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THE CHERRY LEAF-BEETLE.

F. Z. HARTZELL.

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CONTENTS.

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THE CHERRY LEAF-BEETLE.

F. Z. HARTZELL.

SUMMARY.

The cherry leaf-beetle is a native species which normally feeds on the bird, pin, or fire, cherry (*Prunus pennsylvanica*). Both insect and plant have the same geographical distribution. Their habitat embraces Nova Scotia and Quebec westward thru southern Canada and the northern United States to the Rocky Mountains. It extends along the Alleghany Mountains to North Carolina and in the valley of the Fraser River to the Pacific Ocean. The beetle migrates for short distances beyond its normal breeding range.

The history of the species records intermittent attacks on cultivated cherries. The most extensive outbreak as regards extent of invaded territory and abundance of the insect occurred during 1915. The beetle was superabundant in two areas: (1) Western New York, Pennsylvania and northern West Virginia; and (2) the northern portion of the southern peninsula of Michigan. The outbreak in the Appalachian region extended as far east as Cayuga Lake in New York and Williamsport, Pa., and westward to the Ohio-Pennsylvania line, the infestation being most severe in the western portion of this area. In Michigan the beetle was most abundant in the region of Grand Traverse Bay. In 1916 and 1917 the numbers of the beetles in the foregoing areas were greatly reduced.

The eggs of this beetle are ellipsoidal in shape, averaging .78 mm. in length and .70 mm. in breadth, varying in color from stramineous to yellow. From these hatch olive-colored larvæ which later change to a very dark brown with the head and ninth segment black. When full grown the larva shows considerable yellow and characteristic black spots. The mature larvæ average about 7 mm. in length. The pupæ are bright yellow and vary from 4 to 5 mm. in length. The adults upon emergence are yellow, but soon change to yellow-brown and in a few days assume a blood-red color. They vary from 4.5 to 5.5 mm. in length.

The time of emergence from the pupal stage varies with seasonal conditions. During 1915 the adults emerged from August 23 to September 18, but during the summer of 1916, which was warmer, the adults appeared in the breeding cages from July 31 to September 2. The adults are rather sluggish, feeding very little during the late summer and fall. By September 15 some show a tendency to seek hibernating quarters, at least on cooler days, altho most of the beetles will emerge and feed on warm, sunny days. By October 1 all beetles entered hibernation, from which they did not emerge during the warm weather of early October.

The hibernation period of the insect in western New York is nearly eight months, emergence occurring during the latter part of May. In 1916, the first beetles emerged on May 27 at Fredonia. During 1917 at Lily Dale, eight miles from Fredonia and at an elevation five hundred feet greater, the first beetle emerged on May 30. The time of the appearance of the beetles was about one week after the bird cherry was in full bloom. The most extensive feeding by the adults occurs during the early part of June. It is at this time that practically all injury by the species to cultivated trees is inflicted. The greatest natural dissemination of the beetles occurs during the latter part of May and early June, when they may fly considerable distances to new feeding grounds.

Egg laying in 1916 began on June 5, under natural conditions, and on June 10 in observation cages, reaching the maximum in the first week of July and ending in the cages on August 9. The eggs are deposited on or near the trunk of the tree upon which the adults are feeding, usually not more than six inches above the surface of the soil, the majority being placed at the junction of the surface of the soil and the trunk. Some of the eggs are scattered loosely on the soil but most of them are glued to rootlets, small stones or the tree trunk. They are found to a depth of about one inch in the soil. The number of eggs laid in breeding cages by an individual varied from 10 to 294 with an average of 93. The normal life of the beetles appears to vary from 11 to 12 1-2 months, altho some individuals may reach an age of nearly 14 months.

The length of the incubation period during 1916 averaged 13 days, with a maximum of 23 days and a minimum of 9 days. These differences are ascribed largely to variation in temperature, altho there is individual variation in the incubation period of eggs deposited

on the same day. In 1916 hatching began on June 23 and ended August 20, the emerging larvæ being most numerous during the latter part of July.

Upon hatching, the larvæ climb trees and feed upon foliage. They are able to reach maturity only on the leaves of the bird cherry, and when compelled to subsist on the foliage of other species of cherry they invariably succumbed. The total feeding period of the larva varied from 8 to 24 days, with an average during 1916 of 12.3 days.

When the larvæ have reached full growth they burrow into the leaf mold or a short distance into the soil and form cells in which to pupate. The time spent in these cells was found to average 15 days, the shortest period being 12 days and the longest period 23 days. The total developmental period from hatching to emergence as adult averaged 27.2 days at Fredonia during 1916.

The chief factors in the natural control of the beetles are drowning of adults, reforestation which decreases the amount of the bird cherry, a carabid beetle (***Lebia ornata*** Say) which attacks the beetles, and the cedar wax-wing (***Bombycilla cedrorum*** Vieill) which was observed feeding on the adults. The cherry leaf-beetle is effectively controlled by arsenicals, preferably combined with bordeaux mixture, and nicotine sulphate; for the proper employment of which directions are given.

INTRODUCTION.

In view of the lack of detailed information on the bionomics of the insect, the occurrence of myriads of the cherry leaf-beetle (*Galerucella cavicollis* Le Conte) in fruit plantings thruout western New York in 1915 gave the initial impetus for a detailed study, which involved consideration of its origin, distribution, host plants, life history and susceptibility to control measures. This work has been conducted for three consecutive seasons, principally at Fredonia, which is located in the Lake Erie Valley with an altitude of five hundred to one thousand feet less than that of the Alleghany plateau where the species is normally of common occurrence. To insure accuracy the results of these studies were checked from time to time by observations of the beetle in its normal habitat. It should be stated that the extraordinary abundance of the insect led to simultaneous studies by other workers in this and several adjoining states, which will be duly noted elsewhere in this bulletin.

CLASSIFICATION AND SYNONYMY.

The cherry leaf-beetle belongs to an extensive family of beetles known as the Chrysomelidæ. It was described by LeConte who assigned it to the genus Galeruca. It was discussed in literature under the name *Galeruca cavicollis* until Horn, in 1893, made a critical study of the entire tribe and re-established the genus *Galerucella* which had been established by Crotch [1] in 1873 to include species closely related to *cavicollis* but which coleopterists did not recognize. Many of the species at present listed in this genus were originally described as members of the genus *Adimonia*, and some writers have referred to the cherry leaf-beetle under the appellation *Adimonia cavicollis*. The statements of Packard relative to *Galeruca sanguinea* were shown by Schwarz to refer to *cavicollis* [2] and Lugger's account of a cherry leaf-beetle under the name *Adimonia femoralis* obviously refers to this same insect.

The present synonymy of the insect is as follows:

Galerucella cavicollis Le Conte

Galeruca cavicollis. LeConte, J. L. Species of *Galeruca* and allied genera inhabiting North America (original description). *Proc. Acad. Nat. Sci. Phila.*, p. 216, 1865.

Galeruca sanguinea. Packard, A. S. Insects Injurious to Forest and Shade Trees, 5th Rept. U. S. Ent. Com., p. 529, 1890.

Galerucella cavicollis. Horn, G. H. The Galerucini of Boreal America. *Trans. Amer. Ent. Soc.*, 20: 76-77, 1893.

Adimonia cavicollis. Davis, G. C. Rept. of the Consulting Entomologist. Mich. Agr. Expt. Sta., 7th Ann. Rept., p. 93, 1894.

Adimonia femoralis. Lugger, Otto. Minn. Agr. Expt. Station Bull. 66, pp. 236-238; also Ann. Rept. of Minn. Expt. Sta., pp. 236-238,1900.

HISTORICAL NOTES.

The cherry leaf-beetle was first described by Dr. LeConte [3] in 1865 from a single specimen collected in North Carolina. He named

[1] Le Conte, J. L., and Horn, G. H. Classification of the Coleoptera of North America, pp. 348–349, 1883.
[2] Schwarz, E. A. *Insect Life*, 4:94. 1891.
[3] *Proc. Acad. Nat. Sci. Phila.*, 1865, p. 216.

the insect *Galeruca cavicollis*, giving the description in Latin, but made no mention of its host plant. In 1893 Dr. Horn[1] redescribed *cavicollis* and placed it in the genus *Galerucella* where it has since remained. The known area of the distribution of the species is stated by Dr. Horn to be "from Canada to the New England and Middle States westward to Wisconsin; North Carolina (LeConte)." Zesch and Reinecke[2] in 1883 record the beetle under the caption *Galeruca cavicollis* as having been collected near Buffalo, N. Y.

The first mention of the habits of this insect is by Dr. Packard[3] who in 1890 recorded the insect as occurring in abundance at Berlin Falls, N. H., eating holes in leaves of "wild cherry." He also gave a brief description of the beetle, designating it *Galeruca sanguinea*, the name of a European species which it resembles. Schwarz[4] in 1891 called attention to the correct identity of the insect and said it is a common northern species.

The first recorded feeding of *cavicollis* on cultivated cherry is by Davis[5] in 1894 who observed the insect on this fruit at Bellaire, Mich. He designated the species *Adimonia cavicollis*, stating that a few beetles were observed feeding on wild cherry trees, and suggested the possibility of the species becoming a serious pest. He also described the larva for the first time. In 1896 Davis[6] again reported the appearance of the beetles in Michigan, which were in numbers sufficient to cause injury to cultivated trees. Mention is made of their feeding on the foliage of peach, cherry, apple and plum, and it is stated that arsenites were not satisfactory insecticides.

During the period of 1895 to 1899 inclusive the leaf-beetle seems to have been unusually abundant thruout the northern portion of its range and attracted the attention of a number of observers. However, Dr. John Hamilton[7] in 1895 reported the insect as rare in southwestern Pennsylvania but noted its occurrence on plants of the genus *Prunus*. In 1896 Dr. Lintner[8] reported having received specimens of this species from Ausable Forks, N. Y., on June 10,

[1] *Trans. Amer. Ent. Soc.*, **20**: 76–77. 1893.
[2] *Bul. Buffalo Soc. Nat. Sci.*, 4: 12. 1883.
[3] 5th Rept. U. S. Ent. Com. p. 529. 1890.
[4] *Insect Life*, 4: 94. 1891.
[5] Mich. Agr. Expt. Sta. 7th Ann. Rpt., p. 93; also *Insect Life*, 7: 200. 1894.
[6] Mich. Agr. Expt. Sta. 9th Ann. Rpt., p. 136. 1896.
[7] *Trans. Amer. Ent. Soc.*, **22**: 371. 1895.
[8] 11th Rept. Ins. St. N. Y. pp. 197–198. 1896.

1895, from a correspondent who recorded the occurrence of "thousands" of the beetles on cultivated cherries and stated that "the beetles sent from cherry trees were also feeding on a young chestnut tree." The attacks of the insect on the latter host have never been verified. Lintner referred to the literature of the species and said, "the occurrence of this insect on the garden cherry while previously known only on the wild is another instance of the many similar changes known of our native insects from wild to cultivated food plants." Barrows and Pettit [1] in 1898 mentioned the insect as feeding on cultivated cherries in Michigan during 1897 and gave for the first time a general summary of its life cycle. For the prevention of injuries by the insect paris green, fish-oil soap and kerosene emulsion were advised.

In 1897 Johnson [2] stated that "myriads of the beetle and its larvæ were observed during the first week of September, devouring the leaves of the fire cherry (*Prunus pennsylvanica*) at Ricketts, Wyoming Co., Pa." Dr. Felt [3] in 1898 found the insect causing injury about Corning in Steuben County, N. Y. Dr. Smith [4] in 1898 observed the species feeding on peach in Pennsylvania and Chittenden [5] during the following year recorded injury to peaches at Lebanon and Spruce Creek in the same state. The account of the latter was the most comprehensive discussion of the species previous to 1915. In addition to the two localities just enumerated he recorded injury to cultivated cherry foliage at St. Ignace, Mich. He also gave a description of the egg and determined the incubation period for the latitude of Washington, D. C. Arsenicals were recommended for the protection of plantings. Dr Lugger [6] in 1899 reported the cherry leaf-beetle under the appellation *Adimonia femoralis* Melsh. as being numerous on "the native plum" and *P. pennsylvanica* in Minnesota, and Harvey [7] during 1900 recorded the insect by the name *Adimonia cavicollis* as being injurious to cherry in the vicinity of Orono, Maine, during 1899.

[1] 37th Ann. Rept. Mich. State Bd. Agr. 1897–8, pp. 93–4. 1898.
[2] 3rd Ann. Rpt. Penna. Agr. Dept., Pt. II, pp. 106–7. 1897.
[3] *Country Gentleman*, 63:471; 14th Rpt. State Ent. N. Y. p. 235; U. S. Dept. Agr. Div. Ent. Bul. 17, n. s., p. 20. 1898.
[4] U. S. Dept. Agr. Div. Ent. Bul. 17, n. s., p. 23. 1898.
[5] U. S. Dept. Agr. Div. Ent. Bul. 19, n. s., pp. 90–93. 1899.
[6] Minn. Agr. Expt. Sta. Bul. 66, pp. 236–238. 1899. Minn. Agr. Expt. Sta. 5th Ann. Rept., pp. 152–154. 1899.
[7] Maine Agr. Expt. Sta. Bul. 60, p. 35. 1900.

For an interval of fifteen years, from 1900–1915, there is apparently no mention of *cavicollis* causing injuries in fruit plantings. However, during this interval publications were issued which deal either with groups of insects that attack certain plants or certain lists of Coleoptera, in which there are references to *cavicollis*. In 1901[1] and again in 1906[2] Felt mentioned feeding by the beetle on *P. pennsylvanica* in the Adirondacks. Pettit[3] in 1901 stated that the insect occurs thruout the upper peninsula of Michigan, and in 1905[4] he mentioned the species among insects injurious to the cherry. In 1902 MacGillivray and Houghton[5] reported *cavicollis* from Axton, N. Y., on the bird cherry. Washburn[6] in 1903 briefly mentioned the insect in a list of cherry pests. In 1909 Smith[7] listed the beetle as a pest on peach, plum and cherry. Blatchley[8] in 1910 gave tables for separating the several species of the genus *Galerucella* including *cavicollis* found in the state of Indiana. Mention was also made of its distribution, giving the range only east of the Mississippi River. In 1911 Gossard[9] gave remedies for the control of the pest, listing it with other cherry insects but made no mention of any outbreaks occurring in Ohio. In 1912 O'Kane[10] referred to the beetle as a destructive insect of cherry and gave a partial life history and remedies.

The outbreak during 1915, from the standpoint of numbers of beetles and the extent of territory infested is the most extraordinary on record for the species. On account of the attention that was directed to the insect by its superabundant numbers over a large area in several states, a number of contemporaneous and independent investigations were initiated.

Dr. Surface [11] recorded the insect as destructive to cherry, apple and other plants in Lycoming County, Pa., during 1915, and Parrott [12] gave an account of the species in New York, briefly summarizing its life history and experiments on control measures.

[1] 17th Rept. State Ent. N. Y., p. 861.
[2] N. Y. State Mus. Memoir 8, vol. 2, p. 550.
[3] 40th Ann. Rept. State Bd. Agr. Mich., p. 192.
[4] 44th Ann. Rept. State Bd. Agr. Mich., p. 312.
[5] *Ent. News*, 13: 252.
[6] Minn. Agr. Expt. Sta. Bul. 84, p. 96.
[7] Rept. N. J. State Mus., p. 347. 1909.
[8] Coleoptera of Indiana, p. 1169.
[9] Ohio Agr. Expt. Sta. Bul. 233, p. 129.
[10] Injurious Insects, p. 263.
[11] Monthly Bul. Div. Zool. Pa. Dept. Agr., vol. 5, pp. 20–21; vol. 6, p. 104.
[12] N. Y. Dept. Agr. Cir. 130, pp. 174–176; Proc. 61st Ann. Meeting West. N. Y. Hort. Soc., pp. 115, 123.

In 1916 Herrick[1] and Matheson described the egg, larval and pupal stages of the beetle with careful detail and outlined its life history. Crosby[2] also gave an epitome of the habits and life history with remedial measures. During the same year Hartzell and Parrott[3] published a circular giving a brief summary of the habits of the beetle, outlining methods of control based on experiences of the previous year. Dr. Felt[4] gave an account of the outbreak during 1915 in New York and a hypothesis for the sudden dispersion of the beetles. Also during 1916 Cushman and Isley[5] published the more important results of their studies to date on the habits and life history of *cavicollis*, especial attention being given to the larval and pupal stages, and on experiments for the control of the pest. Detailed descriptions were given of all the immature stages and extensive data on the duration of the larval instars and the pupal stage for large numbers of individuals. A bibliography was included by them in this study.

FOOD PLANTS.

In any discussion of the leaf beetle the distinction should clearly be made between the food plants upon which the larvæ are able to develop and those plants on which the adults occasionally feed. For convenience of reference the former are designated the *essential food plants* while the latter are denominated the *incidental food plants*.

There appears to be only one species of plant which is an essential food plant of *cavicollis* and this is the bird, pin, or fire, cherry, *Prunus pennsylvanica*. The larvæ of the leaf-beetle have never been observed to reach maturity on any other plant. This cherry is also the primary food-plant of the adult, and from present knowledge it is believed to be the only plant on which the beetle feeds during periods when conditions are normal. Most observers, as will be noted in the discussion dealing with the history of the beetle, record this species of cherry as the food plant of the adults. When the foliage of the bird cherry is destroyed or is of insufficient quantity the

[1] *Jour. Agr. Research*, 5: 943–949.
[2] Dept. Agr. State N. Y. Bul. 79, pp. 1148–1149.
[3] N. Y. Agr. Expt. Sta. Cir. 49.
[4] N. Y. State Mus. Bul. 186, pp. 83–84.
[5] U. S. Dept. Agr. Bul. 352.

insects do feed upon other species of plants. Among cultivated trees the most important incidental food plants are the peach and sour cherry. All varieties of peach seem to be attacked altho the most serious damage results to young trees owing to the paucity of foliage as compared with the numbers of beetles on the leaves. Sour cherries, as Early Richmond and Montmorency, which are the principal varieties grown in western New York, exhibited considerable evidence of feeding by the insects, and of these two plants some observers claim that the former was preferred. The foliage of mature sweet cherries, according to our observations, was not attacked by the beetles, but several cases of partial defoliation of young sweet cherries were brought to our attention. Varieties of cherries intermediate between sweet and sour sorts, such as the Duke cherries, were quite attractive to the beetles. Observations during 1915 seem to indicate that the age and physiological condition of the tree are perhaps more potent factors than the variety of cherry in determining the preferences of the beetles. Young trees and older trees which were in a weakened condition were especially susceptible to their attacks. At Fredonia the beetles were observed eating the foliage of shoots that had grown from below the graft, which proved to be of the species *P. mazzard*. In the vicinity of Geneva the insect was quite abundant on *P. mahaleb*, apparently preferring it to cultivated trees. This cherry has escaped from cultivation and may be found growing along fences and in waste places. Mr. L. F. Strickland,[1] Inspector for the N. Y. Department of Agriculture, found the beetles attacking stocks of *P. mahaleb* in a nursery at Batavia. Davis[2] reported the beetles feeding on apple at Bellaire, Michigan. Recently Surface[3] gave a similar report of the adults in Lycoming County, Pa. In view of the foregoing statements it should be noted that frequent observations by the author failed to reveal any feeding of the beetles on apple foliage on which they were found during 1915. Cushman[4] and Isley have stated that "the apple was entirely immune" during the attack of 1915 as judged by conditions in Erie County, Pa. A number of observers claim that the beetle feeds on plums but there is

[1] Letter of June 27, 1916.
[2] *Insect Life*, 7:200. 1895.
[3] Monthly Bul. Div. Zool. Pa. Dept. Agr. 5:21. 1915.
[4] Loc. cit., p. 2.

reason to believe that other injury to the foliage has perhaps been mistaken for the work of this insect.

Results of feeding on *Prunus serotina* were noticed by W. T. Davis[1] at Rock City, N. Y., during 1915. In the vicinity of Fredonia, N. Y., the beetles avoided the choke cherry, *P. virginiana*, and the wild black cherry, *P. serotina*, during 1915 and 1916. These species are the most common wild cherries in that region; and careful examination was repeatedly made for eggs and larvæ on them since a portion of the literature dealing with the insect reported it as occurring on " wild cherry " without any apparent distinction as to choice of species. Lugger reported this insect feeding on a " native plum " in Minnesota. Wight[2] records only two species of native plums in that state, *Prunus nigra* and *P. americana;* therefore it is probable that one of these two species is also an incidental food plant of *cavicollis*.

During the invasion of western New York the leaf-beetles were observed on potatoes, timothy, roses, dahlias, plums, grapes and milkweed (*Asclepias syriaca* and *A. purpurascens*). Careful observations failed to reveal any feeding on these plants. It, therefore, appears that the insects merely alighted on such plants to rest after a sustained flight and that later they sought the foliage of cherries and peaches to feed. It is highly probable that the reports in literature of the beetles feeding on cultivated plums, buttercups and chestnut, as previously mentioned, were prompted by the presence of the insects on such plants rather than by any evidence of actual eating of the foliage.

ORIGIN AND DISTRIBUTION.

The cherry leaf-beetle is native to North America. Its breeding range comprises Nova Scotia, Quebec and the region westward, embracing southern Canada and the northern states to the Rocky Mountains. (Fig. 1.) The southern limit of the species extends from southern New Jersey thru eastern Maryland; thence southwest along the eastern portion of the Alleghany highlands thru Virginia and North Carolina where it turns westward and later northward following the western border of the highlands to Lake

[1] Letter of April 3, 1916.

[2] Wight, W. F. Native American Species of Prunus, U. S. Dept. of Agr. Bul. 179. 1915.

Erie in the vicinity of Erie County, Pennsylvania. Across Lake Erie, the line follows the northern shore for a distance of nearly 150 miles, then starts on the southern shore of the lake in the vicinity of Sandusky, Ohio, and extends westward thru Ohio, Indiana, Illinois and Iowa, thence northwest to the Black Hills of South Dakota where it bends sharply to the south, extending along the eastern slopes of the Rocky Mountains thru Wyoming and into

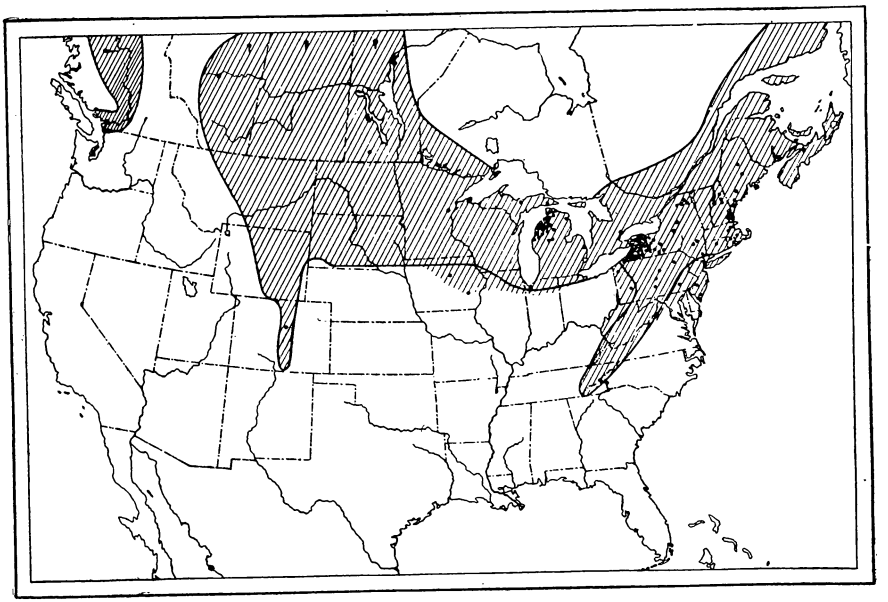


FIG. 1.— MAP SHOWING THE DISTRIBUTION OF THE CHERRY LEAF-BEETLE AND PRUNUS PENNSYLVANICA.

The shaded area represents the probable range of *Galerucella cavicollis*, localities in which the beetles have been found shown by dots. The curved lines show the limits of the bird cherry and also define the breeding range of *G. cavicollis*. Distribution of the bird cherry east of the Rocky Mountains after Wight and Robbins, west of the Rockies adapted from Sargent.

Colorado perhaps to near the southern portion of the state. The northern limit of the beetle extends southwestward thru the northern portion of the St. Lawrence Valley to the northern shores of Georgian Bay and Lake Huron, crossing the Sault St. Marie river and following the southern shore of Lake Superior to the vicinity of Keweenaw Point. Beginning on the northern shore of the lake near Port Arthur the line extends northwestward to the north of Lake Winnipeg; thence westward thru central Manitoba, Sas-

katchewan and Alberta to the Canadian Rockies. The only record of the insect west of the Rocky Mountains is at Vancouver, B. C., but there is reason to believe that it may occur in other parts of British Columbia. In correspondence or in literature the beetle has been reported from the following localities:— Nova Scotia, Truro; New Brunswick, St. John; Ontario, Toronto; Manitoba, Aweme (Wickham); Alberta, Edmonton (Wolcott); British Columbia, Vancouver (Chittenden); Maine, Orono (Harvey), Mt. Desert (Fall), Ogonquit, Old Orchard, and Mt. Katahdin (Wickham), Monmouth (collected by Frost and reported by Wolcott); New Hampshire, Farmington, Haverhill and Exeter (Fall), Berlin Falls (Packard, Chittenden), Mt. Washington (Chittenden, Wickham), Hampton and Durham (Wickham), Mt. Adams (Chittenden); Vermont, (Leng); Masschusetts, Framingham (collected by Frost and reported by Wolcott), Cambridge and Mansfield (Chittenden); Rhode Island (collected by Davis, data by Wickham); Connecticut, Hartford (Chittenden); New York, localities not included in outbreak of 1915, Whiteface Mt. (W. T. Davis, Leng), Ausable Forks (Lintner), Axton (McGillivray and Houghton), Saranac, Old Forge and Newport (New York State Museum), Catskill (Chittenden, N. Y. S. M.), High Peak, Catskill Mts. and Peekskill (Leng), Buffalo (Zesch and Reinecke), Corning (Felt), Ithaca (Chittenden); Pennsylvania, Ricketts (Johnson), Lebanon, Spruce Creek, Allegany, (Chittenden), Williamsport (Surface, Cushman and Isley), Lycoming County (Surface), State College and Center County (Fagan), Northeast (Cushman and Isley), Dicksonburg (Backus); New Jersey, Atco, Anglesea, and Sea Isle (Smith); Virginia, Woodstock (Chittenden); North Carolina (Le Conte); West Virginia (Cushman and Isley); Ohio, Charles Drury [1] writes from Cincinnati as follows: "*Cavicollis* has not occurred here that I know of. In the many years that I have collected Coleoptera here I have never seen the species . . . . In collections from the central and northern part of Ohio which I have identified there were no specimens of *cavicollis* although the species should occur there." Cushman and Isley record the absence of the beetles in the northern part of the state as far west as Sandusky during 1915; Michigan, Bellaire (G. C. Davis and Pettit), Au Train Falls (Pettit), St. Ignace (Chittenden), Bay View (Liljeblad, data by Wolcott), Rudyard, Frederick, Empire,

[1] Letter of April 13, 1916.

Isle Royal (Pettit), other records in account of outbreak of 1915; Indiana, Pine (Wolcott); "Probably to be found thru the northern third of state" (Blatchley); Wisconsin (Horn); Bayfield (Wickham); Iowa, Iowa City and Waterloo (Wickham); Minnesota, Hinckley (Lugger); Colorado, Palmer Lake (Gillette, Wickham); Texas, (Chittenden).

The southern limit of the range of this beetle in the Appalachian highlands is obscure. The type specimen is stated by LeConte to have been taken in North Carolina. There is no other record of the species from this area. Prof. Franklin Sherman Jr.[1] states that "the occurrence of *cavicollis* in this state rests on the statements of Le Conte and no specimens of the species exist in our collections." Regarding South Carolina, Prof. G. M. Amedi[2] writes, "we do not know that *cavicollis* occurs in this state." From the standpoint of definite records, Woodstock, Va., is the most southern point from which the beetle has been noted. Only one record of the occurrence of the leaf-beetle from the extreme northern limits of the normal habitat of *Prunus pennsylvanica* has come to our attention. This specimen was captured at Edmonton, Alberta, Canada, on July 6, 1912, and is now in the collection of Mr. A. B. Wolcott, Field Museum of Natural History, Chicago, who writes,[3] "This specimen is not typical, the occiput being piceous, but I believe it certainly is *G. cavicollis* as repeated study of the specimen has failed to lead to any better determination."

The breeding range of the beetle, from the standpoint of altitude, deserves consideration. In the east the insect has been found near the tops of our highest mountains. Prof. H. F. Wickham has specimens in his collection which were obtained from Mt. Katahdin, Me., at an altitude of 5,000 feet and from Mt. Washington, N. H., at altitudes ranging from 5,000 to 6,000 feet. The altitudes of these two mountains are respectively 5,273 and 6,293 feet. Data bearing on the highest altitude of the growth of bird cherry on these two mountains we have been unable to procure. Mr. Wm. T. Davis[4] writes, "in my visit on July, 1914, to Whiteface Mt., Adirondacks, which has an altitude of 4,872 feet, I found *cavicollis* in considerable

[1] Letter of March 20, 1916.
[2] Letter of March 24, 1916.
[3] Letter of March 20, 1916.
[4] Letter of April 3, 1916.

numbers at the top of the mountain as well as along the trail. It was destructive to the foliage of *Prunus pennsylvanica.*"

The highest elevation of the Adirondacks is Mt. Marcy which has an altitude of 5,344 feet. Dr. Bray [1] describes an Arctic flora existing on the summit of this mountain above 5,000 feet, and a few of the indicator species of shrubs which he gives are bearberry willow (*Salix uva-ursi*), glandular birch (*Betula glandulosa*), and Lapland rose-bay (*Rhododendron lapponicum*). Dwarf balsam fir and spruce forms a conspicuous portion of the vegetation on part of the summit, while a heath-mat type of vegetation, chiefly Lapland rose-bay, is dominant on another portion of the summit of this mountain. The bird, or fire, cherry was not found growing above 5,000 feet by this author.

It would appear from these records that the beetle thrives at an altitude as high as 5,000 feet in the northeastern United States. The altitude of the breeding range in the Rocky Mountains has not been determined. In Colorado *P. pennsylvanica* grows at elevations ranging from 4,000 to 9,500 feet.[2] The beetle has been collected near Palmer Lake, Colorado, at an elevation of 7,500 feet; and as the bird cherry grows at this elevation it would appear that this terrain is in the breeding range of the beetle in this state.

The records give the migratory distribution of the cherry leaf-beetle only south of the breeding range. There are no records which show that the beetles migrate north of the breeding range. The migratory range (Fig. 1) extends thruout the southeastern portion of Pennsylvania and southward in New Jersey as far as Anglesea; also in western Pennsylvania two localities — Allegheny and Dicksonburg — appear to occur outside the breeding range. Another apparent extension occurs in southeastern and central Iowa. This evidently is a migratory region because the bird cherry is not believed to be present except as isolated trees planted by man, and the beetle is rare in this locality. Prof. R. L. Webster,[3] Ames, Iowa, writes "*cavicollis* is not represented in the collection here. I do not believe that the insect has ever caused damage in Iowa."

Inasmuch as the beetles migrate such short distances from their breeding range, it is difficult to explain the finding of the beetles in

[1] Bray, W. L. The Development of the Vegetation of New York State. Tech. Pub. No. 3, N. Y. College of Forestry, Syracuse University, pp. 77–79. 1915.
[2] P. A. Rydberg. Flora of Colorado. Col. Agr. Expt. Sta. Bul. 100, p. 193. 1906.
[3] Letter of March 21, 1916.

Texas, except on the hypothesis that there were undiscovered areas near this locality in which *P. pennsylvanica* grew at the time the beetles were taken. It is possible that in this locality the insect breeds on a closely related species of Prunus.

The correspondence between the range of the cherry leaf-beetle and the range of *Prunus pennsylvanica* is rather striking. The map (Fig. 1) illustrates the range of the bird cherry east of the Rocky Mountains as given by Wight [1] except the southern part of Colorado which data has been furnished thru the kindness of Prof. W. W. Robbins. Wight says, " *Prunus pennsylvanica* ranges from Newfoundland and New England westward through the valley of the St. Lawrence, Pennsylvania, northern Ohio and northern Indiana to the Black Hills and the eastern slopes of the Rocky Mountains, where it passes into the sub-species. It apparently does not occur north of Lake Huron, but extends northwestward from the western end of Lake Superior to the Winnipeg Valley. It is reported to extend to the shores of Hudson Bay (Sargent, Silva of North Am. 6:66), but no specimens have been seen from that region. It is common in the Alleghanies from Pennsylvania southward to southwestern North Carolina and is said to reach its greatest size in this region." Prof. W. W. Robbins [2] writes, " *Prunus pennsylvanica* in Colorado is found at altitudes from 4,000 to 9,500 feet along the whole eastern front of the mountains from the Wyoming line to the New Mexico line. I have never seen it west of the Rocky Mountain range. It does occur eastward on the plains but is found particularly on the rock outcrops, and in gulches." In addition to the foregoing distribution the bird cherry [3] is found on " the eastern slopes of the Coast Range of British Columbia in the valley of the Fraser River."

The larvæ of this insect are not known to develop on any plant except the bird cherry, so, provisionally, we have limited the breeding range of the beetle to the regions inhabited by this tree. The occurrence of *cavicollis* in those areas where *P. pennsylvanica* does not exist (Fig. 1) indicates that a distinction should perhaps be drawn between the breeding range and the migratory range of the insect.

[1] Wight, W. F. Native American Species of *Prunus*, U. S. Dept. of Agr. Bul. 179, pp. 60–61. 1915.
[2] Letter of Nov. 7, 1917.
[3] Sargent, C. S. Silva of North America, 4:36, New York. 1893.

ACCOUNT OF RECENT OUTBREAK.

CONDITIONS IN WESTERN NEW YORK IN 1915.

During the first two weeks of June, 1915, the cherry leaf-beetle appeared in countless numbers on cherry and peach trees thruout western New York. In Chautauqua County the beetles were first noted in fruit plantings during the week ending June 5. At that time they were especially numerous in the southern part of the county where they swarmed on the foliage of many kinds of vegetation. Their presence was soon discovered by fruit growers who appealed for assistance to the various state institutions engaged in the promotion of agriculture. The exact date of the beginning of the invasion was not noted but by June 3 the beetles were sufficiently numerous to injure the foliage of cherry and peach trees at Jamestown. They were observed at Fredonia on June 7. At that date the beetles were present in myriads and continued to increase in abundance for nearly a week. Young sour cherry and peach trees were overrun with the insects and in a few days considerable injury was done to foliage. The most serious damage occurred in orchards nearest the localities in which the pin cherry was abundant. During the period of dispersion the beetles flew great distances and alighted on all manner of vegetation from which they later went to incidental food plants.

The beetles came from waste land and land denuded of forests which are grown over with *Prunus pennsylvanica* in the more mountainous portions of southern Chautauqua County and northern Pennsylvania; and the direction of their flight was northward. So prolonged and direct was their migration that vast numbers of the insects were carried far out into Lake Erie. Many alighted on drift-wood and other floating objects and eventually drifted ashore, where they sought food. Of those which fell in the water and were washed ashore, a small percentage revived but the majority perished. A visit to the shore of Lake Erie at Westfield, on June 23, revealed the dead bodies of millions of beetles in two parallel rows as far as the eye could see along the beach. On the drift-wood which lay on the beach the living beetles were so numerous that it presented a reddish appearance. Similar conditions were reported from the entire Chautauqua County shore of the Lake. On June 10 Cushman and Isley made similar observations on the shore of this lake

in Erie County, Pennsylvania. As an example of popular misconception, it should also be noted that the presence of the beetles on the beaches and in the water gave rise to the idea that the insects came from Canada.

The dispersion was at its height in the vicinity of Fredonia from June 7 to 12. After the latter date the beetles were occupied with feeding and propagating. They fed ravenously until about June 15, when they became appreciably less active in this particular.

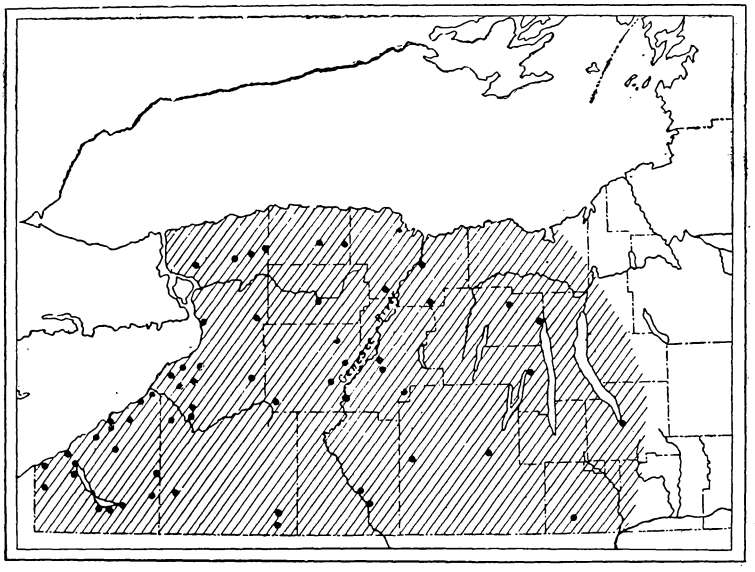


FIG. 2.— MAP SHOWING THE EXTENT OF INFESTATION BY THE CHERRY LEAF-BEETLE IN WESTERN NEW YORK DURING 1915.

Localities in which the beetles were observed or reported are shown by dots.

After June 20 little harm was done by the adults except on young trees. The beetles diminished in numbers during July and by the middle of August all had practically disappeared from cultivated trees.

While the leaf-beetle is indigenous to New York, destructive attacks on cultivated varieties of cherries have only been of local importance and at wide intervals and there is no record of as extensive an outbreak in this State as the one just described. The map (Fig. 2) illustrates what is believed to be the extent of the affected area in the State during 1915. It will be noted that the pest made

its appearance over practically all of the western part of the State as far east as Ithaca. From observations and correspondence the insect appears to have been most numerous in the region west of the Genesee River and it was generally destructive thruout this area. The greatest number of inquiries from fruit growers came to our attention from Chautauqua and Erie counties. However, in the counties of Niagara, Orleans, Livingston and Monroe, where there are large acreages of peach orchards and nurseries many communications were sent direct to the State Horticultural Inspectors who reported that they were flooded with inquiries regarding the pest during the height of the invasion.

The insects were either observed by us or reported by correspondents to be present in conspicuous numbers at Randolph, Conewango Valley, Jamestown, Lakewood, Mayville, Ashville, Findley Lake, Ripley, Westfield, Brocton, Fredonia, Dunkirk, Cassadaga, Sheridan, Silver Creek, Irving, Angola, Brant, North Collins, Eden, Derby, Buffalo, Alden, Sanborn, Lockport, Gasport, Middleport, Albion, Holley, Batavia, Arcade, Wellsville, Dansville, Mt. Morris, Rochester, Hilton, Clifton, Clifton Springs, Geneva and Penn Yan. Wm. T. Davis [1] states that he took specimens at Rock City (Four Mile P. O.), Portage, and in Yates County during June, 1915. Herrick and Matheson [2] give the following additional places from which the species was reported as destructive during this period: Sonyea, Perry, Scio, Honeoye Falls, Bath, Holland, Collins, Gowanda, Wyoming, Perrysburg, Chautauqua, Kennedy, Castile, Elmira, Hornell, Olean and Ithaca. All places mentioned are indicated by means of dots on the map shown in Fig. 2.

OCCURRENCE OF LEAF-BEETLE IN OTHER STATES.

There were two separate regions in which outbreaks of *cavicollis* occurred during 1915; one comprising the Alleghany highlands of New York, Pennsylvania and northern West Virginia and the other the Grand Traverse Region of Michigan.

The beetles were especially destructive in the northern counties of Pennsylvania adjoining Chautauqua, Cattaraugus and Allegany Counties of New York. Surface [3] records the beetles as destructive

[1] Letter of April 3, 1916.
[2] Loc. cit., p. 944.
[3] Loc. cit., p. 21.

in Lycoming County, Pa., which indicates that the outbreak extended as far east in the latter state as in New York. The injury by the beetles in Erie[1] County, Pa., resembled that in Chautauqua County. The outbreak extended thru the highlands of Pennsylvania south to the northern part of West Virginia but apparently it did not extend into Ohio. The beetles were more numerous in the western part of the Pennsylvania region than in the central part of the state. Professor F. N. Fagan,[2] State College, Pa., writes, "in the late summer of 1915 the cherry leaf-beetle made its appearance at State College . . . . . They were not very injurious at that time, but in the summer of 1916 they became very plentiful and caused much damage to peach and cherry foliage."

Regarding the abundance of the beetles in Michigan, Professor Pettit[3] writes that they were exceedingly numerous in the northern portion of the lower peninsula. They also occurred as far south as Port Huron. His correspondence records the insect at Alden, Bear Lake, Bellaire, Beulah, Central Lake, Cheboygan, East Jordan, Evart, Harbor Springs, Kingsley, Leetsville, Pellston, Thompsonville, Traverse City, Williamsburg and Wolverine (see Fig. 3). This outbreak was not a continuation of the invasion of the Alleghany area but doubtless similar conditions prevailed in the two regions preceding the appearance of the beetles in superabundant numbers.

SOME FACTORS THAT FAVORED DISPERSION.

All the factors that were responsible for this great invasion are not known and it is difficult to separate causal factors from coincidental phenomena. Thruout the Alleghany Mountains and the plateaus forming the Piedmont regions to the north and west of the highest ridges much unarable land has been denuded of forests. On most of this land grazing and forest fires have prevented reforestation but it is covered with vegetation in which the less valuable, quick-growing shrubs and trees are dominant. The bird cherry is one of the species which becomes established under such conditions. (Plate IV, fig. 1.) This tree[4] is also found in swales and on much

[1] Cushman and Isley, loc. cit., pp. 3–5.
[2] Letter of October 20, 1916.
[3] Letters of October 20 and 25, 1916.
[4] Regarding the establishment of bird cherry in abandoned farm land and in land denuded of forests see Bray, "The Development of Vegetation of New York State," pp. 162 and 177.

of the unproductive and waste land about farms in the Alleghany plateau region of New York (Plate III, fig. 2; Plate IV, fig. 2). Thus an abundance of essential food had been provided for the

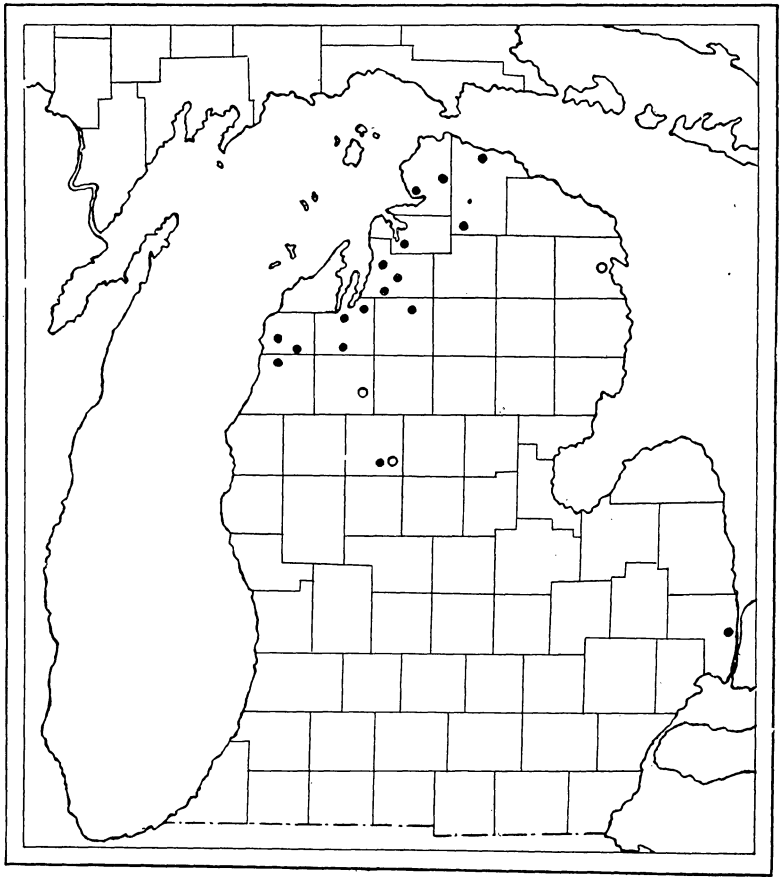


FIG. 3.— MAP OF THE LOWER PENINSULA OF MICHIGAN SHOWING INFESTATION BY THE CHERRY LEAF-BEETLE.

Black dots represent localities reported in 1915, circles show places reported during 1916. Localities furnished by Prof. R. H. Pettit.

beetles previous to 1915 and there exists at the present time a vast feeding ground for this species. Under these conditions an abundance of cherry leaf-beetles developed during 1914. To what extent parasitic and predaceous enemies affected *cavicollis* is not known

nor do we know that a greater percentage of adults survived hibernation than normally. Several facts, however, are known: (1) There was a severe freeze over most of this area on May 27, 1915, which greatly reduced the amount of foliage on much of the vegetation, including the pin cherry. In this connection it is worthy to note that the outbreak of leaf-beetles at Ausable Forks, N. Y., in 1895 described by Dr. Lintner [1] occurred after a late frost. (2) Thruout the southern part of Chautauqua County tent caterpillars were abundant on the various species of wild cherry, including *P. pennsylvanica;* (3) the normal dispersion period of the species occurs in this region during the latter part of May and early June; (4) the beetles are more active when the temperature is above 60 deg. F., and they fly with the wind. On several such days just preceding and during the infestation the wind was southerly; and (5) the beetles were abundant on the pin cherry. The combination of these five factors we believe to be largely responsible for the great movement of the beetles to cultivated trees in western Pennsylvania and New York. It is possible that there were enough beetles in their native habitat to have caused a moderate infestation had there been no frost and no tent caterpillars, but it seems plausible that a diminished food supply would induce a greater percentage of beetles to migrate than would ordinarily abandon their native haunts where the means of subsistence were ample.

With respect to conditions in Michigan, Professor Pettit [2] says: "The beetle is a northern pest, which is very common on pin cherries about Lake Superior. There it is abundant each year." The freeze of May 27, extended thruout the northern part of Michigan.

During 1916 the attacks by the beetle were very slight in both regions with a few exceptions; in fact, so few beetles appeared thruout much of the area infested the previous year that it was not necessary to spray in order to protect cherry orchards. On the other hand tent caterpillars were not abundant during 1916 and there was no late freeze to damage the foliage; and yet, withal, a moderate infestation of the beetle appeared thruout Chautauqua County and in other sections of western New York. This was partially due to the scattered growth of pin cherry becoming more heavily infested during 1915; from which the progeny of these beetles

[1] Rept. of N. Y. State Entomologist for 1895, pp. 197–198.
[2] Letter of October 20, 1916.

migrated to cultivated trees during the spring of 1916. In spite of the behavior of the insect during 1916 it seems not unreasonable to consider the destruction of foliage by frost as one important factor in influencing the appearance of destructive numbers of the leaf-beetle during the previous year in both the Michigan and Alleghany regions.

ACTIVITIES OF LEAF-BEETLE DURING 1916.

During 1916 all reports in New York, with the possible exception of two, showed that the beetles were less numerous than during the preceding summer. They were observed thruout all the State west of the Genesee River, and in many localities in Chautauqua, Cattaraugus, Erie and Niagara counties they were also sufficiently numerous and destructive to influence growers to resort to spraying. At Conewango Valley some damage to young cherry trees was observed. Mr. C. L. Blood [1] of Jamestown reported that in his vicinity the beetles destroyed much foliage of the younger trees. Mr. Gideon C. Gorsline [2] writing from Cattaraugus County says " the red cherry beetle is very numerous in the village of Randolph and some of the outlying districts." Miss Cora Freeman [3] reported this pest as numerous about Angola. Mr. O. H. Houenstein [4] stated that similar conditions existed about Eden, and Mr. Otto A. Wagner [5] found the insects numerous at Alden. These correspondents agree that leaf-beetles were not as numerous during 1916 as during the preceding year. Mr. L. F. Strickland,[6] State Horticultural Inspector, reported that *cavicollis* was very numerous about Lockport during June, 1916, but was less abundant than in 1915. He also mentioned it as destructive to cherry stocks in a nursery at Batavia. Mr. Harvey E. Bolton [7] found the beetles quite scarce in cherry and peach orchards in the vicinity of Batavia. Mr. G. A. Blanchard [8] stated that the insects were very numerous in Middleport, but scarce in peach and cherry orchards in the surrounding country. Mr. A. B. Buchholz,[9] State Horticultural

[1] Letter of June 21, 1916.
[2] Letter of June 22, 1916.
[3] Letter of June 29, 1916.
[4] Letter of June 23, 1916.
[5] Letter of June 27, 1916.
[6] Letter of June 27, 1916.
[7] Letter of June 24, 1916.
[8] Letter of June 28, 1916.
[9] Letter of June 26, 1916.

Inspector, wrote regarding the infestation in Orleans County during the past season: "On trees where the insect was very abundant last year, only a few can be found this season . . . . . They are not sufficiently abundant to attract attention unless one is especially interested in the species." Mr. L. D. Rhind,[1] State Horticultural Inspector, and The George A. Sweet Nursery Company,[2] noted the insect as being scarce in the vicinity of Dansville during 1916. The region east of the Genesee River together with Orleans and Monroe Counties had a much lighter infestation by *cavicollis* during 1916 than did the region west of this river.

The infestation of this year was not due to migration from the usual habitats of this beetle, but was largely, if not entirely, owing to the development of an unusual number of the insects during 1915 on the scattered trees of *P. pennsylvanica* which grow on the waste areas in the vicinity of farms thruout western New York. The insect is normally very scarce on these trees, which perhaps may be accounted for by the unfavorable hibernating conditions that generally exist under trees in such locations. During the winter of 1915–16, many adults, however, hibernated safely and later migrated to cultivated cherries.

Thruout northwestern and western Pennsylvania the leaf beetle was present in numbers sufficient to cause some damage during 1916 but much less than the previous season. In Center County, Pa., however, there appears to have been a greater invasion during this season than in 1915. Professor F. N. Fagan[3] writes: "They were not very numerous during 1915, but during the following summer they became very plentiful and did much damage to peach and cherry foliage. From the numerous reports that came from the nearby territory I assume that the outbreak was quite general in Center County at least." Professor Pettit[4] writes that in Michigan the infestation during 1916 was much diminished in comparison with that of the preceding summer. His correspondence revealed the presence of the beetles in three localities: Alpena, Cadillac and Evart. The distribution of the insects during this season is shown in Fig. 3.

[1] Letter of June 22, 1916.
[2] Letter of June 21, 1916.
[3] Letter of October 20, 1916.
[4] Letter of October 20, 1916.

APPEARANCE OF SPECIES DURING 1917.

In marked contrast to the two preceding years, there were very few beetles during 1917. Repeated examination of bird cherry growing along fences failed to reveal a single beetle. Several beetles were found in a natural habitat where *P. pennsylvanica* grew abundantly. This was on the higher land of the Alleghany Plateau region of Chautauqua County. Even under such favorable conditions of food and shelter we were unable to secure a sufficient number of specimens to continue insectary studies. Only a few letters were received from fruit growers during 1917 reporting the beetles as feeding on cultivated cherry or peach trees. In other words, the insect had diminished from a state of superabundance during 1915 to normal, perhaps subnormal, numbers by the third season following the outbreak.

DESCRIPTIONS OF LIFE STAGES.

Egg.— The eggs of the cherry leaf-beetle are small, yellowish, ellipsoidal bodies, and they vary in color with the amount of moisture on them; those in dry situations are stramineous while those that are moist appear bright yellow. The surface is finely reticulated, each unit of the network being irregularly hexagonal. (Plate I, fig.1).

TABLE I.— MEASUREMENTS AND RANGE OF VARIATION OF EGGS OF THE CHERRY LEAF-BEETLE, FREDONIA, N. Y., 1916.

	Maximum.	Minimum.	Mean.	Standard deviation.	Coefficient of variability.
Length of egg	.896mm.	.608mm.	.782±.0024mm.	.0556±.0017mm.	7.1±.22
Breadth of egg	.777mm.	.507mm.	.695±.0023mm.	.0534±.0016mm.	7.7±.23
Length-breadth index 100		74	88.75±.18	4.12±.13	4.6±.14
Coefficient of correlation between length and breadth (r)					.805±.015
Number of eggs measured					247

The eggs show considerable variation in length and diameter as shown in Table I, which summarizes the measurements of two hundred forty-seven eggs that represent a random sample. From this data there were calculated the mean, standard deviation and coefficient of variability of the length and the breadth as well as the coefficient of correlation between the length and breadth. It was

observed that a few eggs were almost perfect spheroids while others showed considerable difference between the two diameters. To determine the range of this variation a length-breadth index [1] was calculated by dividing the breadth by the length and multiplying the result by 100.

The measurements were made with a lens combination of a compound microscope whereby one space of the micrometer scale, equaled .0169 mm., but owing to the convexity of the eggs the determinations involve an error of about .005 mm.; therefore the mid-values are not given beyond the third decimal. In order that the data may be accessible to other workers the correlation table (Table II) follows:

TABLE II.—SHOWING THE CORRELATION OF EGG LENGTH AND EGG BREADTH.

Egg Breadth. Mid-values.	Egg Length .608	.625	.642	.659	.676	.693	.710	.727	.744	.761	.777	.794	.811	.828	.845	.862	.879	.896	
mm.																			
.507		1	2																3
.524																			0
.541	1	1																	2
.558							1	1											2
.575				1	1	1	1	1											4
.592			1	2	1	2	1	1		1									9
.608			1		3		1	1											6
.625							2	1	1						1				5
.642				1		1	3	2	2	2				1					12
.659							1	3	3	4	1								12
.676							1	2	4	7	4	5	1						24
.693							1	3	5	4	9	6	1	1	3				33
.710									2	4	9	9	6	4	5	1	1		41
.727								2	1	4	2	9	6	6	6	2		2	40
.744											2	7	3	12	6	3			33
.761											2	1	3	3	2	2	1	1	15
.777												2			2	1	1		6
	1	2	4	4	5	5	12	15	18	26	29	39	20	27	25	9	3	3	247

Larva.— After each molt the color of the larva is olive and the head and prothorax are large compared with the body. The setæ over the body and on the head are much more prominent at the beginning of the instar than later but the number and arrangement are the same as in the description below. After several hours the larva becomes a dark brown with the dark patches very close together.

[1] This ratio is employed in anthropomorphic measurements to determine the cephalic index. Pearl and Surface (Bul. 110, Pt. III, Bureau of Animal Industry, U. S. Dept. of Agr.) have used the length-breadth ratio in a study of variation of the egg of the domestic fowl.

The head, prothorax and ninth segment are black. The several instars are much alike except in size (Plate I, fig. 2).

At the end of each instar the larva is almost cylindrical and the ground color of the skin is yellow. (Fig. 4.) Numerous black and fuscous spots and patches are present. The head is nearly hemispherical, slightly less than one-half as broad as the prothorax, black and bears a number of setæ on the dorsal surface. The prothorax is not quite as wide as the meso- or metathorax, but is nearly the same width as the abdomen. The dorsal surface is covered with a continuous oval dark-brown plate with a lighter, very thin, median line. There is a round concave area on each side of the median line. The cephalic margin of this plate bears eight setæ with a larger seta in the cephalic-lateral angle. Two small setæ are situated slightly mesad of the lateral margin midway between the cephalic and caudal margins. Two setæ are on the caudal margin, one on either side of the body and about half the distance from the median line to the lateral margin. The lateral protuberance bears a lune-shaped brown area and from this there project laterally four setæ; several small hairs are present. On the ventral surface the color is yellow, and there is a trapezoidal brown patch in the center with a small oval brown patch cephalad of it. The coxæ are nearly surrounded by two dark patches more or less triangular in shape. The prothoracic legs are black, end in a tarsal claw and bear several setæ.

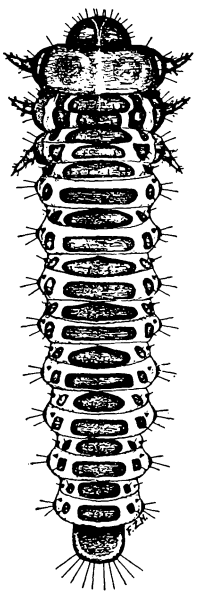


FIG. 4.—FULL GROWN LARVA OF THE CHERRY LEAF-BEETLE (ENLARGED).

The mesothorax and metathorax resemble each other except that sizes of the patches vary. The mesothorax is the broadest portion of the body. Two elongated patches extend across the median line of both of these segments. The cephalic one is the larger, and this on the mesothorax bears four setæ while the one on the metathorax has two setæ. The caudal patch in each case has only two setæ. Laterad of the patches are two dark spots, the caudal being the larger and bearing three setæ while the anterior one has a single seta. Laterad of these two spots is a large hemispherical protuberance bearing a large brown crescent-shaped area and four prominent setæ, the two nearer the center being larger. Just ventrad and slightly caudad of this protuberance is a smaller elongated area bearing two setæ while cephalad and ventrad is a protuberance; that on the mesothorax bearing a spiracle, and the one on the metathorax bearing a seta. Two small setæ are below the mesothoracic spiracle. On the ventral aspect of the meso- and metathorax there is an elongated trapezoidal patch in the center bearing two setæ, and caudad to this there are two small spots bearing one seta each. The legs are the same as on the prothorax.

All the abdominal segments except the ninth and tenth are similar in appearance. Each has two elongated dark patches similar to those on the metathorax; the anterior one bears four small setæ about equal distance apart on a line extending lengthwise thru the middle of the patch; while the posterior patch has two setæ near the ends. The posterior patch of the eighth segment bears four setæ. Laterad of each median patch is a spot bearing a seta. Laterad of each spot and somewhat cephalad is a smaller spot, the anterior one bearing a seta, the posterior spot bearing the spiracle. The lateral protuberances are tipped with large dark areas and bear three prominent setæ, the central one being the largest. Ventrally there is a median transverse trapezoidal patch bearing two setæ and laterad of this is a triangular spot bearing one seta; flanking this is an elliptical brown area bearing two setæ.

The ninth segment is U-shaped, dark brown and bears ten prominent setæ extending from the posterior margin. On the ventral aspect of the ninth segment is an elongated brown patch, and caudad of this is a crescent-shaped protuberance which serves as a foot, to the rear of which is the small tenth segment bearing the anus. The ninth segment and the head do not change in size during the duration of the instar, increase in size taking place at the moult before the parts become heavily chitinized. The measurements of the different instars are as follows:

First instar.— During the first larval instar the diameter of the head averaged .38 mm. with a range in individuals of from .36–.39 mm. The length of the entire insect was found to vary from 1.6–3.3 mm.

Second instar.— The head diameter averaged .54 mm.; individuals varying from .52–.57 mm. The length of the body varied from 2.3–4.5 mm.

Third instar.— The head diameter averaged .76 mm.; individuals varied from .72–.78 mm. The length of the body varied from 3.6–7.2 mm.

Pupa.— The pupa varies from 4 to 5 mm. in length and is bright yellow except the spines and most of the spiracles which are a dark brown (Plate 1, fig. 3). There are no traces of the patches and spots so characteristic of the larva. The abdomen possesses considerable freedom of motion. The head bears well formed eyes, antennæ and mouth parts.

The antennæ show the segments plainly and are curved under the prothoracic and mesothoracic legs, the tips being just caudad of the ends of the tibiæ of the latter. The labrum bears two setæ, one near each lateral angle. The mandibles lie laterad of the labrum. The maxillæ show just below the mandibles. The vertex bears four setæ, one situated mesad of each eye and another mesad and caudad of this seta. On the posterior portion of the pronotum are eight setæ arranged in the shape of a V with the vertex pointing cephalad on the median line. Four setæ are on the anterior margin and a prominent seta in each anterior-lateral angle and another just caudad of the latter. Four small setæ are present on the mesonotum, two on either side of the median line. Four small setæ occur on the metanotum. The mesothorax bears a spiracle. The pro- and mesothoracic legs are folded across the body with tarsi lengthwise of the body. The metathoracic legs are folded under the wings. The tarsi of the prothoracic legs extend to the middle of the third abdominal segment, those of the mesothoracic legs to the middle of the fifth abdominal segment and those of the metathoracic legs to the seventh abdominal segment. Each leg has two prominent setæ on the dorsal aspect of the distal end of the femur. The wings are folded about the body, the elytra extending to the sixth abdominal segment, the metathoracic wings being under these, the tips showing near the legs.

The first six segments of the abdomen resemble each other. Each has a prominent seta on each side of the median line and one on each lateral protuberance. There is a prominent dark spiracle with tracheae showing through the body wall on the first five abdominal segments, mesad of the lateral protuberance and cephalad of the middle of each segment. The spiracles of the sixth and seventh segments are paler but similarly located. The eighth segment is compressed and bears four small setæ. The ninth segment bears two heavy spines each flanked laterally by a seta. The tenth segment bearing the anus is on the ventral aspect of the body and is very small and almost circular.

Adult.— In the northern portion of the range of this species the adult beetles are readily distinguished by their red color and their size (Plate I, fig. 4). The antennæ are black while the legs range in color from black to red. The insects are between 4.5

and 5.5 mm. (.17 and .21 inches) in length. The southern area of the normal habitat of the species overlaps the range of *rufosanguinea* which insect it closely resembles. The adult was briefly characterized by Le Conte,[1] and was later described with considerable detail by Horn [2] as follows:

G. cavicollis Lec., oval, narrower in front, subdepressed; color dull red, slightly shining, very sparsely finely pubescent. Antennæ entirely black. Head red, coarsely punctured, without median depression, frontal tubercles smooth. Thorax nearly twice as wide as long, narrower in front, sides arcuate, or obtusely subangulate, hind angles distinct, base on each side obliquely sinuate, disc feebly convex, a broad depression on each side and another along the middle, surface coarsely punctured, more densely in the depressions; scutellum red. Elytra broader behind the middle, sides arcuate, margin explanate, humeri distinct, but rounded; sutural angle well marked, but obtuse; disc with coarse and deep punctures not crowded, less deep near the apex, interspaces smooth, shining. Body beneath red, the metasternum often piceous, sparsely finely punctate and finely pubescent. Legs variable in color entirely red to almost entirely piceous. Length .18–.22 inch (4.5–5.5 mm.).

Male.— Claws finely bifid at apex. Last ventral segment broadly emarginate at apex, with a deep triangular depression limited by a sharply elevated line.

Female.— Claws more deeply bifid, the parts more divergent. Last ventral segment with a very slight emargination, in front of which is a slight fovea.

The middle coxæ are absolutely contiguous, the mesosternum is not prolonged between them. Except as to the color of the legs no variation has been observed in this species.

G. sanguinea of Europe has been referred to as probably allied to this species, but an examination of that shows that it should be associated with *americana*, by reason of its convex form and not explanate elytral margin.

SEASONAL HISTORY.

EMERGENCE OF ADULTS FROM PUPAL STAGE.

In western New York most of the insects emerge as adults during the month of August of a normal year, altho some appear during the latter part of July and during early September. In 1915 Cushman [3] and Isley found the beetles emerging in their cages between August 23 and September 18 and during this period of twenty-six days the numbers that appeared each day were rather

[1] Le Conte, J. L. Proc. Acad. Nat. Sci., Phila., p. 216. 1865.

G. cavicollis, obscure sanguineo-rufa, ovata convexa, thorace nitido, brevi, lateribus subangulatis, angulis omnibus prominulis, basi utrimque profunde oblinquo sinuato, disco cribratim punctato, profunde canaliculato, et utrimque late excavato, elytris parce brevissime pubescentibus sat dense cribratim punctatis; antennis nigris, tarsis fuscis. Long. .21.

Translation.— *G. cavicollis*, dark blood-red, oval convex, thorax shining, short, with sides subangular, all angles prominent, bases on both sides with deep oblique curve, disc punctated in the manner of a sieve, deeply channelled and broadly excavated on both sides, elytra sparingly covered with short hair rather densely punctated with pits; antennæ black, tarsi fuscous. Length .21 (inch).

[2] Horn, G. H. *Trans. Am. Ent. Soc.* 20 : 77, 1893.

[3] Loc. cit. pp. 14-18.

uniform. In 1916 the adults emerged at Fredonia from July 31 to September 2, covering a period of thirty-four days, and about seventy per ct. of the beetles emerged during the first ten days. The weather for this interval was more nearly normal than for the same months during the preceding year. Variation in seasonal conditions is without question largely responsible for the differences in dates of emergence during these two years. Also the methods employed in rearing the insects would unquestionably account, at least in part, for some of the variances reported in the foregoing observations.

COLORATION CHANGES.

When the adult first emerges from the soil it is of a uniform yellow changing shortly to a yellow-brown color. After feeding it gradually assumes a darker tint and twenty-four hours after emergence the beetle presents a rather dark brown appearance. About the second day, and sometimes not until the third day, a distinct red tinge appears in the elytra and portions of the body. The rate of change in coloration is more rapid on warm than on cool days but during 1916 the minimum time required by males and females to acquire the full blood-red color of the normal adult was three days, while the maximum length was ten days and the mean six days.

FEEDING HABITS AFTER EMERGENCE.

The adults are rather sluggish and feed only slightly after their exit from the pupal cells. At no time during the fall was feeding as active as during the spring, and there was a tendency to seek hibernating quarters soon after emergence. The beetles crawled into the rubbish during cooler days and emerged from places of concealment and fed when the weather was warm.

HIBERNATION.

TIME OF ENTRANCE INTO HIBERNATION.

During the month of September the beetles confined in breeding cages showed a tendency to hibernate, but the complete disappearance of the insects into their winter quarters was a gradual process. On September 2, 1916, when the maximum temperature was 69 degrees F. and the sun shining brightly, nine beetles in one cage were feeding and twenty-eight beetles were in hiding in debris at the

bottom of the cage. Five adults were added to this cage on September 9 and twelve beetles fed during the afternoon while thirty beetles hid in the rubbish. It is to be noted also that the day was clear with a maximum temperature of 74 degrees F. This ratio between the active and passive insects was maintained for nearly a week, during which time the weather was very warm. On September 22 when the maximum temperature was 67 degrees F. six beetles were on the leaves and thirty-six were concealed in rubbish. By October 1 all the beetles in the breeding cages were in hibernating quarters. In order to compare these results with conditions outside careful examinations were made during September of pin cherry foliage, in a locality where the beetles abounded during the summer, but in no instance were the insects detected. It appears from these observations that under normal conditions during 1916, entrance into winter quarters occurred earlier than in the cages.

The temperature records during and after this time of entrance into hibernation raise the question if, as with some other insects, low temperatures are largely responsible for the movement of the beetles to places of concealment for the winter. During the first half of October high temperatures prevailed and there was little rain until the 13th. During the first fifteen days of the month the maximum temperature was 83 degrees, the minimum 32 degrees, and the average mean temperature was 56 degrees. A killing frost occurred October 1 and this it is presumed exerted some influence in driving the beetles to shelter from which the warm weather of succeeding days was apparently not able to entice them.

CONDITIONS OF FOOD PLANTS AT TIME OF ENTRANCE INTO HIBERNATION.

During the month of September the pin cherry foliage was green and, while it perhaps was tougher than earlier in the season, to the eye it presented no distinct change which might be responsible for the cessation of feeding by the cherry leaf-beetles. The killing frost of October 1 did not destroy this foliage immediately but shortly afterwards the leaves began to show signs of decreased vigor. There was a distinct tendency to yellowing and the leaves dropped readily when touched. After the second killing frost on October 10 the trees and shrubs took on the autumnal tints and before many days practically all the foliage had fallen.

STAGES ENTERING HIBERNATION AND NATURE OF SHELTER.

As has already been suggested the adult is the only stage of the cherry leaf-beetle known to enter hibernation. All of the insects in the pupal stage as late as October 1 did not transform, and later died. In seeking quarters for hibernation the beetles crawled to the bases of the trees upon which they had been feeding and ultimately buried themselves in rubbish and leaf mold. The bird cherry generally grows in what ecologists designate as the forest margin association (Plates III and IV). In such situations there are numerous bushes, brambles, weeds, and other vegetation which catch the leaves and other rubbish. As one penetrates deeper into the leaf mold this becomes more decomposed until finally there is the soil. It is this decomposed mold that shelters the beetles, and the nature of the shelter sought by the insects is clearly shown in Plate III, fig. 1, which was photographed a week previous to emergence in the spring. This location contained more than the average amount of leaf mold. In exposed places, as along fences and narrow strips of waste land, there is little opportunity for the formation of much leaf mold, and the absence of this may perhaps explain why the beetles do not normally infest the more isolated bird-cherry trees growing in such locations. A typical location for the hibernation of the beetles is illustrated in Plate IV, fig. 1. Here beetles were observed emerging from winter quarters during the month of May in both 1916 and 1917.

EMERGENCE FROM HIBERNATION.

Time of emergence.— In 1916, the first emergence of the beetles from hibernation occurred in natural surroundings at Fredonia on May 27. Because of the backward season this date is believed to be somewhat later than the time of emergence during 1915. The first appearance of the beetles during 1917 at Lily Dale, eight miles from Fredonia and five hundred feet higher, was on May 30. The first adults emerged during two seasons about one week after the bird cherry was in full bloom.

Weather conditions preceding and during emergence.— Believing that the time of emergence from hibernation for any insect is a function of climatic conditions, records were kept during 1916 of the temperature, relative humidity, amount of rain and condition of the sky.

The temperature records were obtained by a thermograph which was carefully checked by a maximum and minimum thermometer in the regular United States Weather Bureau type of shelter. The relative humidity was secured by means of a sling psychrometer at 8 A. M., 1 P. M. and 8 P. M., and the arithmetical mean of the three readings was determined. Rainfall was measured by the United States Weather Bureau rain gauge and is given in hundredths of an inch. The character of the sky is given as cloudy if the sky averages .7 or more cloudy for the period from sunrise to sunset; clear if less than .3 cloudy, and partly cloudy if between .3 and .7 cloudy. These different conditions are represented by symbols used by cooperative observers:

○ clear ⊖ partly cloudy ⊕ cloudy.

These records from April 11 to May 30, 1916, are shown graphically in Fig. 5.

Similar records of the weather were kept during 1917 but the failure of the beetles to emerge in any of the places in the Lake Erie Valley where records were taken during the spring of 1916 makes it impossible to check the results of the previous season. Owing to the increased altitude, about 500 feet, of Lily Dale over that of Fredonia and the absence of records of the weather at the former place, comparisons are obviously impossible.

LENGTH OF THE HIBERNATION PERIOD.

If we assume October 1 as a normal time of entrance into winter shelter for this insect and the last week of May as the time of emergence, the length of the hibernating period in western New York is nearly eight months. It is possible that an early spring, such as occurred in 1915, might shorten this period to seven and a half months, but it is doubtful whether a combination of early fall and late spring would prolong this period over eight and a half months in this region. As the insect has not been studied in the southern part of its range we have no data regarding the length of this period there, but we would expect it to be shorter than that for western New York.

ACTIVITIES ON EMERGING FROM HIBERNATION.

The beetles upon emerging from their winter quarters are sluggish but they soon seek bird-cherry bushes and trees in search of food.

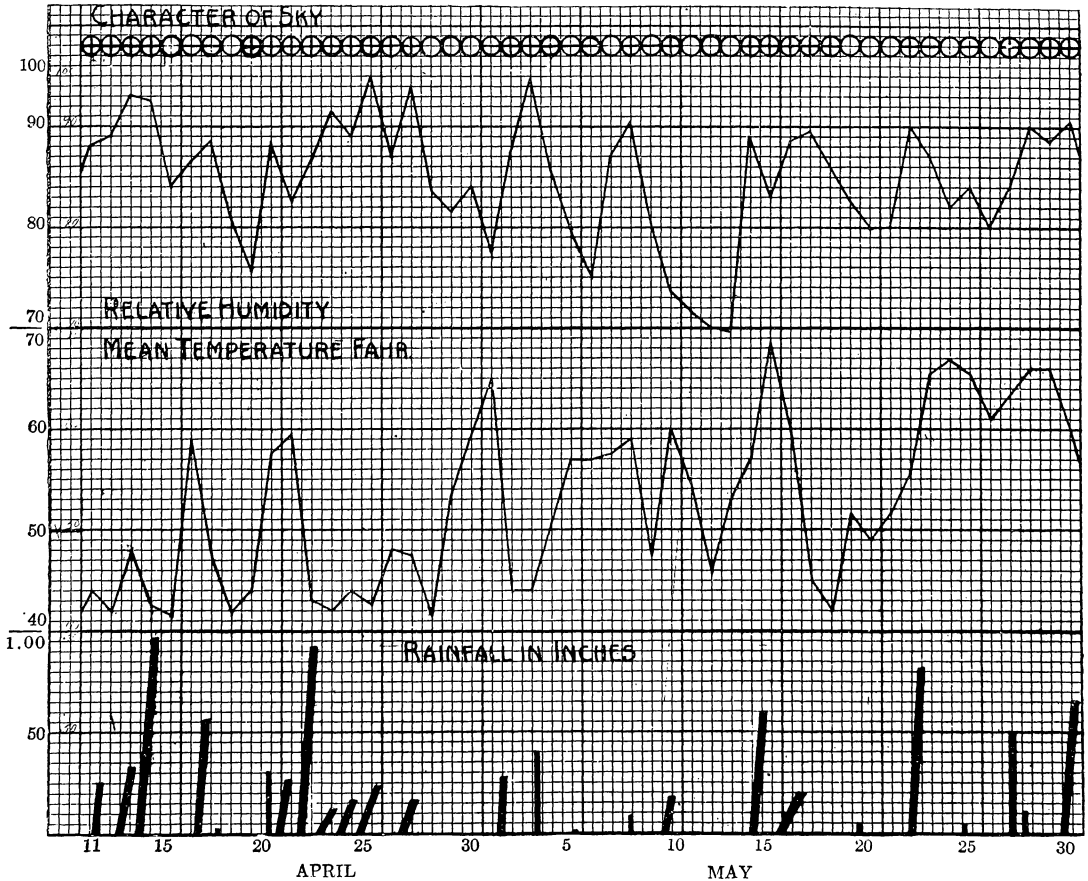


FIG. 5.—CHART SHOWING MEAN TEMPERATURE, RELATIVE HUMIDITY, CHARACTER OF THE SKY AND AMOUNT AND DURATION OF RAINFALL FOR EACH DAY FROM APRIL 11 TO MAY 30, 1916, AT FREDONIA, N. Y.

They seem to prefer younger trees of this species of cherry growing near their hibernating quarters. Feeding is not very active for several days, but thereafter if the temperature is high they feed rather voraciously, and if the weather is cool they crawl into sheltered places. Beetles were observed mating on the days when they emerged, at which time the temperature was 74 degrees F. and the sun was shining brightly.

FEEDING HABITS OF THE ADULTS DURING SPRING AND SUMMER

The nature of feeding by the adults varied to some extent according to the host. On bird cherry and young peach trees the insects attacked both the upper and lower surfaces of the leaves, showing a preference for the undersides. They ate irregular holes thru the leaves, avoiding the larger veins and the midrib. The initial holes in the leaf tissues were often enlarged by the feeding operations of several individuals. In spite of considerable damage the leaves of the pin cherry retained much of their original shape, altho when severely injured they presented a ragged appearance (Plates V and VI, fig. 2). The outer areas of leaves that were badly affected died and curled, but such leaves adhered to the tree for some time owing to the green tissue which remained along the midrib. The wind usually tore such leaves into shreds. During the outbreak of 1915 evidence of the destructive work of the beetles was observed on every hand, and was very conspicuous after the leaves had turned brown. On account of the severity of injuries to foliage one could distinguish very quickly the bird cherry from other species of wild cherries even at considerable distances.

With large peach trees, however, there was much less concentration of the beetles, on account of the great mass of foliage; so that while holes were eaten in the leaves the foliage did not present the ragged appearance so characteristic of smaller trees of this fruit and more especially the bird cherry.

On sour cherries the beetles ate quite differently. They fed almost entirely on the undersides of the leaves, eating the softer tissue as far as the veins (Plate VI, fig. 1, and Plate VII). Leaves that were severely attacked turned brown on the underside and showed a tendency to curl upwards, presenting a scorched appearance (Plate VIII). Occasional leaves were entirely eaten thru and some feeding also occurred on the upper surfaces. After injured

leaves had dried small areas dropped out, producing holes, but generally sour cherry foliage did not show the ragged appearance so typical of both the bird cherry and the peach.

In general, the insects obtained their sustenance from foliage, altho in several instances where trees were completely defoliated the pest attacked the green fruits of the sour cherry. At Jamestown one large sour cherry tree was observed on which practically all the fruit had been extensively pitted by the feeding of the beetles after the foliage had been destroyed. The tree was an isolated one and this form of injury was unusual. In commercial cherry orchards injuries to the young fruits were, in the main, unimportant.

The beetles also exhibited a partiality for the foliage of shoots growing about the bases of cherry trees or for seedlings in fence rows. In a number of instances the presence of such undergrowth served to protect the foliage of young trees from attack.

PROTECTIVE HABITS.

FEIGNING DEATH.

In common with many of the Chrysomelidæ the adults of *cavicollis* have the habit of dropping from the foliage and feigning death upon the approach of enemies. When the weather is cool the beetles do not fall to the ground so readily as when the temperature is above 60 degrees F. and if the weather is hot they are apt to fly instead of feigning death. During windy weather it requires considerable movement of the foliage to cause the beetles to drop, but during a calm the slightest movement of the leaves by any agency except the wind will cause practically every beetle to fall. Experiments with the creatures seem to indicate that they are able to distinguish between movements by the wind and those caused by other agencies. The beetles usually fall on their backs, remain motionless for a short time and, when danger appears to be past, turn over upon their ventral sides by raising their elytra sufficiently to allow their feet to grasp small objects, and right themselves. Feigning death evidently protects the beetles from birds and other predaceous enemies which seek living and moving creatures for food, for many forms of predatory animals refuse dead organisms in their diet and for this reason seldom touch motionless objects. This habit of the insect in dropping to the ground may be used, however, to good

EXPLANATION OF PLATES.

PLATE I.— LIFE STAGES OF THE CHERRY LEAF-BEETLE.

1. Eggs × 10; 2, larva × 6; 3, pupa × 8; 4, adult × 7.

PLATE II.— LARVAE OF LEAF-BEETLE FEEDING ON THE FOLIAGE OF BIRD CHERRY.

Figs. 1 and 2 natural size; Fig. 3 enlarged.

PLATE III.— HABITAT OF HIBERNATING CHERRY LEAF-BEETLES.

1. Conditions about the bases of bird cherry trees shown in Fig. 2. The hibernating adults were found in the rubbish near the bases of these trees.
2. Cluster of trees of bird cherry growing at the edge of a field. Trees in bloom.

Both photos taken May 20, 1916, Fredonia, N. Y.

PLATE IV.— VIEWS IN HABITATS OF THE BIRD CHERRY.

1. Bird cherry growing in cut-over land near Lily Dale, N. Y. This species is the dominant plant in many such areas. The other prominent vegetation is white pine, hemlock and blackberry.
2. Bird cherry growing in swale near cultivated land. The bird cherry is partially dominant here. Favorable conditions for the hibernation of the beetles.

PLATE V.— EFFECTS OF FEEDING BY ADULT CHERRY LEAF-BEETLES ON FOLIAGE OF BIRD CHERRY.

PLATE VI.— EFFECTS OF FEEDING BY ADULTS OF CHERRY LEAF-BEETLE.

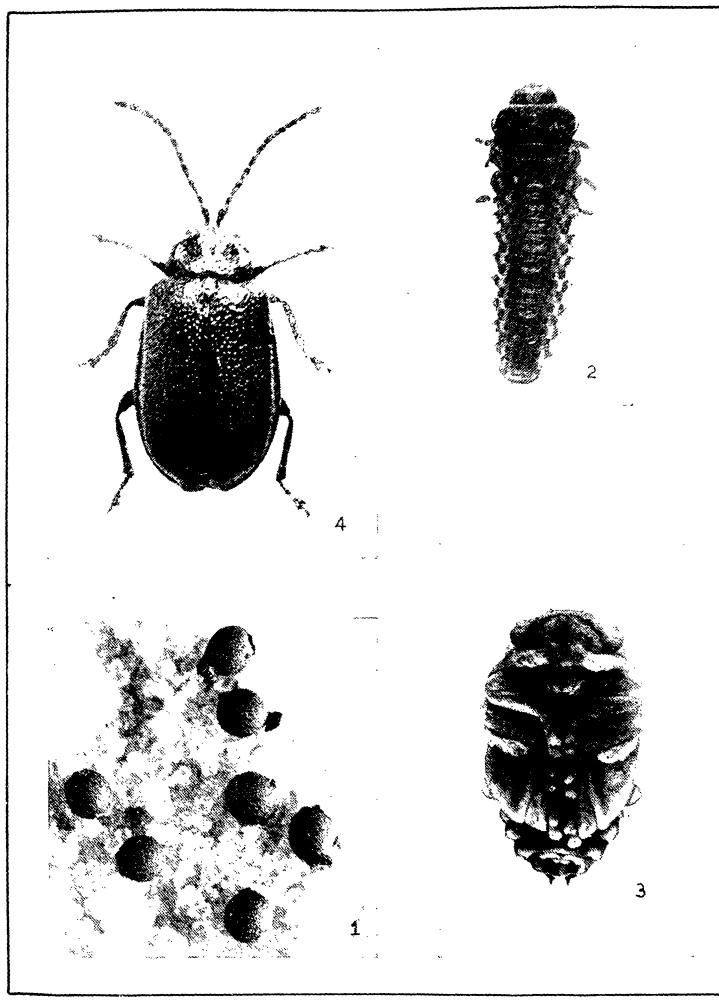
1. Characteristic feeding on the lower surface of a sour cherry leaf.
2. A common condition of the foliage of the bird cherry in Chautauqua County during 1915.

PLATE VII.— EFFECTS OF FEEDING OF CHERRY LEAF-BEETLE ADULTS ON THE UPPER AND LOWER SURFACES OF LEAVES OF SOUR CHERRY.

This foliage was curled when taken from the tree but was expanded to show feeding. All injured portions were brown while uninjured parts were green.

PLATE VIII.— CHARACTERISTIC CONDITION OF SOUR CHERRY FOLIAGE AFTER INJURY BY ADULTS OF CHERRY LEAF-BEETLE.

This foliage had a general brown appearance when photo was taken.



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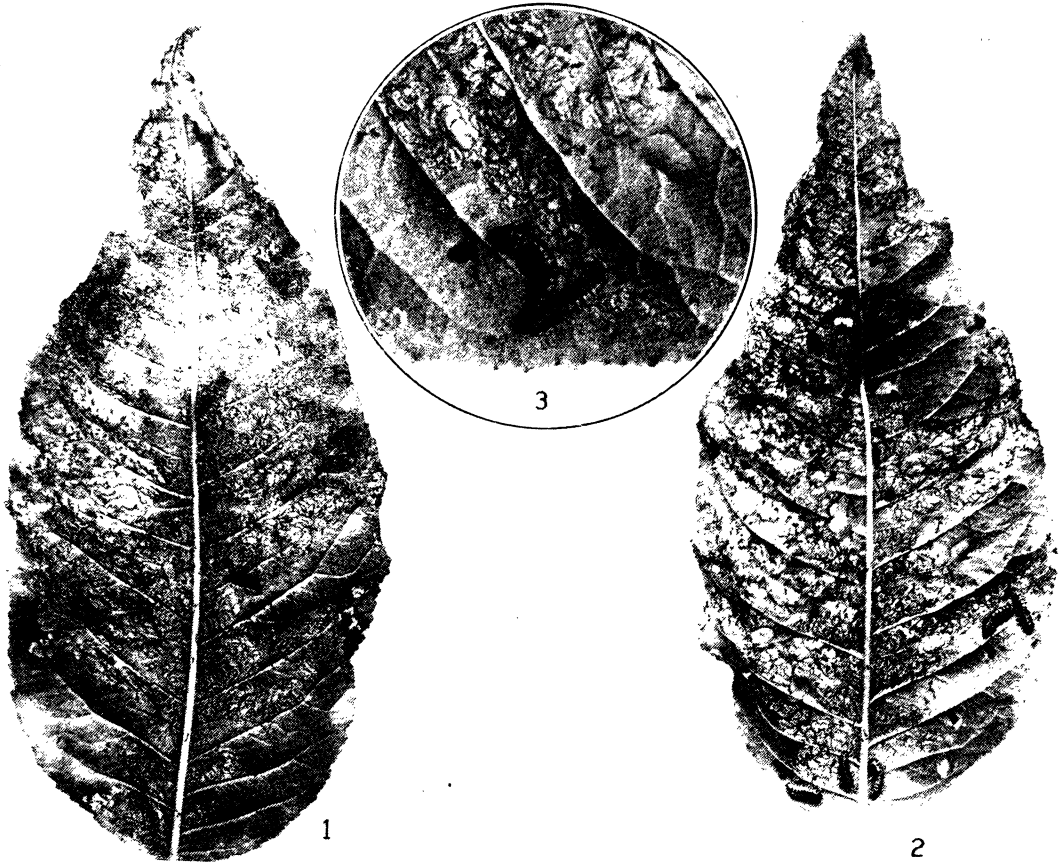


PLATE II.— LARVÆ OF LEAF-BEETLE FEEDING ON THE FOLIAGE OF BIRD CHERRY.
Figs. 1 and 2 natural size; Fig. 3 enlarged

Work-resulting Cherry Leaf-beetles.

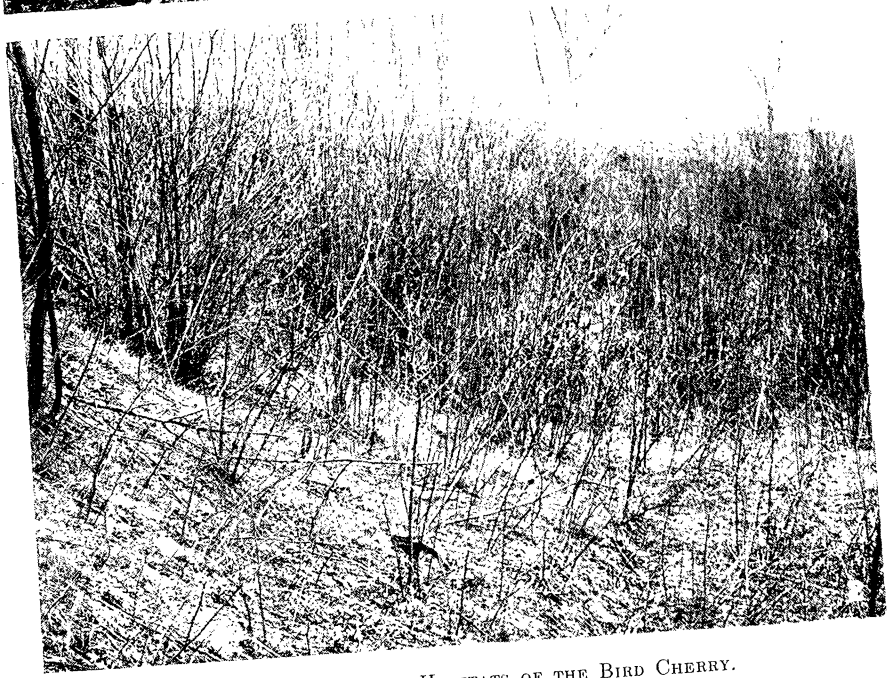
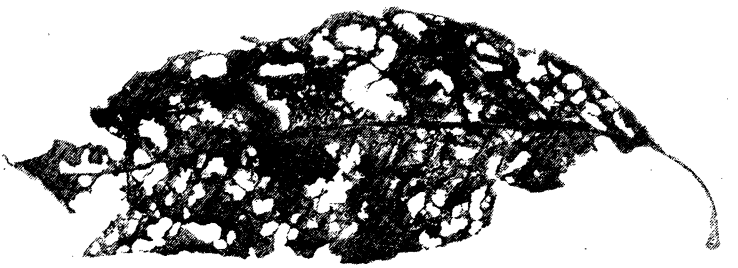
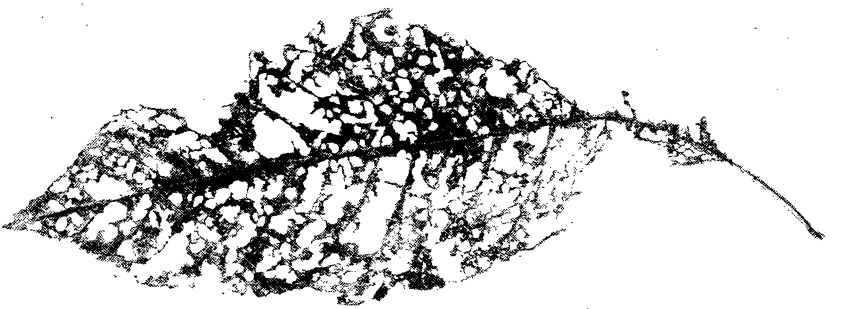
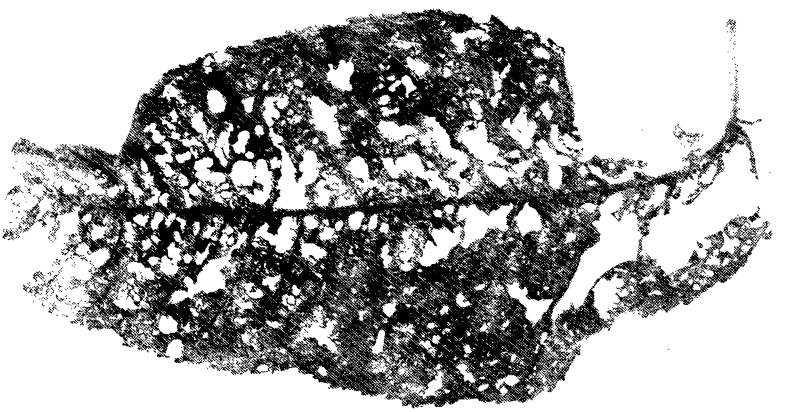


PLATE IV.— VIEWS IN HABITATS OF THE BIRD CHERRY.

(See p. 784 for explanation.)







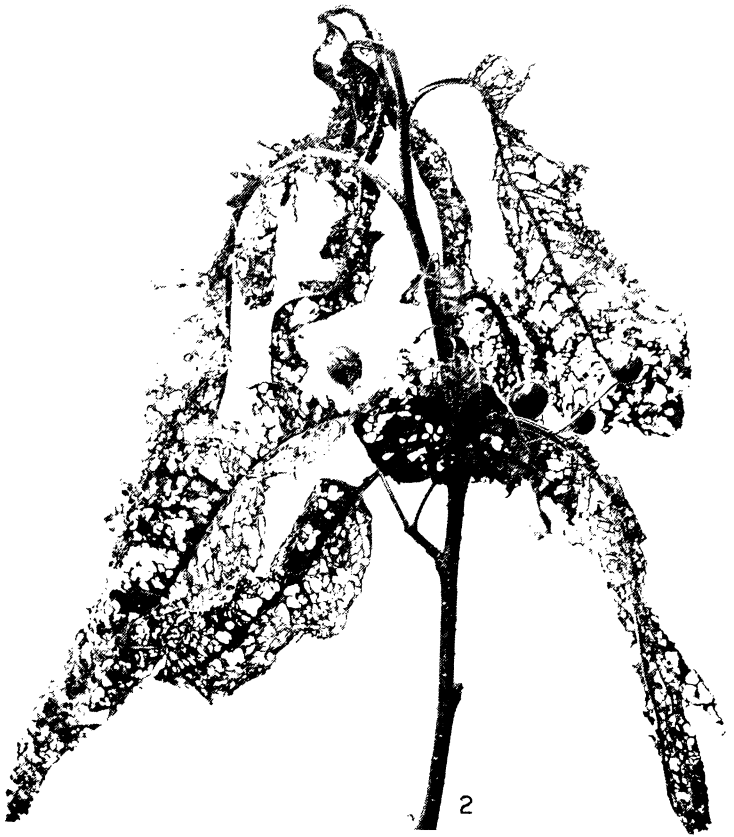


PLATE VI.— EFFECTS OF FEEDING BY ADULTS OF CHERRY LEAF-BEETLE.

(See p. 784 for explanation.)

PLATE VII.— EFFECTS OF FEEDING OF CHERRY LEAF-BEETLE ADULTS ON THE UPPER AND LOWER SURFACES OF LEAVES OF SOUR CHERRY.

(See p. 784 for explanation.)

PLATE VIII.— CHARACTERISTIC CONDITION OF SOUR CHERRY FOLIAGE AFTER INJURY BY ADULTS OF CHERRY LEAF-BEETLE.

(See p. 784 for explanation.)

advantage by the fruit grower for the purpose of collecting the beetles, and thus an instinct which in its natural evironment serves for the protection of its possessor redounds to its disadvantage under orchard conditions.

PROCRYPTIC COLORATION.

By procryptic coloration is meant coloration which aids in concealment. As one sees these shiny, red beetles feeding on green foliage it would seem that their color must render them very conspicuous objects to their enemies; but as soon as the redcoats drop to the ground and lie inactive on their backs they become imperceptible and are very difficult to detect. The venter and legs are quite dark, in some specimens piceous, and they blend with the color of the leaf mold in their native haunts. The dissimulation is not as complete on lighter soil such as obtains in many orchards, especially during dry weather, but even here procryptic coloration is apparent and should be some advantage to the insect. Feigning death and procryptic coloration are supplementary protective factors, which collectively doubtless afford considerable protection to the beetle in its struggle for existence.

FEEDING ON THE UNDERSIDE OF THE FOLIAGE.

The tendency of the beetles to feed largely on the undersides of the leaves may also be classed as a protective factor since it renders them less visible to birds. Moreover it facilitates their dropping to ground with the jarring of the foliage, as when a bird alights on a twig. This habit does not render the beetle entirely immune to attacks by birds, as will be noted in the discussion of predaceous enemies, and there is no definite knowledge as to its influence on predaceous insects. On account of its feeding on the under surfaces of the leaves the pest is more difficult to control by poisons because of the care required to place properly the poisoned spray.

MATING HABITS.

TIME AND FREQUENCY OF MATING.

The beetles were observed mating the day after hibernation and the act was intermittent for a period of about a month and a half. The greatest activity occurred during the month of June and was always most marked on warmer days. Individual couples in cages were observed mating a number of times, six coitions being

the maximum of one pair. However, as it was impossible to keep these cages under constant observation the actual number of copulations for each pair in confinement was not secured but was doubtless greater than that given. The time of each act was not long and the beetles during copulation were easily disturbed.

AGE AT BEGINNING OF COPULATION AND DURATION OF PERIOD.

Copulation was not observed among the beetles before the hibernation period, so all beetles must have been at least nine months from the time of hatching before reaching sexual maturity. The majority were nearly ten months of age at the beginning of this period. They continued to mate for nearly two months so the age at the end of this period would average about twelve months.

OVIPOSITION.

AGE OF BEETLES AT BEGINNING OF OVIPOSITION.

So far as is known no adult of this species deposits eggs until after passing the hibernating period, and moreover this function does not appear normally until after fertilization. Since egg laying occurs during the months of June, July and August, as will be explained later, the beetles are then never less than nine months from the time of hatching. Some individuals may be thirteen months of age at the time they deposit their last eggs.

PERIOD OF OVIPOSITION AND NUMBER OF EGGS LAID BY BEETLES.

In general the oviposition period extends from the first week in June until the middle of August, the maximum number of eggs being deposited during early July. In 1915 the first eggs were found at Fredonia on June 11, but as we were unacquainted with the eggs and especially the place of oviposition it is likely that the first eggs were laid several days earlier and not found. The first eggs discovered during 1916 were found under natural conditions on June 5. This was nine days after the first beetles were observed in coitu. For more than a week after emergence the beetles did not copulate freely so it was June 7 before we secured the first cages of copulating pairs to observe egg-laying habits and the first eggs were deposited in the cages on June 10.

Four copulating pairs of beetles were caged on June 7 and another pair on June 10; and on June 14 thirty-one additional couples taken

from cherry foliage during mating were placed in individual cages. The cages consisted of glass jars of different sizes in which soil and leaf mold were placed to a depth of about one inch and careful attention was given to keep the soil conditions similar to those at the bases of cherry trees.

Foliage of the bird cherry was added to serve as food and a piece of growing bird-cherry wood was placed in the soil to imitate a growing tree, particular attention being paid to have a portion of the wood enveloped with foliage. Most of the eggs were placed on this bark just beneath the surface of the soil. It was found that the size of the cage had practically no effect on the egg laying but that the proper amount of moisture was an important factor. The cages of 1915 proved that the beetles are very fastidious regarding conditions for oviposition and that they will not lay eggs unless conditions are to their liking. Owing to the time required to find the eggs and the number of cages it was necessary to examine one-half, only, of the cages each day, hence the egg record is given in two-day periods. It was feared that unless several cages were used we would fail to secure results comparable to conditions in nature since in all life-history work individual variation is a factor that must be kept in mind. From these cages oviposition records were secured which are summarized in Tables III to VI inclusive.

TABLE III.— EGG-LAYING PERIOD AND DURATION OF LIFE OF THE CHERRY LEAF-BEETLE AT FREDONIA, N. Y., DURING 1916.

	Days	Dates
Total egg-laying period for all females	66	June 5 to Aug. 9.
Longest egg-laying period for a single female	54	June 17 to Aug. 9.
Shortest egg-laying period for a single female	10	June 17 to June 26.
Average egg-laying period for a single female	28	
Maximum number of days after June 8th that female lived	66	Aug. 13.
Minimum number of days after June 8th that female lived	18	June 26.
Average number of days after June 8th that female lived	42	July 20.
Maximum number of days after June 8th that male lived	109	Sept. 25.
Minimum number of days after June 8th that male lived	21	June 29.
Average number of days after June 8th that male lived	41	July 19.

As will be noted in Table III, the egg-laying period for all females in the cages extended from June 9 to August 9 or about sixty-one days, and the total egg-laying period observed at Fredonia during 1916 was sixty-six days. After June 26 the number of females was

gradually reduced by death until by August 9 only one female remained. In this respect the caged insects closely followed conditions in nature, barring accidental deaths. It was our aim to secure the copulating pairs on the same date but the sluggishness of the beetles due to rains and low temperatures for over a week prevented this. However, very few eggs were laid at the bases of cherry trees before June 15 and we believe that the results in the cages are a fair index of the number of eggs laid under outside conditions.

The number of eggs laid by a female beetle varied greatly in the thirty-six cages as Table IV shows.

TABLE IV.— NUMBER OF EGGS LAID BY THE CHERRY LEAF-BEETLE AT FREDONIA, N. Y., DURING 1916.

Largest number of eggs laid by a single female	294
Least number of eggs laid by a single female	10
Mean number of eggs laid by a single female	93±7
Standard deviation (eggs)	62.8±5.0
Coefficient of variability	67.8±5.5
Number of cages of paired beetles	36

The excessive variation in the number of eggs laid by a female as shown by the standard deviation, coefficient of variability and the high probable errors, illustrates the fastidiousness of the beetles as regards environment during egg laying. This variation occurred notwithstanding the fact that an effort was made to keep conditions the same in all the cages.

We are inclined to believe that the true mean number of eggs laid is somewhere between the average and the maximum given in the above table; for it is probable that the number of eggs secured in several of the cages is below that which the beetles would normally have deposited in nature. It would seem that in some of the cages with low records we failed to secure the proper conditions for egg-laying and therefore the beetles refused to deposit the normal number of eggs. If the records of five low cages are left out of consideration the mean would show one hundred five eggs per female.

The number of eggs deposited in all the cages during each period shows marked variation. Attention is called to Table V, which contains the egg-laying record of the insects under observation.

TABLE V.— NUMBER OF EGGS DEPOSITED BY ALL CAGED BEETLES FOR EACH TWO-DAY PERIOD. FREDONIA, N. Y., 1916.

Period	Number of eggs	Number of females	Period	Number of eggs	Number of females
June 9–10	6	4	July 11–12	209	31
June 11–12	6	5	July 13–14	199	28
June 13–14	6	5	July 15–16	152	23
June 15–16	21	36	July 17–18	108	19
June 17–18	75	36	July 19–20	92	19
June 19–20	129	36	July 21–22	43	15
June 21–22	20	36	July 23–24	31	13
June 23–24	75	36	July 25–26	30	9
June 25–26	111	36	July 27–28	43	8
June 27–28	308	35	July 29–30	22	7
June 29–30	237	35	July 31–Aug. 1	19	6
July 1–2	182	35	Aug. 2–3	12	5
July 3–4	366	35	Aug. 4–5	15	4
July 5–6	371	32	Aug. 6–7	1	1
July 7–8	254	31	Aug. 8–9	1	1
July 9–10	190	31			
Total				3,334	

The average number of eggs per female during the same period is given in Table VI. The meteorological conditions occurring during the period of egg-laying are shown in Fig. 6.

TABLE VI.— NUMBER OF EGGS LAID PER FEMALE CHERRY LEAF-BEETLE FOR EACH TWO-DAY PERIOD, FREDONIA, N. Y., 1916.

Periods.	Average number of eggs per female.	Periods.	Average number of eggs per female.
June 9–10	1.5	July 11–12	6.7
June 11–12	1.2	July 13–14	7.1
June 13–14	1.2	July 15–16	6.6
June 15–16	.6	July 17–18	5.7
June 17–18	2.1	July 19–20	4.8
June 19–20	3.6	July 21–22	2.9
June 21–22	.6	July 23–24	2.4
June 23–24	2.1	July 25–26	3.3
June 25–26	3.1	July 27–28	5.4
June 27–28	8.8	July 29–30	3.1
June 29–30	6.8	July 31–Aug. 1	3.1
July 1– 2	5.1	Aug. 2– 3	2.4
July 3– 4	10.2	Aug. 4– 5	3.8
July 5– 6	11.6	Aug. 6– 7	1.0
July 7– 8	8.2	Aug. 8– 9	1.0
July 9–10	6.1		

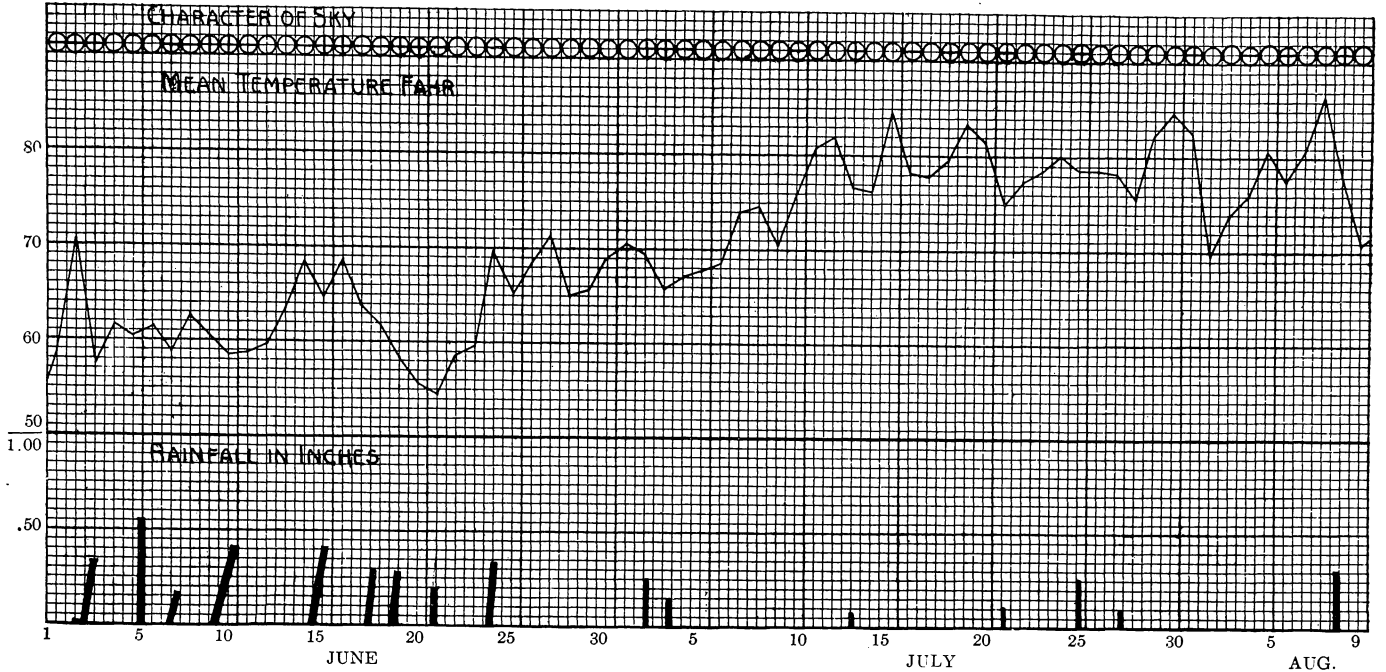


FIG. 6.— CHART SHOWING CLIMATIC CONDITIONS FROM JUNE 1 TO AUGUST 9, 1916, AT FREDONIA, N. Y.

PLACE OF EGG DEPOSITION.

Under natural conditions the majority of the eggs are laid in the ground at the bases of the trees upon which the insects are feeding. Most of them are placed in the soil just beneath the surface, altho a few are found to a depth of one inch, and some are deposited on top of the ground. They are often deposited loosely, but generally are attached by a gluish substance to rootlets, small stones and rubbish. It is therefore often difficult to remove the eggs without injuring them. In the breeding cages it was necessary to remove the eggs as they were counted, and as a result many were injured so that only a small percentage hatched.

During the course of our observations eggs were generally found glued to the bases of the trees from a depth of about an inch beneath the soil to a height of several inches above the surface. An exception to this habit was observed in a cherry orchard at Westfield where eggs were detected over all portions of the trunks as high as the forks of the limbs, or as much as three feet above the ground.

Moisture appears to be the controlling factor in the selection of a suitable place for oviposition by the females and so during periods of ordinary weather the females place the eggs in the damp soil. However, during rainy periods the bases of the trees are damp and are apparently attractive to the beetles for purposes of egg laying. In the cherry orchard at Westfield the trees were headed low so that the trunks were well shaded and remained moist for a considerable period. Besides, rainy and cloudy weather prevailed from June 14 to June 21, during which time these trees were continuously wet. By reason of these conditions beetles apparently were induced to lay eggs in what appeared to be unnatural situations.

PROTECTION OF EGGS.

The deposition of the eggs in the soil would naturally protect them from many predaceous enemies, but the chief protection is doubtless against unfavorable physical conditions, such as dryness and heat from the direct rays of the sun. It is believed that the latter is the more important factor because of the fact that no destruction of the eggs, by either predaceous or parasitic enemies, was noted, even during 1915 when eggs were deposited in such abundance.

DURATION OF LIFE OF THE CHERRY LEAF-BEETLE.

The first larvæ of the cherry leaf-beetle were found on July 1, 1915, but the maximum number emerged during July and August. During 1916 the first larvæ appeared on June 23, while the majority of individuals hatched during July and the first half of August. In the cages a number of the hibernated beetles died during June but July was the month during which most of the beetles succumbed. The last female died August 13, but four males lived until the last week of September. The average life of the beetles therefore was about twelve and one-half months. Of the specimens displaying exceptional longevity, the greatest duration of life of the female was not over fourteen months, while the males may have survived for about fifteen months, unless they hatched later than the average during the preceding year, in which case their period of existence would be somewhat less than that mentioned.

THE EGG.

DURATION OF INCUBATION PERIOD.

In his observations of the species at Washington, D. C., during 1899 Chittenden[1] states that the first egg hatched on June 26, which was eleven days from the date of deposition. During July, 1915, Herrick[2] and Matheson at Ithaca obtained as the longest incubation period eighteen days, and the shortest period was fourteen days, with an average of sixteen days.

Owing to the difficulty of securing eggs from the beetles in the observation cages during 1915, it was found necessary in order to secure data on the length of the incubation period to remove eggs from the soil at the bases of certain trees, precautions being taken to obtain them shortly after they were deposited. These were transferred by means of a camel hair brush to a cage consisting of a Van Tieghem cell cemented with vaseline to an ordinary glass slide. On the bottom of the cell a few fibers of cotton were spread to hold the eggs and prevent their rolling; and a drop of water was placed in the cell occasionally to keep the air moist, reproducing as far as possible the conditions of moisture of the earth from which the eggs were obtained. A cover glass was used to enclose the cell.

[1] U. S. Dept. Agr. Div. Ent. Bul. 19, n. s., p. 93. 1899.
[2] *Jour. Agr. Research*, 5:946–947. 1916.

Three lots were started with eggs which were laid on June 17 and one lot with eggs which were deposited on June 18, 1915. The records of hatching are summarized in Table VII.

TABLE VII.— INCUBATION OF EGGS OF CHERRY LEAF-BEETLE AT FREDONIA, N. Y.

Record of eggs deposited on June 17, 1915. (Temperature records in degrees F.)											Total eggs hatched.
Duration of incubation period (days)	10	11	12	13	14	16	18	19	20	21	
Average daily mean temperature to day indicated	65.9	65.6	65.6	66.2	66.3	66.6	66.5	66.4	66.1	66.1	
Lot 1, No. of eggs hatched	1	0	9	0	0	1	5	6	0	3	25
Lot 2, No. of eggs hatched	1	3	0	13	1	5	0	7	1		31
Lot 3, No. of eggs hatched	2	0	0	0	0	0	2				4
(Record of eggs deposited on June 18, 1915.)											
Duration of incubation period (days)				12	13	15	18	19			
Average daily mean temperature				66.4	66.5	66.8	66.9	66.6			
Lot 4, No. of eggs hatched				1	6	2	8	3			20
Longest incubation period								21 days.			
Shortest incubation period								10 days.			
Average								15.8 days.			
Average mean temperature								66.3 degrees F.			

By reason of the experience during the previous year it was possible to carry on more extensive observations on the egg stage during 1916. In the breeding cells eggs hatched over a period ranging from June 23 to August 1. These dates do not represent the entire period of hatching of eggs under normal conditions, which was somewhat greater; and they are of value only in connection with the particular eggs which were under observation. Notwithstanding the considerable number of larvæ that hatched, it should be stated there was high mortality among the eggs, which was largely ascribed to the methods of handling them. The records dealing with the incubation of three hundred thirty-nine eggs are given in Table VIII.

TABLE VIII.— INCUBATION OF EGGS OF CHERRY LEAF-BEETLE AT FREDONIA, N. Y., DURING 1916.

LOT NO.	Date of oviposition.	Date of hatching.	Number of eggs hatched.	Length of egg stage.	Average mean temperature for period.
				Days	*Degrees F.*
1	June 5	June 23	5	18	61.1
	June 5	June 25	5	20	60.9
	June 5	June 28	2	23	61.9
2	June 19	July 4	25	15	65.0
3	June 21	July 5	9	14	66.3
4	June 25	July 14	7	19	70.9
	June 25	July 16	32	21	71.8
5	July 3	July 13	6	10	72.7
	July 3	July 14	15	11	73.0
	July 3	July 16	50	13	74.2
	July 3	July 17	38	14	74.4
	July 3	July 19	2	16	75.0
6	July 8	July 19	3	11	77.9
	July 8	July 22	1	14	78.3
7	July 10	July 19	3	9	79.0
	July 10	July 22	12	12	79.3
	July 10	July 23	1	13	79.1
8	July 18	July 27	38	9	79.3
	July 18	July 28	40	10	79.2
	July 18	July 29	23	11	78.8
	July 18	July 30	21	12	79.1
	July 18	Aug. 1	1	14	79.8

Maximum number of days required for incubation	23
Minimum number of days required for incubation	9
Average number of days required for incubation	13.20±.13
Coefficient of variation (incubation)	26.96±.75
Average daily mean temperature (based on hourly temperatures) for period for all eggs	74.5
Number of eggs hatched	339
Coefficient of correlation between mean temperature and length of incubation period	—.705±.018

RELATION OF TEMPERATURE TO THE LENGTH OF THE INCUBATION PERIOD.

A comparison of Table VII and Table VIII shows that the daily mean temperature during the incubation period was lower during 1915 than during 1916 and that the incubation period for 1916 averaged 2.6 days less than during the preceding year. In order to determine the relationship that exists between the daily mean temperature and the incubation stage of the cherry leaf-beetle, we have calculated the coefficient of correlation between these two phenomena using the data of 1916. This coefficient was found to

be —.705 ± .018 and is rather high, showing there is marked correlation between the two phenomena. The coefficient is negative, which means that as the temperature increases the length of the egg stage decreases. From the regression equations we learn that on the average an increase of one degree in the daily mean temperature of the incubation period decreased the period by practically one day in our cages.

While the above analysis shows the important part temperature plays in determining the incubation period, it should also be noted that it is not the only factor to be considered. As has been observed with other species of insects, there existed marked variation in the length of the period of incubation in the same cage where the eggs were of the same age and presumably were subjected to identical conditions. Examples of this variation may be noted in lots 1, 5, 7 and 8 of Table VIII.

HATCHING.

Time of hatching of first, maximum number and last eggs.— The period during which hatching occurs extends from the latter part of June until the latter part of August of a normal year. The incubation of the eggs is influenced by the weather as noted above and during abnormal seasons variations occur in the length of the hatching period. It appears from the data that the maximum time during which hatching takes place is two months.

During 1915 the first larvæ were found in their native haunts at Fredonia on July 1, and Cushman [1] and Isley record larvæ hatching in their cages as late as August 18. These facts would give seven weeks as the period during which hatching occurred during this season.

During 1916 the first larvæ of the season were found both in the field and in breeding cages on June 23, but the eggs hatched very slowly until after July 4. The maximum number of larvæ emerged from July 12 to 31. With the eggs under confinement the hatching period ended about August 20, and during the months of July and August the weather was quite warm. The hatching period extended slightly over eight weeks, during the first two and last three weeks of which the relative number of larvæ emerging was rather small.

[1] Loc. cit. p. 17.

THE LARVA.

ACTIVITY OF LARVA AFTER HATCHING AND NATURE OF FEEDING.

After emerging from the egg the larvæ ascend the tree at the base of which the eggs were laid and begin feeding on the foliage. If the tree happens to be a bird cherry the insects are able to develop to full growth, but if the eggs are placed at the base of another species of cherry the larvæ feed for a short time and if unable to find foliage of the bird cherry they have, according to our observations, invariably succumbed before passing thru the last instar, most of them dying during the first instar. The larvæ are active creatures, capable of crawling rapidly, and they feed almost entirely on the underside of the foliage. They eat the lower epidermis and the parenchyma, but generally do not eat thru the palisade layer and the upper epidermis. Occasional feeding occurs on the upper surface of the leaf. The nature of their feeding is shown in Plate II. The injured portions of the leaves turn brown and portions of the palisade layer and the upper epidermis die and drop out, thus causing the foliage to have a ragged appearance.

FOOD PLANTS OF LARVA.

At the time of the outbreak of the cherry beetle during 1915 attempts were made to rear larvæ on foliage of the choke cherry, rum cherry and cultivated sour cherries and peaches, but in no instance was it possible to rear them beyond the second instar, and the majority of the creatures died during the first instar. These experiments were repeated in 1916 with identical results. Cushman [1] and Isley, on the basis of their studies during 1915, reported similar experiences. In the cages we were able to rear the larvæ only on the bird cherry, and in all field observations the only foliage on which the larvæ have been observed to reach maturity was that of this plant. It is for this reason that *P. pennsylvanica* has previously been designated as an *essential food plant* of this insect. It appears that infestation of cultivated cherries and peaches has its origin in the bird cherry. Observations indicate that where these fruits are grown outside the range of the bird cherry they are seldom attacked, and the probability of injury by the insects decreases

[1] Loc. cit. p. 2.

directly as the distance from the range of the bird cherry increases. These facts also seem to warrant the statement that cherry and peach growers need pay no attention to any stage of the pest except the adult. The intermittent character of the outbreaks may be explained by the fact that only during periods of abnormal numbers of adults, especially if food be scarce, do these insects migrate to cultivated trees.

GROWTH OF LARVA.

The larvæ feed voraciously and grow rapidly, especially during the warm periods. Two molts occur during the feeding period and a third molt takes place upon transformation to the pupal stage, which make three larval instars for this species.

Molting.— In molting the skin splits along the median line of the back, usually extending from the occiput down the thorax over several segments of the abdomen.

The larva first withdraws its head and thorax and after securing a hold on the leaf by means of its feet gradually withdraws the abdomen. During a portion of this process the larva was motionless and this quiescent period was followed by writhing motions to withdraw portions of the body from the skin. These operations were repeated at intervals of several minutes. The exact length of time required to molt has not been noted but on July 23 a larva was found in the course of molting at 3:20 P. M., at which time the head and body were pea green in color, the head being slightly lighter in shade. The spiracles were black and the legs were the same color as the head. At this time the larva had the shed skin on the abdomen from the eighth to the anal segment and it was motionless. The specimen was then closely observed and notes were made of any changes in its appearance as follows:

3:25 P. M. Head of the same color as at 3:20 P. M., body slightly darker, feet intermediate in color between that of head and body. A few writhing movements of the body, head raised several times at short intervals, then motionless again. Head measured .54 mm. in diameter which shows that the larva was in the second instar.

3:30 P. M. Color of head as before, body slightly darker, feet almost same color as body, first appearance of the formation of spots, larva generally quiet.

3:35 P. M. Head darker, body becoming an olive green. The larva was active at longer intervals than in preceding periods.

3:37 P. M. Larva leaves molted skin. Head a light olive green, body becoming quite dark, all the darker areas a dark olive green.

3:40 P. M. Head exhibiting same color as at 3:35 P. M. Traces of black begininng to show in the spots. Anal plate not as dark as the spots.

3:45 P. M. All portions of the body growing gradually darker. Spots prominent.

4:00 P. M. Head of a dark olive green with traces of black. Spots and anal plate very dark but not fully colored, legs slightly lighter than the body, claws and tarsi almost black. Larva resting quietly.

4:05 P. M. Body and legs almost black, head slightly lighter than the body. Larva crawling.

4:15 P. M. Body and legs black, head a dark brown.

These notes show that the act of molting may consume at least twenty minutes and that about an hour is required for the full development of the color of the larva.

Increase in the size of larva.— In order to measure the rate of growth, individual larvæ were placed in separate cages shortly after hatching and these were carefully observed until they entered the soil to pupate, daily measurements being made of the head diameter and length of each individual. Fifteen larvæ under observation passed thru the three instars and finally entered the soil. The measurements of these were made under a compound microscope with a lens arrangement whereby one space of the micrometer was equal to .0325 mm.

A leaf upon which the larvæ were resting was placed under the objective and the mirror set to reflect light thru the leaf, thus making it easier to note the position of the image on the micrometer stage. Owing to the size of the larvæ no measurement could be carried to a greater degree of refinement than the space of one division on the micrometer.

The diameter of the head of the larva of the cherry leaf-beetle, as is true of other species, does not increase during an instar, but the change in size occurs at the time of molting, while the epidermis is capable of expanding and before the chitin has become hardened. The average diameter of the head for the several instars was found to be as follows: First instar, .38 mm.; second instar, .54 mm.; third instar .76 mm. There was some variation in the sizes of the head in the different larvæ, as follows: First instar, from .36 to .39 mm.; second instar, .52–.57 mm., and third instar, .72–.78 mm.

The length of the body varies with the development of the larva, growth being constant between molts. There is no doubt considerable difference in the sizes of different individuals during each period of growth, but as it would have required a larger number of measurements to ascertain the extent of variation than the time at our disposal would allow, no effort was made to determine it. The variation in length of larvæ for each instar for a goodly number of specimens is as follows: First instar from 1.6 to 3.3 mm.; second instar, 2.3–4.5 mm., and third instar, 3.6–7.2 mm.

DURATION OF THE SEVERAL INSTARS AND THE LARVAL STAGE.

Observations of the length of the several instars were made on fifteen larvæ over a period ranging from July 13 to August 7. The data are given in Table IX.

TABLE IX.— STAGES OF DEVELOPMENT OF CHERRY LEAF-BEETLE FROM LARVA TO ADULT. FREDONIA, N. Y., 1916.

Lot.	Date of hatching.	Date of 1st molt.	Length of 1st instar.	Date of 2nd molt.	Length of 2nd instar.	Date of entrance into ground.	Length of 3rd instar.	Total feeding period.	Date of emergence.	Time in ground.	Period from hatching to adult.
	July.	July.	Days.	July.	Days.	July.	Days.	Days.	Aug.	Days.	Days.
1	13	17	4	21	4	23	2	10	.....	.....	.....
2	13	17	4	19	2	23	4	10	.....	.....	.....
3	13	19	6	22	3	25	3	12	8	14	26
4	15	18	3	21	3	25	4	10	.....	.....	.....
5	15	18	3	21	3	25	4	10	8	14	24
6	17	22	5	25	3	28	3	11	10	13	24
7	17	21	4	26	5	29	3	12	.....	.....	.....
8	17	21	4	25	4	28	3	11	10	13	24
9	17	22	5	24	2	27	3	10	.....	.....	.....
10	17	21	4	23	2	25	2	8	.....	.....	.....
11	17	21	4	25	4	28	3	11	.....	.....	.....
12	18	21	3	24	3	27	3	9	9	13	22
13	19	24	5	26	2	31	5	12	13	13	25
				Aug.		Aug.					
14	24	29	5	3	5	7	2	12	.....	.....	.....
15	24	29	5	1	3	5	4	12	23	18	30

Average for different larval instars: 1st, 4.3 days; 2d, 3.2 days; 3d, 3.2 days. Period in soil 10.7 days.

As the temperature during the months of July and August of 1916 was considerably above normal, attention is called to the studies on the different larval instars by Herrick [1] and Matheson at Ithaca and by Cushman [2] and Isley at North East, Pa. The observations were made in 1915 during the months of July, August and September, which were cool and wet, with temperatures below normal. The data dealing with each instar are considered separately.

First instar.— In Table X there are summarized the more important facts by the foregoing observers, as well as our own, which bear on the duration of the first instar.

TABLE X.— LENGTH OF THE FIRST INSTAR OF THE LARVA OF THE CHERRY LEAF-BEETLE.

	Herrick & Matheson	Cushman & Isley	Author
Maximum length (days)...	7	11	6
Minimum length (days)...	4	4	3
Average length (days)....	5.9	4.8	4.3
Period of observation....	July 23–30, 1915	Aug. 11–24, 1915	July 13–29, 1916

[1] Loc. cit., p. 947.
[2] Loc. cit., pp. 10–17.

It will be noted that the longest period required for a larva to pass the first instar was eleven days and the shortest period three days. The average length of time for this stage as based on the records of two years in the Lake Erie valley is 4.6 days. It is unsafe to make a general average of the foregoing three sets of observations, owing to the fact that the climate of Ithaca is different from that of the Lake Erie valley, while the climate of North East, Pa., and Fredonia are quite alike, both being situated near Lake Erie and only thirty miles apart. As Ithaca is located in the plateau region of southwestern New York its climate resembles more closely that of the southern tier of counties than does that of Fredonia, wherefore the data from the former should be fairly representative of the native habitat of the insect.

Second instar.— The data dealing with this instar are summarized in Table XI.

TABLE XI.— LENGTH OF THE SECOND INSTAR OF THE LARVA OF THE CHERRY LEAF-BEETLE.

	Herrick & Matheson	Cushman & Isley	Author
Maximum length (days)	5	7	5
Minimum length (days)	3	3	2
Average length (days)	4.3	3.6	3.2
Period of observation	July 27–Aug. 4, 1915	Aug. 5–29, 1915	July 17–Aug. 3, 1916

The longest period for the second instar was seven days, the shortest two days and the average for two years in the Lake Erie valley was 3.4 days.

Third instar.— The data on this instar are tabulated in Table XII.

TABLE XII.— LENGTH OF THE THIRD INSTAR OF THE LARVA OF THE CHERRY LEAF-BEETLE.

	Herrick & Matheson	Cushman & Isley	Author
Maximum length (days)	6	8	5
Minimum length (days)	3	3	2
Average length (days)	5	4.1	3.2
Period of observation	Aug. 1–9, 1915	Aug. 10–Sept. 5, 1915	July 19–Aug. 7, 1916

The maximum length of the third instar is 8 days and the minimum 2 days, while the average period for two years at Fredonia and North East, Pa., is 3.7 days.

TOTAL FEEDING PERIOD OF LARVA.

The data bearing on this point consists of records by Herrick [1] and Matheson on nine larvæ, those of Cushman [2] and Isley on two hundred twenty-seven larvæ, and our observations on one hundred forty-four larvæ. These are tabulated in Table XIII.

TABLE XIII.— TOTAL FEEDING PERIOD OF LARVA OF THE CHERRY LEAF-BEETLE.

	Herrick & Matheson.	Cushman & Isley.	Author.
Maximum length for single larva (days)	17	20	24
Minimum length for single larva (days)	12	10	8
Average length for single larva (days)	15.2	12.3	12.3
Period of observation	July 23–Aug. 9, 1915	Aug. 5–Sept. 5, 1915	July 4–Aug. 13, 1916

From these figures it would appear that from twelve to thirteen days constitute the average period of the larvæ during a normal year in the Lake Erie valley. The Ithaca records indicate that on the Alleghany plateau of western New York the average length of life of the larva may be several days longer.

PUPATION.

When the larvæ have completed their growth they burrow into the leaf mold or, if not present, into the soil, which they penetrate a very short distance, usually about one centimeter, where they form a small spherical cell. Sometimes the larva forms scarcely any cell but transforms underneath rubbish. Moisture appears to be the chief factor in determining the depth of these cells. In such situations the larvæ pupate and the pupæ later transform to adults. The larvæ do not transform immediately on their entrance

[1] Loc. cit. p. 947.
[2] Loc. cit. pp. 12 and 14–17.

in the ground but require a number of days before undergoing a change in form. Cushman[1] and Isley found that the period was from five to eight days, depending on the temperature, and they also found the pupal stage varied from seven to eleven days. By means of Comstock root cages efforts were made to obtain pupæ, where they could be under constant observation, but our efforts resulted in failures. The only data obtained that bears upon the duration of the pupal period were the number of days that the insects were actually in the ground. In our cages there was considerable mortality, and of one hundred forty-four larvæ that entered the ground only fifty beetles finally emerged. The data bearing on the extent of the period occupied by the insect in the ground are summarized in Table XIV.

TABLE XIV.—PERIOD OF EXISTENCE OF INSECT IN THE GROUND DURING PUPATION.

	Herrick & Matheson.	Cushman & Isley.	Author.
Maximum period (days)	20	28	23
Minimum period (days)	17	14	12
Average period (days)	18.3	22.4	15
Number of individuals	9	563	50
Dates	Aug. 5–28, 1915	Aug. 5–Sept. 18, 1915	July 18–Sept. 2, 1916

As will be observed, there is quite a little variation in the figures given by the different observers. This is believed to be due to variations in climate but may be partially due to differences in methods of rearing the insects. As will be explained later, weather conditions during 1915 and 1916 were somewhat abnormal, the two years differing greatly in the Lake Erie valley. The climate of Ithaca during 1915 differed markedly from that of the Lake Erie region.

PERIOD FROM HATCHING TO EMERGENCE OF ADULT.

The total period of development of the cherry leaf-beetle from the larval stage to adult was found by all observers to vary considerably, and in our studies there was a difference of twenty days

[1] Loc. cit. p. 12.

between the minimum and maximum periods. As shown in Table XV the records indicate that about one month is required for the average individual to reach the adult stage after hatching from the egg. If to these figures there are added thirteen days for the egg stage, the period for the complete development of the insect ranges from forty to forty-seven days for the Grape Belt along the shores of Lake Erie and about forty-eight days on the higher lands to the south.

TABLE XV.— TOTAL DEVELOPMENTAL PERIOD OF THE CHERRY LEAF-BEETLE.

	Herrick & Matheson.	Cushman & Isley.	Author.
Maximum length for a single individual (days)	36	40	40
Minimum length for a single individual (days)	32	31	22
Average length for a single individual (days)	34.6	33.8	27.2
Period of observation	July 23–Aug. 28, 1915	Aug. 5–Sept. 18, 1915	July 4–Sept. 2, 1916

CLIMATE VARIATION DURING 1915 AND 1916.

The climatic conditions during the developmental period of the cherry leaf-beetle during 1916 are shown in Figs. 6 and 7.

In order that the results of the studies by various workers may be fairly compared the meteorological conditions that prevailed in the different localities where the insect was studied should be noted (Table XVI). In regard to 1915 we have used the weather reports of Westfield, N. Y.,[1] which is only fourteen miles from North East, Pa.; and the location of the cooperative observer is about the same distance from Lake Erie and at only a slightly greater elevation than the laboratory where Cushman and Isley conducted their studies. We have also used the Westfield records to secure the departure from normal for 1916 since the Fredonia records do not cover a long enough period for such a calculation. As the Westfield observer is only fourteen miles distant and only slightly higher than the Vineyard Laboratory no great error is introduced. The amount

[1] Wilson, W. M. Climatological Data, New York Section. U. S. Dept. Agr., Weather Bureau. June to September 1915; and June to August 1916.

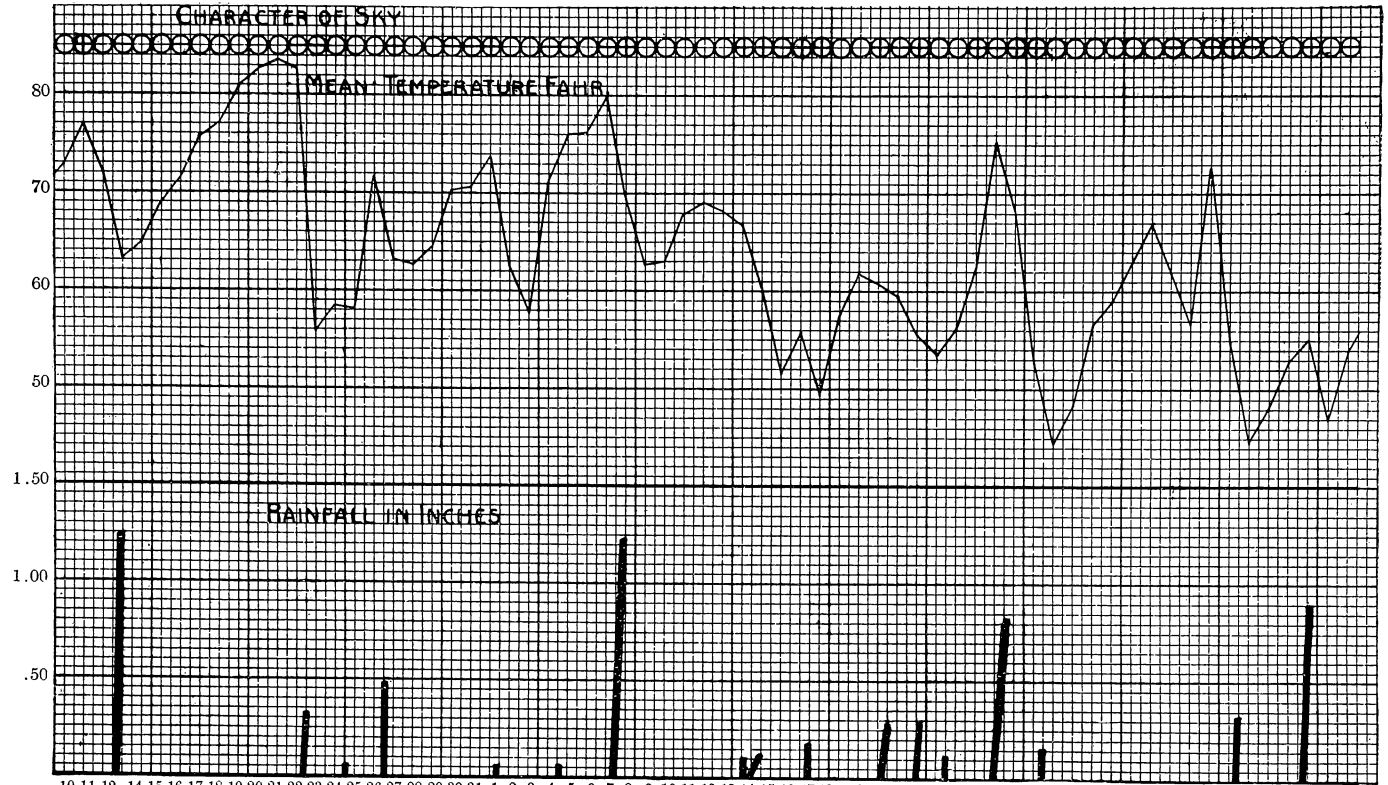


FIG. 7.— CHART SHOWING CLIMATIC CONDITIONS FROM AUGUST 10 TO OCTOBER 15, 1916, AT FREDONIA, N. Y.

of cloudiness during both years except at Ithaca[1] and all other records for 1916 were obtained from the report of our laboratory at Fredonia.

TABLE XVI.— CLIMATIC CONDITIONS DURING 1915 AND 1916 AT WESTFIELD, ITHACA AND FREDONIA, N. Y.

	Westfield 1915.	Ithaca 1915.	Westfield 1916.
Temperature, departure of mean from normal.	June —1.5*	.....	—3.9
	July —3.3	—1.4	+3.3
	Aug. —3.1	—2.0	+2.1
	Sept. +1.4*	.....	.....
Precipitation, departure of mean from normal.	June —0.70 in.	.....	—0.39 in.
	July +7.42 in.	+2.43 in.	—0.97 in.
	Aug. +2.02 in.	+0.46 in.	—0.72 in.
	Sept. +0.14 in.	.....	.....
	Fredonia 1915.		Fredonia 1916.
Percentage of clear days during period in which observations were made on developmental stages.....	34	11	66
Percentage of cloudy days (same period).....	34	38	17
Percentage of partly cloudy days (same period).....	32	51	17

* From the records of the observer at Volusia (5 miles from Westfield but 500 feet higher) since the data are not given in the Westfield records.

SUMMARY OF THE SEASONAL HISTORY.

With respect to western New York the insect emerges from the pupal cell as an adult during August and the early part of September. In 1916 the adults emerged from July 31 to September 2, but during 1915 adults emerged as late as September 18. Little feeding is done at this season and during the latter part of September the beetles seek sheltered locations in which to pass the winter. They burrow for a short distance into the soil and form their hibernating cells, where they remain for nearly eight months. Emergence from hibernation takes place during the latter part of May of a normal year. After the beetles abandon their winter quarters they feed voraciously for a time on the bird cherry and then begin to disperse. This movement of the beetles is usually to other bird cherry trees. However,

[12] Furnished thru the kindness of Prof. W. M. Wilson.

when vast numbers of the beetles have escaped the rigors of winter, especially if the preferred food is scarce, the insects migrate to cultivated cherry and peach trees. The migratory period usually occurs during the early part of June, altho some dissemination may occur during the last week of May. In 1915 the period extended from about June 1 to June 12, and during 1916 the migration occurred during the first and second weeks of June.

Mating occurs shortly after the beetles first feed in the spring and continues during the entire month of June and a portion of July, continuing about six weeks.

During 1916 the earliest eggs were laid June 5 and the last eggs were laid in breeding cages August 9. The total egg-laying period was sixty-six days. The greatest oviposition activity occurred during the last week of June and the first week of July. The average egg-laying period for a single female in the breeding cages was twenty-eight days. The greatest number of eggs laid by a single female was 294, the least number was 10, and the average number was 93. During 1915 the incubation period averaged 15.8 days, with a maximum of 21 days. The incubation period during 1916 averaged 13.2 days with a maximum of 23 days. Hatching occurred from June 23 to about August 20, 1916, or over a period of practically two months.

The larvæ required an average of about 12 days from hatching until they entered the soil. The longest period was 24 days, and the shortest 8 days. The larvæ upon reaching full growth entered the soil and formed cells in which they pupated. The period spent in the ground varied in 1916 from 12 to 23 days with an average of 15 days. In 1915 Cushman [1] and Isley found the period spent in the ground varied from 14 to 28 days with an average of 22.4 days. These variations are believed to be due to differences in temperature, and 19 days appears about the average for a normal season. The total developmental period of the cherry leaf-beetle varied from 22 to 42 days with an average of 27 days during 1916. Cushman [2] and Isley in 1915 found this period to average about 34 days. It is concluded that one month is about the average length for the developmental period during a normal season. The

[1] Loc. cit. pp. 12, and 14-17.
[2] Loc. cit. pp. 13-17.

time from the deposition of the eggs until the emergence of the adult averages about 43 days.

A graphic summary of the seasonal history of the insect is shown in Fig. 8.

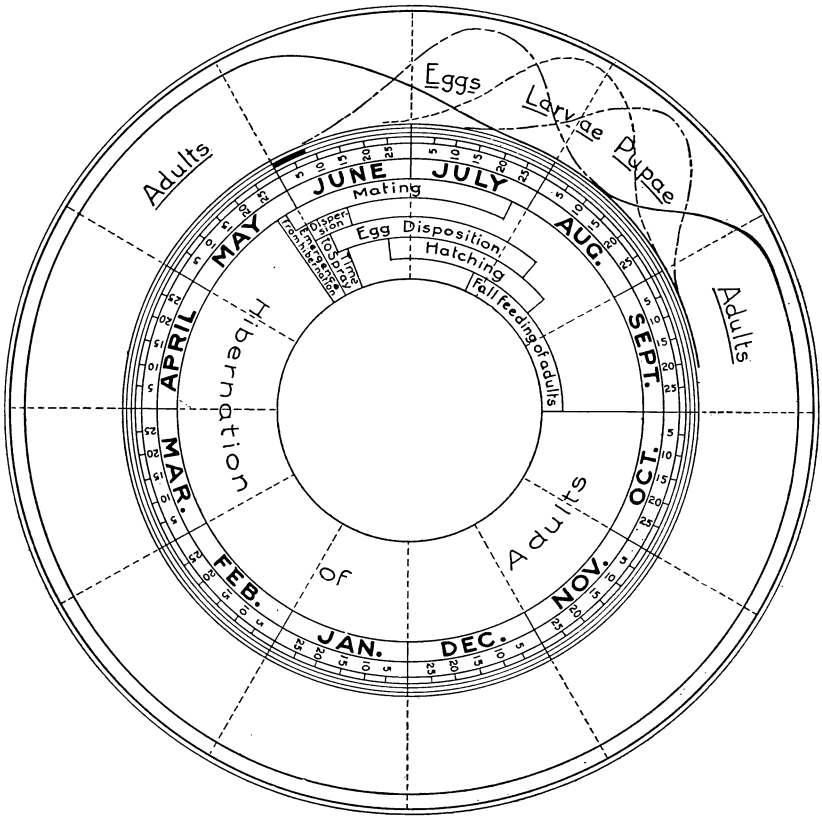


FIG. 8 — DIAGRAM SHOWING THE SEASONAL HISTORY OF THE CHERRY LEAF-BEETLE AS OBSERVED AT FREDONIA, N. Y., DURING 1916.

NATURAL DISSEMINATION.

DISPERSION DURING THE LARVAL STAGE.

The first movements of the larvæ are to obtain food and are chiefly vertical owing to the eggs being laid at the bases of trees. When branches intertwine there doubtless is some movement horizontally, but this activity apparently carries the insect only short distances.

SUMMER AND FALL FLIGHTS OF THE BEETLES.

After the emergence of the beetles during August and early September it is possible that some movements by the insects occur. As the hibernating places of these insects are usually at the bases of the trees upon which they feed and as the food supply at this season is usually abundant there is little reason to believe that the beetles attempt any extensive flights. Observations made in the habitats of these beetles during the late summer have shown the adults to be rather sluggish and not inclined to fly as readily as in the spring. This behavior on their part is not believed to be due to temperature. At this season they are not voracious feeders, even when surrounded with an abundance of food. In cages they fed so sparingly as to lead one to wonder how they were able to maintain life. In feeding they seemed to prefer foliage that was near the ground.

SPRING DISPERSION OF BEETLES.

All movements of the species are insignificant in comparison with the dispersion of the beetles in the spring. During 1915 and 1916 this began slowly during the latter part of May and early June, suddenly reaching a maximum at the end of the first week of June and gradually diminishing until the middle of this month when dispersion was practically concluded. During 1917 the beetles were very scarce and no migration was observed. Observations during 1916 indicated that a few eggs were deposited before this movement occurred, but the bulk of the eggs were laid after the migration. Several conditions may precipitate and intensify this movement, of which the principal factors are apparently the existence of enormous numbers of beetles and scarcity of food. Restriction in the means of subsistence may be due to various causes but the destruction of the foliage of the bird cherry by other insects or by freezing have apparently been chiefly responsible for the migration to incidental food plants during the three years that the insect has been under observation.

The beetles fly with the wind and the direction and velocity of the wind largely determine the course and extent of their movement into new territory. No data are available showing how far the beetles may travel in a single flight, but observations indicate that it is only a short distance and they then alight on any plant that is at

hand. If the selection does not prove to be to their liking they resume their flight. The reports of fishermen finding the beetles on stationary floats several miles off shore in Lake Erie would indicate that the insects flew this distance. It is claimed that they were found on driftwood ten miles from shore in this lake, but in such instances we were unable to determine the distance the object drifted after the beetles alighted. On land the combined flight of the beetles was extensive. Since most of the beetles came from the northern part of Pennsylvania and southern New York and they were found flying several miles out over Lake Erie there are good reasons for believing that during 1915 vast numbers of the insects flew about forty miles in Chautauqua County.

It is presumed that the beetles are able to locate cherry trees, but it should be noted that during the invasion of 1915 the beetles were observed alighting within one hundred feet of these trees on all manner of plants upon which they did not feed, and that afterwards they sought cherry trees.

RELATION OF WATER TO DISSEMINATION.

Small bodies of water do not appear to influence the spread of the insect, but large bodies of water, such as the Great Lakes, are barriers to its progress. It is possible that beetles which alight on driftwood may be washed to a distant shore, but from the behavior of the insects during 1915 apparently not many are carried by this means. However, the beetles would quite easily cross a territory of this width if no water intervened. While the beetles are not easily drowned, nevertheless many are killed in the water and it is difficult to imagine under what circumstances large bodies of water would assist in the dispersal of the species.

NATURAL CONTROL.

Under this heading there are considered drowning of adults, deposition of eggs in situations which are unfavorable to development of larvæ, and parasitic and predaceous enemies.

DROWNING OF ADULTS.

During 1915 it was observed that numbers of these insects were drowned in Lake Erie. The beetles, conveyed either thru their own powers of flight or assisted by heavy winds, were found in great

numbers in the lake at considerable distances from shore. Some of these alighted on driftwood and some fell in the water not far from land and were washed ashore alive, but the vast majority fell into the water and were drowned, their dead bodies being later washed up by the waves until they formed windrows on the lake beaches.

Counts of the insects along the shore at Westfield showed an average of fifty dead beetles to each linear foot of beach. If the destruction of the species was uniformly as great along the entire forty miles of lake shore in Chautauqua County, as there are reasons for believing, the total fatality according to these estimates was not less than 10,500,000,000 beetles.

EGG SITES UNFAVORABLE TO LARVAL DEVELOPMENT.

As previously stated, the larvæ of the cherry leaf beetle did not mature on any of the orchard fruits, so that beetles which deposited their eggs only on cultivated cherries and peaches died without maturing progeny. In the invasion of a region where the bird cherry exists only in small numbers there is perhaps no other factor which makes for the more rapid decline of the insect in importance than the inability of the larvæ to subsist on any other plant than its native host.

REFORESTATION.

Cutover land which has grown up to bird cherry and other less valuable vegetation, when protected from fire and grazing, becomes replanted with the more valuable deciduous and coniferous trees which crowd out the bird cherry and other forest margin species of plants. Where this reforestation is extensive it naturally controls the cherry leaf-beetle by decreasing its food plants. Such an effect would be marked in the uplands of the Alleghany plateau if better fire protection were maintained and more systematic tree planting practised.

PREDATORY INSECT ENEMIES.

Only one insect enemy of the cherry leaf-beetle has been recorded. This is a carabid beetle, *Lebia ornata* Say, which has been reported by Cushman [1] and Isley as attacking and killing the adult beetles soon after they emerged from the soil.

[1] Loc. cit. p. 19.

BIRDS.

During the invasion of the beetles in Chautauqua County, Mrs. H. M. Putnam of Fredonia, who is a student of bird life, observed a pair of cedar waxwings (*Bombycilla cedrorum* Vieill.) feeding extensively upon the insects. The pair returned several times to a sour cherry tree and during each visit they captured considerable numbers of the adults. With a pair of field glasses she was able to count over fifty beetles that were eaten by the birds. Notwithstanding the great abundance of the species, it is a singular fact that none of those who have carefully studied the cherry leaf-beetle ever had their attention directed to birds as important predatory enemies of this insect.

ARTIFICIAL CONTROL.

Since the larvæ do not feed on the foliage of cultivated fruits and the adults only are destructive, the experiments to devise efficient control measures were directed largely against the beetles. Special emphasis was placed on arsenicals and nicotine solutions in these operations and the principal details of the different tests are as follows:

TEST NO. 1 WITH ARSENICALS.

The first experiments during 1915 for the control of the beetles were made on June 7 when they were first discovered at Fredonia. The tests were made on young cherry and peach trees which at that time were partially defoliated. The cherry trees were two years old from the time of planting and for the purpose of experiment were divided into two plats. Plat 1 was treated with a mixture of 2 pounds of dry arsenate of lead in 50 gallons of water, while Plat 2 was sprayed with a mixture of 4 pounds of paste arsenate of lime in 50 gallons of water. The trees were thoroly sprayed so as to wet all surfaces of the leaves. In addition a block of peach trees received an application of arsenate of lead as above for cherries.

A light rain occurred during the night. As many beetles continued to feed on the trees and the owner feared that the rain had washed off the poison, the plats were, without the author's knowledge, resprayed as before. An examination of the trees on July 9 showed that there were many dead beetles on the ground and that the work of defoliation had been effectively stopped. The cherry trees sprayed with arsenate of lime showed less infestation on July 9

than did the plat sprayed with arsenate of lead. In no instance was there any evidence of injury to the cherry foliage by arsenate of lime nor to peach foliage by arsenate of lead. It may be added that in none of the experiments during 1915 by the author was there any damage to peach foliage either by arsenate of lead or arsenate of lime, altho in several instances injury was reported by growers who used arsenate of lead.

TEST NO. 2 WITH AN ARSENICAL AND NICOTINE SOLUTION.

A rather extensive series of experiments for the control of the adults of the cherry leaf-beetle were made June 8–10, 1915, in the cherry and peach orchards of R. J. Paschke near Fredonia.

On June 8 three plats of trees that were fairly uniform in size were treated respectively as follows: Plat 1 received an application of ½ pint of nicotine sulphate (40 per ct. nicotine) in 80 gallons of water; Plat 2 was sprayed with bordeaux mixture after the formula of 4–4–50, 3 pounds of paste arsenate of lead and 5 ounces nicotine sulphate. Plat 3 was sprayed with a mixture of 3 pounds of paste arsenate of lead, 2 quarts molasses and 50 gallons of water. All trees were thoroly sprayed in order to wet the upper and undersides of the foliage. Whenever nicotine solution was applied the beetles which dropped from the trees at the beginning of the treatment were afterwards thoroly sprayed while on the ground. This operation, it may be added, required the employment of larger quantities of spraying mixture but was effective.

An examination on June 9 of the trees in plats 1 and 2 showed many dead beetles on the ground with a corresponding decrease in the number of the insects on the trees. The trees in plat 3 were in a much less satisfactory condition as many beetles were feeding on the leaves and only a few had succumbed to the treatment. The trees sprayed with bordeaux mixture, arsenate of lead and nicotine solution presented markedly superior conditions as compared with the remaining plats. Altho the number of beetles killed was no larger, perhaps, than on the trees sprayed with nicotine solution alone, yet the number of insects feeding on the foliage was less than on the trees not receiving the combined treatment. The foliage sprayed with bordeaux mixture and arsenate of lead was thickly coated with the spray which appears, in addition to its toxic properties, to have acted as a repellent to the beetles. It should,

however, be added that the trees showed more infestation on June 10 than on June 9, due to the constant migration of beetles. Notwithstanding the re-infestation, the trees in each plat were, as a result of a single spraying, saved from defoliation altho considerable feeding occurred on the trees sprayed with molasses and arsenate of lead.

TEST NO. 3 WITH ARSENICALS.

On June 10 large Montmorency trees were thoroly sprayed with bordeaux mixture after the formula of 4–4–50, to which were added 3 pounds of paste arsenate of lime. Examination of the trees on June 11 showed excellent protection of the foliage, altho there was little evidence of insects having succumbed to the treatment. The freedom of the trees from the work of the insects appeared to have been due to the repellent properties of the mixture.

It is also important to note in this connection that the season of 1915 was very favorable for brown rot on cherries, owing to excessive rainfall and high humidity, but fruit on all trees sprayed with bordeaux mixture was harvested for the most part in excellent condition while with untreated trees there was considerable rot.

TEST NO. 4 WITH ARSENICALS.

During the afternoon of June 10 a number of young peach trees were sprayed with bordeaux mixture after the formula of 4–4–50 and 3 pounds of paste arsenate of lead, while other trees were sprayed with bordeaux mixture with 3 pounds of paste arsenate of lime. The beetles were killed by either treatment and the foliage for the most part showed little evidence of further feeding by the insects. Spraying of peaches with bordeaux mixture is considered an unsafe practice and it should be noted that in these tests there was no evidence of leaf injury or of defoliation of the trees by either of the treatments.

TEST NO. 5 WITH VARIOUS INSECTICIDES.

A block of young cherry trees of the variety Montmorency belonging to Mr. D. B. Belden in Fredonia became severely infested with the leaf-beetle, and on June 10 this planting was divided into plats which were sprayed as follows: Plat 1, Pyrox, one pound to eight gallons of water; Plat 2, Insectine, one pint to fifty gallons of water; Plat 3, nicotine sulphate (40 per ct. nicotine) one pint to

eighty gallons of water; and Plat 5, nicotine sulphate, one pint to sixty gallons of water. All applications were very thoro, both surfaces of the leaves being drenched with the sprays. In applying the nicotine mixtures and Insectine special efforts were made to wet the insects with the spray. The tendency of the beetles to drop from the leaves before being wetted with the mixture showed the necessity of spraying them again while on the ground in order to allow none of them to escape. Insectine is primarily a poison, but it is, however, a combination of various insecticides and fungicides, containing some chemical substances that are toxic to insects by contact. It was to test the preparation as a poison and as a contact spray that the precaution of spraying the foliage as well as the beetles on the ground was observed.

All of the applications of the nicotine solution at different strengths killed many of the beetles; and from the numbers of dead insects on the ground it appears that thoroness of treatment was of more importance than the dilution of the spraying mixture. A serious limitation of nicotine sprays is plainly indicated in this experiment — they do not possess lasting toxic or repellent properties, so that trees treated with them are liable to be reinfested.

Many dead beetles were observed beneath the trees sprayed with Pyrox, and the numbers of the insects on the foliage was very small. The material appeared to exert a repellent effect in addition to its usual toxic action.

The trees sprayed with Insectine showed no dead beetles and the number on the foliage did not seem to be less than on untreated trees.

TEST NO. 6 WITH TREE TANGLEFOOT.

The discovery that the beetles lay their eggs at the bases of the trees and the belief that the larvæ would feed on the foliage led to the opinion that the adults might possibly be captured by adhesives.

It seemed advisable to undertake experiments to prevent oviposition by the beetles and any movement by the larvæ.

On June 18 several large peach and cherry trees were treated with Tree Tanglefoot. This was applied in a band about five inches wide, encircling the base, and was put either on the bark or on a band of muslin. The ground about the trees had been removed previously to eliminate any eggs that may have been present. The trees were mounded in such a manner that the ground covered about

half of the band of Tanglefoot, i. e., the earth extended one-half of the distance to the top of the band. Other trees were mounded after having all eggs removed but the Tanglefoot was omitted.

An examination of these trees, June 21, showed that many beetles had been captured by the Tanglefoot and that at this date no eggs had been laid at the bases of the treated trees. In order to have more detailed data on the effect of the banding, the ground about two treated and two untreated trees was carefully examined on June 26 when counts were made of the eggs. The results of these counts are given in the following table:

TABLE XVII.— NUMBER OF EGGS OF THE CHERRY LEAF-BEETLE ON TREES TREATED WITH TREE TANGLEFOOT.

Untreated peach tree	224 eggs
Untreated cherry tree	227 eggs
Peach tree with Tanglefoot	25 eggs
Cherry tree with Tanglefoot	27 eggs

A general examination of the other treated and untreated trees indicated that similar conditions prevailed, and while these results are of interest in demonstrating what might possibly be accomplished by banding bird cherry trees in parks or arboretums, this method of protecting orchards from this insect is unnecessary since few if any of the larvæ are able to exist on the foliage of cultivated trees.

SUMMARY OF EXPERIMENTS.

Arsenate of lead at the rate of 4 pounds to 50 gallons of water or bordeaux mixture killed many of the beetles if care was exercised to cover the undersides of the foliage. The most lasting effect was secured by the use of arsenate of lead and bordeaux mixture.

Arsenate of lead and molasses in combination were not as effective nor did they possess the lasting properties of arsenate of lead with bordeaux mixture.

Arsenate of lime at the rate of 4 pounds to 50 gallons of water was apparently somewhat more efficient than arsenate of lead at similar proportions and there was no injury to the foliage of either cherry or peach. In combination with bordeaux mixture the arsenicals were equally effective.

Nicotine sulphate (40 per ct. nicotine) was found to be very effective when used as a contact insecticide at the rate of one pint with either 60 or 80 gallons of water or bordeaux mixture. One experi-

ment indicated that even greater dilutions might be used but the increased care needed to thoroly wet the insects tended to offset the economy in the use of the stock material. The best results with nicotine extracts, so far as permanent effects are concerned, were secured by combining them with arsenate of lead and bordeaux mixture.

Pyrox used at the rate of one pound to eight gallons of water killed the beetles and also served as a repellent.

Insectine did not control the cherry leaf-beetle.

Tanglefoot reduced the number of eggs deposited at the bases of peach and cherry trees.

RESULTS OF TESTS BY OTHER EXPERIMENTERS.

Experiments by Cushman [1] and Isley to develop efficient spraying methods were largely directed to testing arsenate of lead and nicotine sulphate, and the results of their operations were similar to those described except that somewhat better results were obtained with arsenate of lead in combination with molasses. They also tested crude carbolic acid emulsion, using the formula of 10 pounds fish-oil soap, $\frac{3}{4}$ pint of crude carbolic acid and 50 gallons of water. This proved efficient as a contact spray but, as was the experience with nicotine sulphate, it lacked lasting toxic and repellent qualities.

CONCLUSIONS AND DIRECTIONS FOR CONTROL MEASURES.

In the light of the results of the foregoing experiments it appears that the cherry leaf-beetle can best be controlled on large cherry trees by spraying during the first week of June or as the beetles first appear, with bordeaux mixture (4-4-50) combined with either four pounds of paste arsenate of lead or two pounds of dry arsenate of lead. It is believed that paste arsenate of lime can be used with the bordeaux mixture in place of the arsenate of lead, but more experimentation is needed before it can be generally recommended. In spraying, the foliage should be thoroly covered on both the upper and lower surfaces. In addition to protection from several species of insects, another benefit from this treatment is the control of various diseases of fruit and foliage, which during some seasons are the cause of considerable apprehension among cherry growers.

[1] Loc. cit. pp. 19–24.

For young cherry trees, especially those that have been set not more than two years, jarring the beetles into sheets placed under the trees, followed by the destruction of the beetles, is a satisfactory method of control. This is especially recommended when infestation is severe since the small amount of foliage present on young trees makes it possible for the beetles to defoliate them before the insects succumb to the poison if sole reliance is placed on an arsenical. After the number of beetles has been reduced by jarring, an application of bordeaux mixture with arsenate of lead should render the trees immune to further attacks.

The protection of peach trees is a more difficult problem because of the great danger of injury to foliage from applications of bordeaux mixture and arsenate of lead. If large trees are attacked by numbers of the beetles the only recourse appears to be an application of arsenate of lead at the rate of 4 pounds to 50 gallons of water. To every barrel of the spray add two pounds of lump lime to neutralize any soluble arsenic present in the mixture. Inferior brands of arsenate of lead should be avoided. With young peach trees, jarring the beetles into sheets spread on the ground will greatly reduce the numbers of the insects, and if the insects tend to increase in numbers again, follow jarring with an application of arsenate of lead. Bordeaux mixture should not be used on peach foliage.

Nicotine sulphate (40 per ct. nicotine) may be employed effectively against the cherry leaf-beetle if trees are first thoroly sprayed and then treatment is directed to the beetles which drop to the ground. In the experiments with tobacco mixtures the best results were obtained when one pint of the nicotine solution was added to 60 gallons of water, altho a dilution of one pint to eighty gallons of water proved very effective. The advantage of using nicotine solution is that it can be used on peach trees without injury to foliage. However, it possesses several disadvantages, which are the cost of application, owing to the rather excessive amount used per tree, and the necessity of frequent applications during the dispersion period of the beetles. Failures on the part of the growers to combat the pest satisfactorily with nicotine solution were largely due to lack of thoroness in spraying and neglect to spray the insects after they had dropped to the ground.

The use of a soap-carbolic acid solution as described above is to be recommended with the caution that, while it has generally

proven safe to foliage, injuries to leaves of cherry trees have been reported.

Experiments with a commercial coating composition known as Tree Tanglefoot for capturing the beetles before they lay eggs at the bases of trees indicates that this method might be of use in controlling the larvæ of the cherry leaf-beetle on bird cherry in parks or arboretums.

While a cooperative effort to clear much of the waste land of bird cherry about farms might at first seem advisable, further study has shown us that during ordinary years these do not harbor the beetles, presumably because the proper conditions for hibernation do not develop; and only during years of severe outbreaks do the trees become infested. It therefore appears to be a good practice to allow these trees to remain that their fruit may serve as food for useful birds.

All efforts in reforestation that succeed in re-establishing new timber tracts on the waste, cutover and abandoned land of the Alleghany plateau region of western New York and Pennsylvania will not only help in increasing a state and national asset, but incidentally they will reduce the number of bird cherry trees and bushes, many of which are too young for producing fruit. It is the seedlings that spring up in large numbers after every fire that furnish food for the hordes of cherry beetles which overrun cherry orchards during years when the normal supply of food is restricted.

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