Kerosene or whisky barrels will be found very convenient. The copper sulphate will all dissolve in from 12 to 18 hours if suspended in a loosely-woven sack, but if it is thrown loose in the bottom of the barrel it will take several days and considerable stirring to dissolve it. This makes a solution containing 2 pounds of copper sulphate to each gallon of water. This may be kept as long as desired without deterioration, if covered so as to prevent evaporation.

Lime solution.—The various kinds of ground and prepared lime can not always be relied upon; stone lime is therefore to be preferred, and is more likely to give uniformly satisfactory results. Slake 100 pounds of stone lime in a 50-gallon barrel, adding the lime in small quantities with sufficient water and mixing thoroughly. When the lime is all slaked fill the remainder of the barrel with water. You will now have a stock preparation of lime which when thoroughly mixed will be thin enough to dip, and pour readily. Each gallon of this preparation will contain 2 pounds of stone lime. This may be kept under cover and used as needed. Where large quantities of material are being used it is desirable to have two or more barrels each of stock lime and bluestone instead of one, so that the bluestone in one barrel may be dissolving while that in the other is being used.

Mixing copper sulphate solution and lime solution.—To prepare a 100-gallon spray tank of Bordeaux mixture, take two 50-gallon barrels and fill them nearly full of water; to one barrel add 5 gallons of the bluestone stock solution, which will be equivalent to 10 pounds of bluestone. To the other barrel add 5 gallons from the barrel of the stock lime preparation, which will be equal to 10 pounds of stone lime. Mix the lime thoroughly and allow the contents of the two barrels to run together in a trough, or through hose attached at the bottom of the barrels into the tank of the sprayer.

If an insecticide is to be used, it may now be added to the mixture.

After the mixture is prepared it should be used very soon, and not be allowed in any case to stand more than a few hours before using.

The quantities mentioned in this account of the preparation of Bordeaux mixture will give 100 gallons of the 5–5–50 formula. For the other formulas, the manner of preparation is precisely the same, and the necessary changes in quantities of bluestone and lime are easily calculated.

PLANTS FOR PREPARATION OF THE SPRAY MIXTURE.

Plate X, figure 1, shows a mixing plant erected beside a creek in a vineyard, using a hydraulic ram to elevate the water to the tank, the lime being slaked and the copper sulphate dissolved in the barrels standing upon the ground. An abundant water supply which can be delivered to the sprayer tank either by pressure or by gravity greatly minimizes both the cost and labor of preparing spray mixtures and in addition saves a great deal of time at a season when the vineyardist is almost overwhelmed with the routine work of vineyard operations.

Lack of preparation for spraying operations and failure to utilize to the greatest advantage the flow of water down creeks or from springs adjoining vineyards, either by gravity or by the use of hydraulic rams, to elevated mixing stations frequently cause the vineyardist who is rushed with work either to neglect spraying entirely or to be so delayed in making the application that it is only partly effective; whereas if plans are made in advance to simplify the mixing and loading of the spray mixture, the apparent magnitude of the task is greatly lessened. The thing of prime importance is for the vineyardist to become thoroughly convinced that spraying is one of the absolutely necessary operations in successful vineyard management.

TIME OF APPLICATION OF SPRAYS.

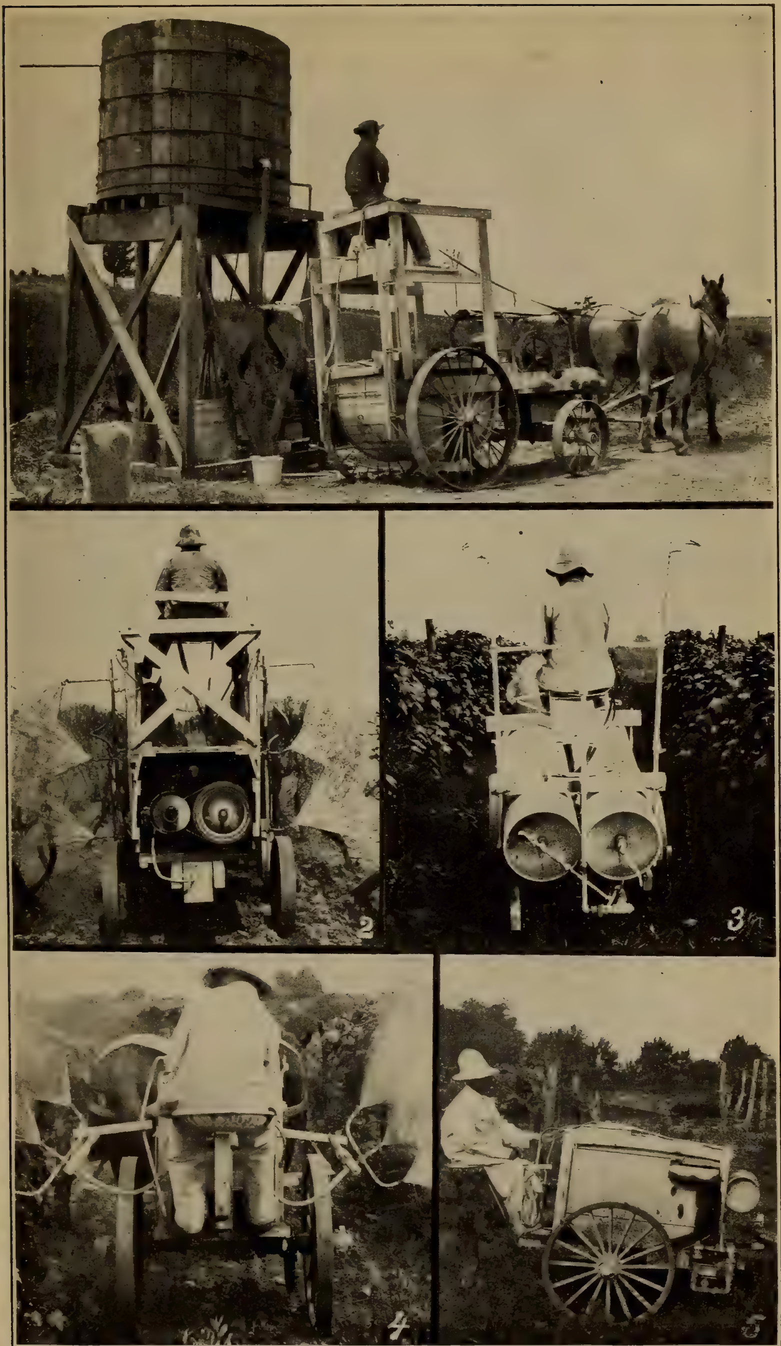
Much time and labor is actually wasted in making spray applications after beetles have done considerable feeding and deposited many of their eggs. The necessity of having all equipment and material in readiness to make the first application as soon as the first beetles appear can not be too strongly emphasized. There is no doubt that the indifferent results secured from spraying by many vineyardists is largely due to failure to make the first application as soon as the first beetles appear upon the vines.

Unfortunately no definite date can be set for the making of this first application on account of the wide range in the date of emergence of beetles from the soil from year to year, due to variations in seasonal temperature conditions, especially during the spring months. Our records show that the beetles emerged fully three weeks later in 1907 than in 1908 and spraying operations had to be planned accordingly.

Normally the first beetles may be expected to appear between the 20th and 25th of June. It should not be inferred, however, that the insect does not exist in the vineyards in serious numbers if the beetles are not in evidence at the latter date, for it happens that even experts have been led astray, as occurred in Chautauqua County, N. Y., in the spring of 1907, when experts visited the grape belt during the first week in July and, finding no beetles at this date, inferred that the pest no longer existed in very injurious numbers. Yet late in July it was found that beetles had emerged in enormous numbers in many vineyards throughout the area visited. This emphasizes the fact that only by the closest observation can the vineyardist determine the damage which this insect may inflict upon his vines and he must be fully prepared every season to combat the pest on its first appearance. A more detailed discussion of the changes in time of emergence of the beetles from year to year is given under the head of seasonal history of the insect.

NUMBER OF SPRAY APPLICATIONS.

During this investigation it has been learned that two thorough spray applications will reduce this pest to numbers which will not materially affect the health of the vine or the production of profitable crops. The second application should be made about a week or ten days after the first to cover the growth of new foliage which has developed, and also to destroy those beetles which may not have emerged from the soil at the time the first application was made. Since rearing records indicate that the maximum number of beetles emerge within the period of ten to fifteen days after the first beetles appear (see fig. 23) the small percentage of late emerging beetles will not be likely to effect very great injury. The fact that there is some



SPRAYING OUTFITS FOR VINEYARDS, IN USE AT NORTH EAST, PA.

Fig. 1.—Spray-mixing plant. Fig. 2.—Gasoline-engine sprayer in operation. Fig. 3.—Compressed-air sprayer. Figs. 4, 5.—Horsepower or geared sprayers. (Original.)

danger of staining the fruit with spray applications made much later than the middle of July is an additional reason for making the second application not later than that date.

Nearly every season since spraying grapevines with a poison has become a practice there has been more or less rumor concerning illness of persons by poisoning resulting from the eating of sprayed grapes. We have given considerable attention to looking up reports of this nature but have never been able to secure direct evidence of poisoning of persons in this manner. From our observations and

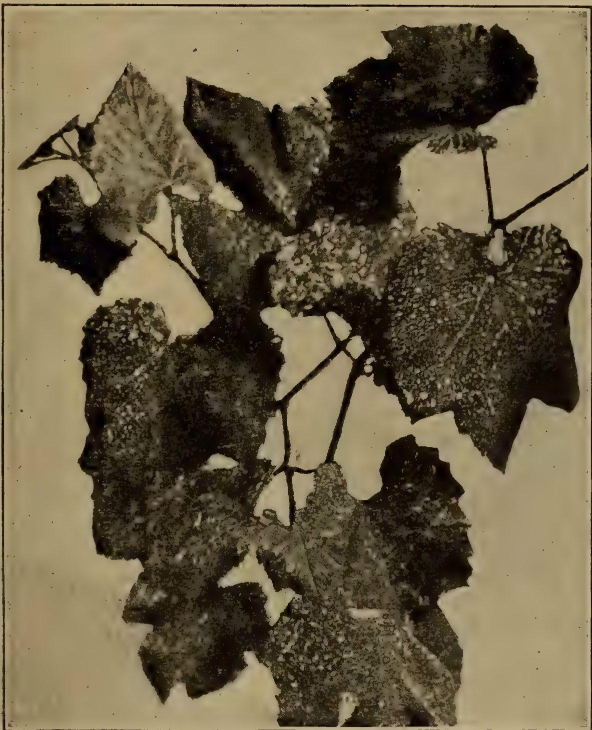


FIG. 30.—Young grapevine sprayed with arsenate of lead against the beetles of the grape root-worm. North East, Pa., 1909. (Original.)

experiments with poison sprays against the grape root-worm beetle and all other insect pests known to us at present in vineyards in the Lake Erie Valley, all applications should be made in normal seasons not later than the middle of July, and in exceptionally late seasons like that of 1907 not later than July 25. If vineyardists will endeavor to make their last poison application before that date they need have no fear of either staining their fruit or creating cause for rumor of poisoning by persons consuming the same and also may feel assured that they have made the applications at a period when they will prove most effective in the control of this pest.

PRESSURE TO BE MAINTAINED IN SPRAY APPLICATIONS.

In order that effective results may be obtained with poison sprays it is very desirable that, as nearly as possible, all of the foliage be covered with a mistlike spray. (See fig. 30.) Since in many vineyards having thrifty growing vines the foliage is quite dense during the latter part of June and early July it is necessary that this finely divided spray be thrown into the vines with considerable force. For effective work a steady pressure of not less than 100 pounds should be maintained and if this can be increased to 125 or 150 pounds still better work may be accomplished.

SPRAYING APPARATUS.

In order to cover vineyard areas of several acres in this manner it has become necessary to use power sprayers and during the past few years several types of power vineyard sprayers have come into use.

Horsepower sprayers.—Geared sprayers operated by horsepower (Pl. X, figs. 4, 5) are in general use in many vineyard sections. There are a number of sprayers of this type upon the market. With many of them, however, it is difficult to maintain a sufficiently high pressure to cover thoroughly all of the foliage without driving through the vineyard at too rapid a rate. In addition to this the nozzle arrangement is not adjusted so as to cover the foliage on the top of the trellis. A very unpleasant feature in the operation of many of these machines is that the driver is seated directly between the nozzles which are attached to the sides of the machine and consequently is drenched with the spray. It would seem however, that with a little ingenuity on the part of the manufacturers this unpleasant seating position and ineffective nozzle arrangement could be satisfactorily adjusted.

Gasoline-engine sprayers.—Many vineyardists prefer to have the power for providing pressure independent of the rate at which the machine travels through the vineyard and more directly under the control of the operator than it is with the geared sprayers. Since, however, the regulation gasoline-engine outfit used for spraying orchards is too heavy and cumbersome to use in the narrow rows of vineyards it has become necessary to mount the tank and machinery on a specially constructed shortened truck having low front wheels to admit of easy turning into the narrow vineyard rows. Plate X, figure 2, is an illustration of this type of gasoline-engine vineyard outfit and is the sprayer used for the past three seasons in making the application of poison sprays in the field experiments conducted during this investigation. An outfit of this kind has the additional advantage of being adaptable for use as an orchard outfit by simply disconnecting the fixed nozzles at the pump and connecting a lead of hose and rod when wishing to spray trees. It was for the purpose of tree spraying that the derrick or platform was erected above the tank. When used for vineyard work the derrick proved useful as an elevated seat where the driver would be clear of the spray. (See Pl. X, fig. 2.)

Compressed-air outfits.—Compressed-air outfits are a type of sprayer which find favor with a number of vineyardists and perform excellent work. The air is compressed by means of a stationary engine at the loading station and one of the cylindrical tanks is charged with air and the other filled with the spray liquid. The two tanks are connected so that the air may pass into the tank containing the liquid and force it out through the nozzles in the form of a fine spray. Since there is no machinery connected with this sprayer except at the loading station there is practically no danger of delay from machinery getting out of order while working in the field.

Carbonic-acid-gas sprayers.—Carbonic acid is employed as power in a similar manner to compressed air. It is, however, somewhat more expensive than either horsepower engines, gasoline engines, or compressed air. More or less difficulty sometimes occurs in procuring the drums of gas, which have to be obtained from large cities where this gas is manufactured. Yet there are many of these outfits in use and giving good satisfaction.

Hand pumps.—Where but limited areas of vineyard are to be treated quite effective work may be done with a pump operated by hand to treat vines, and in gardens or places where it is impossible to drive a cart a knapsack sprayer may be used. For larger areas, however, it will be found more economical to use power outfits.

The care of spraying apparatus.—For the successful operation of spray pumps it is highly desirable that the working parts be made of brass, since iron is acted upon by Bordeaux mixture. It is also important that the pump be so constructed that packing can be conveniently removed and replaced. Each time after the pump is used a few pailfuls of water should be run through the pump, hose, and nozzles to remove all of the spray mixture so that sediment in the mixture may not dry up and clog the valves and nozzles while the machine is not in use. If this precaution is taken much annoyance may be avoided when the machine is next put in operation.

Nozzle adjustment.—Practically all of the power sprayers are equipped with adjustable nozzles attached to a vertical rod firmly fastened to the sides of the tank, usually at the rear end of the machine. There are usually two or three of these nozzles set horizontally to throw the spray into the side of the vines. In addition to these horizontally directed nozzles, the uppermost nozzle should be carried out over the top of the trellis and directed downward to insure the covering of all the foliage on the top of the trellis (Pl. X, figs. 2, 3), since it is upon the new growth developing at the top of the trellis that the beetles are likely to do much feeding, especially after the lower foliage has been thoroughly covered with a spray mixture.

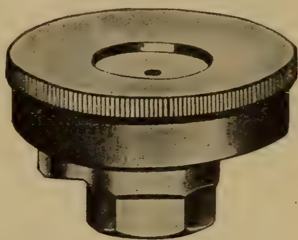


FIG. 31.—A large nozzle of the cyclone type. (Original.)

Nozzles.—Nozzles of the Vermorel type are the kind in general use for vineyard spraying and produce a fine mistlike spray which is so necessary for effective work, and for this reason they are more desirable than nozzles of the Bordeaux type, which throw a heavier, fan-shaped spray. The chief drawback with the ordinary Vermorel nozzles lies in the rapid wearing out and enlarging of the opening of the cap, resulting in a coarse spray if allowed to become too much worn. More recently larger nozzles of the Cyclone type (fig. 31) have come into general use, especially where high pressure with power machinery is used. These nozzles throw a larger cone of spray, have steel disks for caps, which can be removed when the opening becomes much worn, and possess the added advantage of not clogging so readily as the smaller Vermorel nozzles.

RECOMMENDATIONS.

DESTRUCTION OF THE ADULTS OR BEETLES.

The beetles of the grape root-worm feed upon the upper surface of the leaves of the grapevine, and may be poisoned by thoroughly spraying the foliage of the vines with an arsenical. The first poison-spray application should be made as soon as the first beetles are found upon the vines. Our observations indicate that the beetles feed much more freely immediately after emergence from the soil than they do several days later, during the period of egg deposition, and since the object of this application is to prevent egg deposition, it is very desirable that the poison application be made early, so that the first meal of the beetle will consist of poisoned foliage.

The beetles may be expected to appear on the foliage during the last week or ten days in June or the first few days in July, depending on the earliness of the season. After June 20 vineyardists should keep a sharp watch for their appearance and have their spray equipment in readiness to make the first spray application.

The development of the pupa in the soil will also indicate approximately the appearance of the beetles, for they may be expected to appear within a week or ten days after the pupæ can be found in the soil in considerable numbers. Since a large majority of the beetles emerge from the soil from ten to fifteen days after the appearance of the first beetles, it is necessary to make a second spray application within a week or ten days after the appearance of the first beetles. In this way it will be possible to keep the foliage well covered with poison spray during the emergence of a maximum number of the beetles.

Observations and experiments indicate that, if these two applications are made promptly and thoroughly, this pest can be reduced to such small numbers that it will not materially affect the vigor of the vines.

The spray formula recommended is as follows:

Arsenate of lead	pounds..	3
Water	gallons..	50
Copper sulphate (blue vitriol)	pounds..	5
Lime (fresh lump lime)	do....	5

The first ingredient of the formula, arsenate of lead, is the arsenical poison and the active killing agent or insecticide. The two last ingredients, copper sulphate and lime, with the water, form Bordeaux mixture, which is a fungicide used to control black rot, mildew, and other fungous diseases of the grape. Fortunately this insecticide and this fungicide can be mixed without changing the quality of either, and for this reason their use in combination is recommended.

DESTRUCTION OF THE PUPÆ.

In the vineyards throughout the Lake Erie grape belt pupation of the grape root-worm may be expected to commence about June 10, reaching the maximum about June 15 to 18. These dates can not be fixed, however, on account of variation in weather conditions. The exact time of pupation of the insect can best be determined by the person operating the infested vineyard by carefully removing the soil around the base of infested vines to a depth of from 2 to 4 inches.

When pupæ are discovered, the soil beneath the trellis should be removed by the horse hoe and the soil directly around the base of the vine carefully and thoroughly stirred with a hand hoe. The efficiency of this method of destroying the pupæ may be increased by throwing up a ridge of earth beneath the trellis during the last cultivation of the preceding summer. This will tend to encourage the insects to form their pupal cells above the roots of the vine and thus admit of their destruction by cultivation without serious injury to the roots of the vine by the horse hoe.

It is in these two stages—namely, the pupa and the beetle—that the insect appears to be most readily overcome; in fact, no effective measures have yet been developed for the destruction of the larvæ or of the eggs. Experiments conducted against the larvæ in the soil with oils, carbon bisulphid, fertilizers, salt, etc., have proved ineffective, and in some cases injurious to the grapevine; and since the eggs are deposited beneath the bark of the canes when the vines are in full foliage, it is practically impossible to reach them with a spray application.

GENERAL TREATMENT OF INFESTED VINEYARDS.

In addition to these recommendations dealing with direct means of controlling the insect in producing vineyards, a few suggestions are offered concerning the care and treatment of newly planted vines, and also of old, run-down vineyards in relation to this insect problem.

Serious injury is most likely to occur to young vines planted in soil on which infested vines were growing during the preceding season, for this soil is likely to be heavily infested with grape root-worm larvæ which will transform to beetles. These emerging beetles readily discover the newly planted vines and soon riddle the leaves of these small plants. For this reason it is very desirable, when the replanting of an old vineyard area is found necessary, that some annual crop be grown for at least one season, in order that the soil may be free of the insect when the new vines are planted.

In order that newly planted vines may be maintained in a thrifty condition during the period between planting and the bearing of the first crop of fruit, the vineyardist should keep a sharp watch during the month of July for the appearance of the grape root-worm beetles upon his young vines. When the beetles are numerous, they skeletonize many of the leaves, and this greatly retards the growth of the plant. If the infested vines are thoroughly sprayed with arsenate of lead at a strength of 3 pounds to 50 gallons of water, the injury by the beetles may be in a great measure prevented.

There is little danger that young vines will become reinfested during the first season, since there is a very limited amount of cane or stem upon which the beetle can deposit its eggs. By the second summer, however, the area upon which eggs may be deposited is somewhat increased, and we have discovered occasional egg clusters of this insect under the loose bark of the short stem of 1-year-planted vines and have also found a few larvæ at their roots late in summer, indicating that permanent infestation may take place early in the life of the vineyard. Hence it may be necessary to spray some vineyards from the time of planting.

Generally it is during the third season's growth of the vines, when the cane is trained to the trellis, that serious permanent infestation, by means of egg deposition by the beetle, takes place. The larvæ hatching from these eggs are especially injurious to these young vines, which possess but a limited root system compared with that of an old-established producing vine. It is the opinion of the writers that the first year or two of fruit production of young vines exposed to infestation is the most critical period of their existence, and especial care should be taken during that period to prevent infestation by the beetles. This can be accomplished by following the suggestions made on pages 89–90, giving directions for the destruction of the beetles.

When vines in a producing vineyard have been badly injured by this pest, such vines may frequently be renovated by cutting them back to the ground, so that the limited vitality of the injured vine may be devoted entirely to the making of vegetative growth. A heavy application of fertilizer should be made, consisting either of barnyard manure or a commercial fertilizer containing a high percentage of nitrogen. The vines should be thoroughly sprayed at the time the beetles make their appearance and thorough cultivation of the soil should be maintained throughout the season. The grapevine possesses remarkable recuperative power and, as the results tabulated in this paper, under the heading of field experiments, indicate, responds bounteously to careful and generous treatment.

BIBLIOGRAPHY.

1826. Sturm, J.—Catalog meiner Insecten-Sammlung, Käfer, pls. 4 col., pp. 1–207.

1837. Dejean, P. F. M. A.—Catalogue des Coléoptères, Third Edition, Paris.

1843. Sturm, J.—Catalog der Käfersammlung von J. Sturm, p. 295.
Fidia lurida Dej., synonym *flavescens* Sturm Cat. 1826.

1847. Melsheimer, F. E.—Description of new species of Coleoptera of the United States.<Proc. Acad. Nat. Sci. Phila., vol. 3, pp. 158–181.

1863. Baly, J. S.—An attempt at a classification of the Eumolpidæ.<Journ. Ent., vol. 9, pp. 143–163.
Original description of the genus Fidia.

1866. Walsh, B. D.—Answers to correspondents. An undescribed species of Fidia.<Pract. Ent., vol. 1, No. 10, pp. 99–100.
This insect later proved to be *F. viticida* Walsh.

1867. Walsh, B. D.—The grapevine Fidia (*Fidia viticida* Walsh).<Pract. Ent., vol. 2, pp. 87–88, fig.
Original description of the species.

1867. Walsh, B. D.—Grapevine beetles.<Pract. Ent., vol. 2, p. 118.

1868. Riley, C. V.—First Annual Report Insects of Missouri, p. 132.

1870. Riley, C. V.—Grapevine Fidia.<Amer. Ent. and Bot., Sept., vol. 2, p. 307.
Answer to correspondent.

1872. Kridelbaugh, S. H.—Injurious insects.<Ann. Rep. Iowa State Hort. Soc. for 1871, pp. 153–167.

1873. Crotch, G. R.—Materials for the study of the Phytophaga of the United States.<Proc. Acad. Nat. Sci. Phila., vol. 3, pp. 158–181.
Original description of *Fidia longipes* Melsh.

1874. Chapuis, F.—Histoire naturelle des insectes. Genera des Coléoptères, vol. 10, p. 275.

1877. Lefévre, E.—Descriptions de Coléoptères nouveaux ou peu connus de la famille des Eumolpides.<Ann. Soc. Ent. France, ser. 5, vol. 7, pp. 115–166.

1880. Stout, O. E.—Insects injurious and beneficial.<Rep. Kans. State Hort. Soc. f. 1879, vol. 9, pp. 86–91.
Mention of *Fidia viticida* Walsh.

1880–1892. Jacoby, M.—Biol. Centr.-Amer., Insecta, Coleoptera, vol. 6, Pt. I, p. 166.

1885. Lefévre, E.—Catalogus Eumolpidarum.<Mém. Soc. Roy. Sci. Liège, ser. 2, vol. 2, separ., pp. 1–172.

1891. Riley, C. V., and Howard, L. O.—Insect Life, vol. 3, p. 249.
Refers to investigation in Europe of *Adoxus vitis* L., and mentions Fidia, the American rrlated beetle.

1892. Horn, G. H.—The Eumolpini of Boreal America.<Trans. Amer. Ent. Soc., vol. 19, pp. 195–234.
Three species of Fidia in Boreal America. Mentions synonyms of *F. viticida* Walsh.

1893. Riley, C. V.—Insect Life, vol. 5, p. 18.
Injury by *F. viticida* at Vineland, Ark.

1894. Ashmead, W. H.—A new genus and species of Proctotrypidæ and a new species of Brachystichia, bred by Prof. F. M. Webster.<Journ. Cinc. Soc. Nat. Hist., vol. 17, pp. 170–172.

Egg parasites of the grape root-worm.

1894. Howard, L. O.—The grapevine root-worm.<Insect Life, vol. 7, p. 48.

1894. Webster, F. M.—Studies of the development of Fidia viticida Walsh.<Journ. Cinc. Soc. Nat. Hist., vol. 17, pp. 159–169, pl. 9.

The first account of the underground habit of the grape root-worm larvæ; this constitutes the more technical features of the publication in Ohio Exp. Sta. Bul. 62, 1895.

1894. Webster, F. M.—Questions and answers.<The Ohio Farmer, January 18, p. 57.

1894. Webster, F. M.—Entomology.<The Ohio Farmer, May 3, p. 357, 5 figs.

Answers to correspondents.

1894. Webster, F. M.—Entomology.<The Ohio Farmer, June 28, p. 509.

1894. Webster, F. M.—Inquiries and answers.<The Ohio Farmer, September 27, p. 257.

Grape root-worm injury at Lawrence, Kans.

1895. Dille, N. W.—Entomology.<The Ohio Farmer, July 11, p. 37; continued June 20, p. 497.

Popular account of the grape root-worm.

1896. Marlatt, C. L.—The principal insect enemies of the grape.<Yearb. U. S. Dept. Agr., 1895, pp. 391–393, fig. 98; (abstract in Amer. Nat., 1896, p. 759).

A general account of the grape root-worm; recommends carbon bisulphid and also kerosene emulsion to be applied to the roots.

1895. Webster, F. M.—The grape root-worm.<Bul. 62, Ohio Agr. Exp. Sta., October, pp. 77–95, 1 pl. (Abstract in Ent. News, 1896, pp. 82–83.)

A more detailed account of studies first published in Journ. Cinc. Soc. Nat. Hist., 1897, vol. 17, pp. 159–169; includes Ashmead's paper on egg parasites.

1895. Webster, F. M.—Grape root-worm.<The Ohio Farmer, August 22, p. 147.

Answers to correspondent.

1896. Murtfeldt, Mary E.—Grapevine pest.<Colman's Rural World, St. Louis, Mo., March 26, pp. 75, 97.

1896. Stimson, J. T.—Report of the horticulturist.<Bul. 43, Ark. Agr. Exp. Sta., p. 114, fig.

Injury caused by *F. viticida* Walsh in Arkansas.

1896. Webster, F. M.—Insects affecting the roots of the grapes.<Ann. Rep. Ohio State Hort. Soc., p. 31.

Egg parasites of the grape root-worm occurring in increased numbers.

1897. Webster, F. M., and Mally, C. W.—Insects of the year in Ohio.<Bul. 9, n. s., Div. Ent., U. S. Dept. Agr., pp. 40–45.

Experiments with tobacco and kainit applied to the soil to kill larvæ of the grape root-worm.

1899. Lugger, O.—Beetles injurious to fruit-producing plants.<Bul. 66, Minn. Agr. Exp. Sta., p. 223.

Adoxus obscurus L. common on cultivated grapes in 1898.

1899. Webster, F. M., and Mally, C. W.—Insects of the year in Ohio.<Bul. 20, n. s., Div. Ent., U. S. Dept. Agr., pp. 68–73.

Grape root-worm abundant in 1897 in Ohio.

1900. Slingerland, M. V.—The grape root-worm, a new grape pest in New York. <Bul. 184, Cornell Agr. Exp. Sta., pp. 21–32, 11 figs.

An account of the grape root-worm condition in the Chautauqua grape belt; with compilations from Webster's papers of 1894 and 1895.

1900. Smith, J. B.—Catalogue of the insects of New Jersey, p. 303.

Both the European and the native grape root-worms found throughout the State.

1901. Howard, L. O.—Notes from correspondence.<Bul. 30, Div. Ent., U. S. Dept. Agr., pp. 97–98.

Serious injury to vineyards at Bloomington, Ill.

1901. Slingerland, M. V.—Entomology.<Proc. West. N. Y. Hort. Soc. f. 1901, pp. 68–73.

Mention of grape root-worm.

1902. Doty, S. N.—Destructive grape-worms.<Journ. of Agr., St. Louis, June 26.

General comments on the grape root-worm.

1902. Felt, E. P.—Seventh report of the state entomologist on injurious and other insects of the State of New York for 1901.<Bul. 53, N. Y. State Mus., pp. 699–925, 6 pls., 29 figs.

Mention of *Fidia viticida* Walsh.

1902. Felt, E. P.—Grape root-worm.<Country Gentleman, May 15; June 26.

Value of cultural methods.

1902. Felt, E. P.—Report of the committee on insects.<6th Ann. Rep. Eastern N. Y. Hort. Soc., pp. 210–218.

1902. Felt, E. P.—Grapevine root-worm.<Bul. 59, N. Y. State Mus., pp. 49–84, 6 pls.

Results of studies in the Chautauqua grape belt, 1902; use of beetle catcher recommended.

1902. Felt, E. P.—Report of the committee on insects.<6th Ann. Rep. Eastern N. Y. Hort. Soc., pp. 210–218. (Published by New York Fruit Growers' Association, 1902.)

1902. Felt, E. P.—Grapevine root-worm.<Country Gentleman, July 10, pp. 574–575.

Effectiveness of cultivation in the control of the grape root-worm.

1902. Felt, E. P.—The grape root-worm.<Country Gentleman, May 15, 1902, p. 413, 2 figs.

Comprehensive account of the grape root-worm condition.

1902. Felt. E. P.—Insects in New York, III.<Country Gentleman, April 10, p. 308.

1902. Johnson, W. G.—Remedies for the grape root-worm. <Amer. Agr. (New York), June 7, 1902, p. 750, 2 figs.

Summary account of the life history of the grape root-worm; refers to Slingerland's work.

1902. Slingerland, M. V., and Craig, J.—The grape root-worm. <Bul. 208, Cornell Agr. Exp. Sta., pp. 177–200, 16 figs.

Account of infestation in Chautauqua grape belt; successful results from poison spray experiments.

1902. Webster, F. M., and Newell, W.—Insects of the year in Ohio. <Bul. 31, n. s., Div. Ent., U. S. Dept. Agr., pp. 84–90.

Grape root-worm, less destructive in 1901, again taking on a new vigor.

1903. Burgess, A. F.—Remarks on the grape root-worm. <Bul. 40, Div. Ent., U. S. Dept. Agr., p. 34.

Arsenate of lead spray showing good results.

1903. Chittenden, F. H.—The principal injurious insects in 1902. <Yearb. U. S. Dept. Agr., 1902, p. 729.

1903. Felt, E. P.—Grapevine root-worm. <Bul. 72, N. Y. State Mus., pp. 55, pls. 13.

Replaces Bul. 59, l. c., and contains records of further experiments with beetle catcher.

1903. Slingerland, M. V.—A big fight against grape pests. <Proc. Western N. Y. Hort. Soc. f. 1903, pp. 75–78.

Effectiveness of an arsenical spray.

1903. Felt, E. P.—Insecticides and notes. <Country Gentleman, January 15, p. 47.

1903. Felt, E. P.—Summary of root-worm situation and experiments. <Country Gentleman, September 24, p. 828.

Results of experiments with beetle catcher.

1904. Burgess, A. F.—Notes on economic insects for the year 1903. <Bul. 46, Div. Ent., U. S. Dept. Agr., pp. 62–65.

Grape root-worm continues to appear in injurious numbers.

1904. Chittenden, F. H.—The principal injurious insects of 1903. <Yearb. U. S. Dept. Agr., 1903, p. 564.

1904. Felt, E. P.—Recent work upon the grapevine root-worm. <Proc. Western N. Y. Hort. Soc. f. 1904, pp. 48–51.

1904. Felt, E. P.—Report of the committee on entomology. <N. Y. State Fruit Growers Ass'n, 1904, pp. 28–29.

1904. Felt, E. P.—Insect pests of the year. <N. Y. State Fruit Growers Ass'n, 1904, pp. 136–139.

1904. Felt, E. P.—Contribution for the destruction of the grape root-worm. <Grape Belt, June 14, p. 7.

1904. Felt, E. P.—In the Chautauqua grape belt. <Country Gentleman, June 9, pp. 544–545.

1904. Felt, E. P.—Time to get out the beetle catchers. <Grape Belt, June 28, p. 7.

1904. Felt, E. P.—Grape-vine root-worm. <Grape Belt, Feb 9, 23; Mar. 8, 15; Apr. 5, 12; May 6, 17.

Republished from Bul. 72, N. Y. State Mus., 1903; also republished in part in Jamestown Journ., Feb. 10, 1904, p. 5.

1904. Pettit, R. H.—Insects injurious to fruits in Michigan. <Spec. Bul. 24, Mich. Agr. Exp. Sta., pp. 79.

1904. Schæffer, C.—New genera and species of Coleoptera. <Journ. N. Y. Ent. Soc., vol. 12, p. 227.

Includes a key to the species of Fidia of Boreal America.

1904. Slingerland, M. V., and Johnson, F.—Two grape pests. <Bul. 224, Cornell Agr. Exp. Sta., pp. 65–73, figs. 4.

Good results from spraying experiments.

1904. Slingerland, M. V.—Notes and new facts about some New York grape pests. <Bul. 46, Div. Ent., U. S. Dept. Agr., pp. 73–78, 1 fig.

Failure of experiments with "catchers"; spraying shows encouraging results.

1904. Slingerland, M. V.—Our insect enemies in 1903. <Proc. Western N. Y. Hort. Soc. f. 1904, pp. 72–77.

1904. Washburn, F. L.—Ninth Ann. Rep. State Ent. Minn. f. 1904. St. Anthony Park, Minn.

Grape root-worm listed, without specific instance of its occurrence in Minnesota.

1905. Burgess, A. F.—Some economic insects for the year 1904 in Ohio. <Bul. 52, Div. Ent., U. S. Dept. Agr., p. 54.

The root-worm is reported less injurious in Ohio in 1904.

1905. Burgess, A. F.—Some destructive grape pests in Ohio. <Bul. 5, Ohio Dept. Agr., Div. Nursery and Orchard Inspection, pp. 17.

Spraying most advisable method for its control.

1905. Chittenden, F. H.—The principal injurious insects of 1904. <Yearb. U. S. Dept. Agr. for 1904, p. 603.

1905. Felt, E. P.—Twentieth report of the state entomologist on injurious and other insects of the State of New York for 1904. <Bul. N. Y. State Mus., pp. 35, 95–97. (In part reprinted in the Grape Belt, June 27, 1905, p. 7.)

Further contributions to the grape root-worm investigations.

1905. Felt, E. P.—Notes for the year. <Bul. 52, n. s., Bur. Ent., U. S. Dept. Agr., pp. 51–52.
Spraying may reduce the pest 50 per cent.

1905. Felt, E. P.—New York State Fruit Growers Ass'n, Rep. Committee on Entomology. <Proc. Fourth Ann. Meet., 1905, pp. 27–30.

1905. Felt, E. P.—Grape root-worm. <Country Gentleman, February 2, 1905, pp. 70, 106.

1906. Burgess, A. F.—Some economic insects of the year in Ohio. <Bul. 60, Bur. Ent., U. S. Dept. Agr., pp. 71–74.
Injury to the grape root-worm in 1905 slight.

1906. Felt, E. P.—Twenty-first report of the state entomologist on injurious and other insects of the State of New York for 1905. <Bul. 104, N. Y. State Mus., pp. 45–186.
Further grape root-worm experiments.

1906. Felt, E. P.—Notes for 1905 from New York. <Bul. 60, Bur. Ent., U. S. Dept. Agr., pp. 89–90.

1906. Felt, E. P.—Grape root-worm. <Grape Belt, July 24, p. 5.
Condition of infested vineyards.

1906. Felt, E. P.—Grape root-worm. <Grape Belt, May 29, p. 1.

1906. Felt, E. P.—Injurious Insects of 1905. <Proc. N. Y. Fruit Growers Ass'n, pp. 120–124.

1906. Slingerland, M. V.—Final demonstration of the efficiency of a poison spray for the control of the grape root-worm. <Bul. 235, Cornell Agr. Exp. Sta., pp. 91–93.
Effectiveness of a poison spray; egg parasites.

1907. Atwood, G. G.—Some items of information for orchardists and fruit growers. <Bul. 1, N. Y. Dept. Agr., Bur. Hort. Insp., pp. 20.

1907. Felt, E. P.—Twenty-second report of the state entomologist on injurious and other insects of the State of New York for 1906. <Bul. 110, N. Y. State Mus., pp. 39–186.

1907. Quaintance, A. L.—The grape root-worm. <Farmers' Bul. 284, U. S. Dept. Agr., pp. 6–12, fig.

1908. Felt, E. P.—Entomological Notes for 1907. <Journ. Econ. Ent., vol. 1, pp. 148–150.

1908. Felt, E. P.—Twenty-third report of the state entomologist on injurious and other insects of the State of New York for 1907. <Bul. 124, N. Y. State Mus.

1908. Johnson, F.—Grape root-worm investigations in 1907. <Bul. 68, Pt. VI, Bur. Ent., U. S. Dept. Agr., pp. 61–68.
History of the root-worm condition in the Lake Erie grape belt; results of experiments of 1907.

1908. Quayle, H. J.—A new root pest of the vine in California. <Journ. Econ. Ent., vol. 1, pp. 175–176.
The European grape root-worm (*Adoxus obscurus* L.).

1908. Quayle, H. J.—The California grape root-worm (*Adoxus obscurus* L.). <Bul. 195, Cal. Agr. Exp. Sta., pp. 26, figs.

INDEX.

	Page.
Adoxus obscurus, bibliographic references	94, 97
related to *Fidia viticida*, distribution and habits	15–16
vitis, bicolored form of *Adoxus obscurus*	15
vitis, bibliographic reference	93
Ampelopsis quinquefolia, food plant of grape root-worm	13
Arsenate of lead against red-headed Systena	18
and arsenite of lime, comparative effectiveness against grape root-worm beetle	68–70
Bordeaux mixture against grape root-worm beetle	64–68, 71–75, 77–78, 81–82, 84, 90
comparison with arsenite of lime and Paris green as insecticide	83–84
Arsenite of lime and arsenate of lead, comparative effectiveness against grape root-worm beetle	68–70
Bordeaux mixture against grape root-worm beetle	84
comparison with arsenate of lead and Paris green as insecticide	83–84
Bordeaux mixture and arsenate of lead against grape root-worm beetle	64–68, 71–75, 77–78, 81–82, 84, 90
arsenite of lime against grape root-worm beetle	84
Paris green against grape root-worm beetle	84
directions for preparation	84–85
Brachysticha fidiæ, parasite of grape root-worm	51, 56–57
Carabid beetles and their larvæ, enemies of grape root-worm	50
Cercis canadensis, food plant of grape root-worm	13
Chrysopa sp., enemy of grape root-worm	51
Colaspis brunnea, mistaken for grape root-worm beetle, description and habits	18
Craponius inæqualis, mention as enemy of grape	18
Cremastogaster lineolata, enemy of grape root-worm	51
Cultural methods for destruction of pupæ of grape root-worm	61–63
Dipterous parasite of grape root-worm	55–56
Elm leaf-beetle. (See *Galerucella luteola*.)	
Fertilizers used in renovation experiment on old vineyard injured by grape root-worm	76
young vineyard injured by grape root-worm	82
Fidia flavescens, bibliographic reference	93
known species	16
longipes, bibliographic reference	93
injurious to cultivated grape, distribution	16
lurida, bibliographic reference	93
= *Fidia viticida*	11
murina = *Fidia viticida*	11
viticida (*see also* Grape root-worm).	
bibliographic references	93–97
copy of original description	21
validity of name	11
Fidiobia flavipes, copy of original description	51
parasite of grape root-worm, life history	51–55
Fungicides, combination with insecticides	84
Grapeberry moth. (See *Polychrosis viteana*.)	
Grape, cultivated varieties, food plants of grape root-worm	13–14
curculio. (See *Craponius inæqualis*.)	
food plant of *Colaspis brunnea*	18
Craponius inæqualis	18
Haltica chalybea	17
Macrodactylus subspinosus	17
Polychrosis viteana	18
Systena frontalis	17–18
Typhlocyba comes	18
leafhopper. (See *Typhlocyba comes*.)	
production in Lake Erie Valley, 1900 to 1909	58
root-worm (see also *Fidia viticida*).	

Page.
Grape root, worm as affecting vineyards in Lake Erie Valley ... 57-59
beetle, beetles mistaken therefor ... 16-19
related thereto ... 15-16
description ... 21
destruction ... 89-90
seasonal history ... 22-33
bibliography ... 93-97
California. (See *Adoxus obscurus.*)
control measures ... 59-89
cultural method for destruction of pupæ ... 61-63
description of stages ... 19-21
destructiveness ... 14-15
development and feeding of larva before wintering ... 35-36
distribution ... 12-13
egg deposition, feeding before and after it ... 25-28
mating and its bearing upon it ... 28
period for season of 1909 ... 31-32
process ... 28
variation in number of eggs per cluster ... 29
depositions, numbers by individual females ... 29
description ... 19
incubation period ... 33-35
eggs, number per cluster, variation ... 29
female beetle ... 30
emergence of beetle ... 22-25
experimental and rearing methods ... 44-50
feeding and development of larva before wintering ... 35-36
of beetle before and after egg deposition ... 25-28
larva in spring ... 37
food plants ... 13-14
history ... 10-12
injury, character ... 14-15
insect enemies, parasitic ... 51-57
predaceous ... 50-51
introduction ... 9-10
larva, description ... 19-20
seasonal history ... 35-39
life cycle as determined by rearing ... 40-41
history, seasonal variations ... 41-44
studies, summary ... 50
longevity of male and female beetles ... 32-33
mating and its bearing on egg deposition ... 28
natural enemies ... 50-57
occurrence of larvæ in different soils ... 36
origin ... 12
parasitism, double ... 56-57
poison sprays against beetle in cages, experiments ... 64-65
field, effect ... 63-64, 70-75
experiments ... 66-68
position of pupa in cell ... 39
post-larval stage ... 38-39
preface ... 3-4
preventive measures, evolution ... 59-61
pupa, description ... 20-21
destruction ... 61-63, 90-91
seasonal history ... 39-40
pupal cell, time and making ... 37-38
period, duration ... 40
pupation in field and in breeding cages, time ... 39-40
process ... 39
rearing and experimental methods ... 44-50
recommendations for destruction of beetles ... 89
pupæ ... 90-91
remedial measures for control ... 59-89
renovation experiment on old vineyard ... 75-80
young vineyard ... 80-83

Page.
Grape root-worm, seasonal history ... 22–50
variation in life history ... 41–44
sprays in control ... 83–88
summary of life-history studies ... 50
temperature records during breeding period of 1909, North East, Pa ... 43
treatment of injured vineyards ... 91–92
vineyard renovation experiments, results ... 75–83
vitality of newly hatched larva ... 35
wintering of larva in earthen cell ... 36–37
Grapes, wild, food plants of grape root-worm ... 13–14
Grapevine Colaspis. (See *Colaspis brunnea.*)
Fidia. (See *Fidia longipes.*)
flea-beetle. (See *Haltica chalybea.*)
Haltica chalybea, mistaken for grape root-worm beetle, description and habits ... 17
Heteropus [*Pediculoides*] *ventricosus*, enemy of grape root-worm ... 51
Hippodamia convergens, enemy of grape root-worm ... 51
Hoplophora [*Phthiracarus*] *arctata*, enemy of grape root-worm ... 51
Insecticides and fungicides, combination ... 84
Lachnosterna sp., enemy of grape root-worm ... 51
Lasius brunneus var. *alienus*, enemy of grape root-worm ... 51
Lathromeris (*Brachysticha*) *fidiæ*, parasite of grape root-worm ... 51, 56–57
Macrodactylus subspinosus, mistaken for grape root-worm beetle, description and habits ... 17
Nozzle adjustment for spraying vineyards ... 89
Nozzles for spraying vineyards ... 89
Paris green and Bordeaux mixture against grape root-worm beetle ... 84
comparison with arsenate of lead and arsenite of lime as insecticide ... 83–84
Pediculoides ventricosus, enemy of grape root-worm ... 51
Phthiracarus arctatus, enemy of grape root-worm ... 51
Polychrosis viteana, mention as enemy of grape ... 18
Redbud. (See *Cercis canadensis.*)
Red-headed Systena. (See *Systena frontalis.*)
Renovation experiment on old vineyard injured by grape root-worm ... 75–80
young vineyard injured by grape root-worm ... 80–83
Rhizoglyphus phylloxeræ, enemy of grape root-worm ... 51
Rose-chafer. (See *Macrodactylus subspinosus.*)
Spraying apparatus, care ... 89
for vineyard use ... 88–89
Spray formula recommended against grape root-worm beetle ... 90
mixture, plants for preparation ... 85
Sprays against grape root-worm beetle ... 83–88
number of applications ... 86–87
pressure in applications ... 88
time of application ... 86
Staphylinus vulpinus, probable enemy of grape root-worm ... 51
Systena frontalis, mistaken for grape root-worm beetle, description and habits, remedy ... 17–18
Telephorid enemy of grape root-worm ... 51
Temperature records during breeding period of grape root-worm during 1909 at North East, Pa ... 43
Typhlocyba comes, mention as enemy of grape ... 18
Tyroglyphus [*Rhizoglyphus*] *phylloxeræ*, enemy of grape root-worm ... 51
Vineyard conditions in Lake Erie Valley ... 57–59
experiments with poison sprays against grape root-worm beetle, results ... 70–75
renovation experiments against grape root-worm, results ... 75–83
Vineyards, recommended treatment of those injured by grape root-worm ... 91–92
Virginia creeper. (See *Ampelopsis quinquefolia.*)

O

86-89, 1910

r. Ent., U.S.D.A.