A THESIS

entitled

THE BIOLOGY OF THE PEPPER-GRASS BEETLE, GALERUCA EXTERNA SAY, WITH FREQUENT REFERENCES TO THE RED TURNIP BEETLE, ENTOMOSCELIS ADONIDIS (PALLAS); AND THE EXTERNAL LARVAL MORPHOLOGY OF BOTH SPECIES.

(COLEOPTERA, CHRYSOMELIDAE)

by

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Presented May, 1932,

to the faculty of Arts and Science of the

University of Saskatchewan, in partial

fulfilment of the requirements for the

degree of Master of Science.

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INTRODUCTION

The study of the peppergrass beetle (*Galeruca externa* Say) and the red turnip beetle (*Entomoscelis adonidis* (Pallas)), was begun during 1928 on the suggestion of Mr. Norman Criddle, Entomologist in charge of the Dominion Entomological Laboratory at Treesbank, Manitoba, who for several years had been aware of the similarity in habits of the two species as well as the degree to which the larvae resemble each other. It was, however, carried on only as one small phase of a minor investigation in conjunction with other more important projects. Increased attention was given both species during the winter of 1930-31, but it was not until the spring of 1931 that they were given the full attention and status of a separate project. Thus most of the observations were made near Treesbank, Manitoba, during the summer of 1931, and the morphological studies were conducted almost entirely during January and February, 1932, at the Dominion Entomological Laboratory, Saskatoon.

The insects being garden pests, and the writer holding a position as an investigator of economic entomological problems, it was natural that the economic aspect of the study should be stressed. A few of the experiments, however, are only remotely applicable to the economic field, and were included more for the purpose of obtaining leads to other, possibly new, economic studies.

Though the red turnip beetle, at least, has been troublesome in gardens for several decades, very little has been written regarding its life-history. Nor does there appear to be any experimental data available on the control of either species, though the commonly used chemical methods are recommended. Fletcher's report of 1892 contains a brief description of the larvae, but most literature on the species refers only to outbreaks in various localities from year to year. This is discussed later.

From various members of the Dominion Entomological Branch and from entomologists of provincial universities the writer has obtained valuable information and advice. He welcomes this opportunity to express his appreciation and extend his sincere thanks for their unstinted kindnesses.

For four seasons the writer has worked under the direction of Mr. Norman Criddle and during that time has received only the kindest consideration and most useful advice. Mr. Criddle's keenness of observation and wealth of entomological experience have enabled him to point out many pitfalls which might easily have caused much waste of time and effort. Mr. R. M. White, also of the Treesbank laboratory, has on several occasions indicated points of interest that the writer had overlooked. Miss M. Criddle and Mr. E. Criddle have assisted in locating infestations and in collecting specimens.

From Dr. L. G. Saunders of the University of Saskatchewan, to whom the plans of the study were submitted for final approval, many valuable suggestions were received, especially in regard to morphological technique and the preparation of the manuscript.

Mr. K. M. King, of the Saskatoon laboratory aided the writer in choosing his thesis, and has done everything possible to provide adequate facilities for the winter work on the project. To the other members of the Saskatoon staff — Messrs. Arnason, Paul, Glen, and McMillan — the writer also owes much for advice and assistance.

The writer is indebted to Mr. Arthur Gibson, Dominion Entomologist, and Mr. H. G. Crawford, Chief of the Division of Field Crop and Garden Insects, for their kindly attitude toward his work and for permission to present in this thesis the data secured while working on projects of the Entomological Branch.

Professor A. V. Mitchener of the Manitoba Agricultural College, from whom the writer received his first instruction in entomology, furnished information on the distribution, seasonal appearance, and food habits of the adults, especially E. adonidis, which information very suitably supplemented similar data collected by the investigator himself.

Messrs. H. L. Seamans, Alan G. Dustan, W. Downes, E. R. Buckell, F. L. Skinner (Proprietor of Hardy Plant Nurseries at Dropmore, Manitoba), K. E. Stewart, and K. M. King, have supplied the writer with unpublished data on the distribution of these species. With the permission of Messrs. Swaine and Crawford, the unpublished records on the distribution of E. adonidis, by the late R. C. Treherne, in the files of the Dominion Entomological Branch, Ottawa, have also been used.

The data and discussions presented in this thesis are not considered complete or conclusive in every respect. Rather has an attempt been made to extend the lines of investigation in as many directions as possible, pushing each project to its conclusion only when such extension did not prevent the investigation of other phases of the study. In some of the sections included below, the data are not presented in full, only summaries being given in a few instances. However, the data are available in detail in the writer's reports to the Dominion Entomologist, Ottawa, for the years 1928 to 1931 inclusive, one copy of which is filed at the Treesbank laboratory and another is in possession of the author.

RECORDS OF ECONOMIC IMPORTANCE

The earliest report on Galeruca externa Say, to come to the attention of the writer, was one by Norman Criddle in the entomologist's report for 1905 (published 1906). A few other insects of Manitoba are discussed therein and the report goes on to say "..... Galeruca externa Say, a chrysomelid which feeds naturally on Lepidium apetalum, an indigenous member of the cress family, turned its attention to turnips and cabbages." In 1911 and 1912 Criddle mentions the larvae as being enormously abundant on Lepidium, Arabis and other wild Cruciferae at Aweme, Manitoba, during May. That they were not present on farm crops he attributes to the scarcity of members of Cruciferae among the crops grown. Larvae and adults were again reported abundant at Aweme in 1923 and injury to turnips was expected. The next report of actual injury was made by Buckell in 1924 when adults were observed at Ootsa Lake, B. C., aiding Entomoscelis adonidis in the destruction of radishes and turnips. At Aweme the larvae seriously injured Alyssum saxatile, a perennial flower, in the spring of 1929, and have attacked it to some extent each succeeding spring.

Entomoscelis adonidis (Pallas) is mentioned by Fletcher (1892) as causing injury to rape in Hungary in 1865. In his report for 1891 Fletcher refers to localities in Western Canada where injury was done to cruciferous crops in that year. The species is mentioned in nearly all reports from that time forward, several of the reports intimating that it was present every year. Some of the comments are of special interest. Fletcher (1906) says, "The Red Turnip Beetle is every year abundant throughout the prairie provinces, but there are so many wild weeds of the Mustard family all through the West, that these plants have prevented the Red Turnip Beetle congregating upon cultivated crops to any serious degree." Injury has been reported almost yearly since that time, though there was only one report during 1929. Very few reports were received during 1930 and only one (from Therien, Alta.) in 1931, though this latter was a report of an outbreak on weeds only. Attention should be called to the fact, also, that the reports were not always from the same localities in successive years. Reports of larval injury have been very few, the adults seeming to have caused most of the damage. Whether this is because of the very early appearance of the larvae, or because the species was not recognized, is a point that should be kept in mind for further investigation.

In Manitoba, Professor A. V. Mitchener received five reports in 1922, one in 1925, two in 1926, two in 1927, five in 1928, one in 1929, and one in 1930. No two of these seventeen reports were from the same locality. This does not necessarily mean that the insects disappeared after each outbreak, but it suggests that some such occurrence must have taken place in at least some instances. This view is supported by the absence of the species at Dropmore, Manitoba, in 1931 though they were present in large numbers in the years 1929 and 1930.

GEOGRAPHICAL DISTRIBUTION AND ECOLOGICAL NOTES

Leng (1920) records G. externa as occurring in Washington, and from Kansas to Arizona, but the species is mentioned in so few publications that the writer has been forced to securé distribution records from collections and unpublished records. Records were obtained as follows:-

Manitoba.- Aweme, Napinka, Winnipeg.

Saskatchewan.- Flaxcombe, Gull Lake, Plato, Regina, Saskatoon.

Alberta.- Crows' Nest Pass, Elkwater Lake, Jasper Park, Nordegg, Orion.

~~British Columbia.~~- Ootsa Lake.

Lochhead (1919) mentions E. adonidis as occurring in the prairie provinces, Essig (1926) includes Europe and Siberia in its range, and Crosby and Leonard (1918) do not limit the species to Siberia, but simply state that it occurs in Asia as well as in Europe and western North America. That the species is native to Western Canada all writers seem to agree, but there appears to be no hypothesis in the literature as to why it occurs on three continents.

As in the case of G. externa, the distribution records listed below for Western Canada were secured from the unpublished data of several members of the Dominion Entomological Branch (see Introduction).

Manitoba.- Aweme, Balmoral, Beaver, Beulah, Binscarth, Boggy Creek, Brandon, Dropmore, Elkhorn, Fort Ellis, Gladstone, Gypsumville, Kirkella, Marchand, McAuley, Minnedosa, Morden, Neepawa, Rorketon, Rosebank, Roseisle, Snowflake, Souris, St. Lazare, Swan River, Treesbank.

Saskatchewan.- Alameda, Birch Hills, Cailmount, Crystal Springs, Dafoe, Delisle, Dilke, Dilton Park, Eston, Foxdale, Frenchman's Butte, High Hill, Indian Head, Jordan River, Kinistino, Lanigan, Leslie, Lorlie, Marsden, Maryfield, Maymont, Meota, Midnight Lake, Norquay, Prince Albert, Quill Lake, Richard, Rosthern, Saskatoon, Scott, Spruce Lake, Traynor, Unity, Wadena, Weldon, Yorkton.

Alberta.- Albert Park, Beaver Lake, Beaverlodge, Bernie, Calgary, Chauvin, Coaldale, Edmonton, Enilda, Gleichen, Lacombe, Lesser Slave Lake, Lethbridge, Magnolia, McLeod, Nauton, North Bank, Olds, Peace River, Peace River Crossing, Red Deer, Riviere qui Barre, Shaftesbury, Spirit River, Strathcona, Strathmore, Therien, Tremblay, Vermillion, Wainwright, Wayne.

British Columbia.- Buckley Valley, Burns Lake, Dawson Creek, Fort.St.John, Francois Lake, Hazleton, Henceville, Lillooet, Lower Nicola, Midday Valley,

Ootsa, Pouce Coupe, Rolla, Spence's Bridge, Telegraph Creek, Vernon.
Yukon Territories.- Carcross, Dawson, Forty Mile, White Horse.

On examining the maps of rainfall, vegetation, railways, etc., one learns that the districts listed above for adonidis are all either within, or just outside, the grove belt, where the yearly rainfall averages about eighteen inches. In Saskatchewan the beetles have been reported much farther outside the grove belt than they have in Manitoba or Alberta, but the areas of moderately heavy rainfall extend farther into the prairie section in that province. In Manitoba neither species has been collected in the dryer areas of prairie south and west of a line running through Virden, Treesbank, Glenboro, and Pilot Mound. That the type of soil is of less importance than rainfall and shelter is suggested by the fact that the soil at Aweme, where the beetles have been present in considerable numbers, is quite sandy, while the soil at Dropmore is heavy black loam.

Conclusions as to the climatic requirements of externa can scarcely be drawn from the limited distributional records available, but this species has been collected at points more widely removed from the grove belt than has adonidis. At Aweme the larvae were discovered in the first two, and the adults (externa only) in all three of the areas described below.

AREA A.- This is a flower garden just outside the eastern limits of the laboratory grounds. The insects were found on clumps of Alyssum saxatile in the perennial border. The garden itself is somewhat lower than the surrounding areas and slopes gently toward the south. One of the groups of A. saxatile was situated in the lowest part of the garden. A group of poplar trees stood about twenty feet south of it, but it was never shaded except toward evening. The other two clumps were nearer the laboratory on slightly higher ground. The trees here were also about twenty feet to the south, but shrubbery shaded the Alyssum at certain periods of the day.

AREA B.- This area, situated in a pasture north of the laboratory, supported many plants of Arabis brachycarpa, A. holboellii, ground cedar, bear berry, gramma grass and other grasses. Trees surrounded the area at a distance of about fifty feet. The insects were usually found in depressed parts of the clearing or else on the parts that sloped in a northerly direction.

AREA C.- A small section in a field of scattered brome and western rye grass, about three -quarters of a mile south of the laboratory, harbored a large number of adults (and eggs) during the autumn. The part in which the beetles were found was about six yards wide by twelve yards long. It was rectangular in shape, though somewhat rounded at the south end. It sloped gently to the north. The grass clumps occupied very little space, but there was considerable Lepidium apetalum, Sisymbrium altissimum, Artemisia frigida, A. dracunculoides, green foxtail, pigweed, sweet clover, and low rose bushes, besides a considerable area of bare soil.

MORPHOLOGY

The detailed study of the external morphology of the mature larvae of both species was conducted during Jan. and Feb., 1932, under the direction of Dr. L. G. Saunders.

(a) Galeruca externa Say

The Mature Larva

Methods and Technique

A careful study was made of ten mature larvae of G. externa and drawings and descriptions made from one most nearly average of the group. The mouth parts of additional specimens were mounted on slides with gum arabic for study of characters not easily seen on the undissected larva. Mounts were also made of larval skins. The head was removed and the skin cut with small dissecting scissors along the pleural areas between the spiracles and the epipleural sclerites. In order to prevent folding, it was necessary to lift them with a small flattened wire and float them on a drop of gum arabic considerably diluted with water (alcohol or xylol could be used if mounting in euparal or Canada balsam). After some of the water had evaporated a drop of the undiluted mounting medium was placed on top of the skin and the cover glass dropped into place. Some of the skins were cut along the middle of the dorsal and ventral areas giving a better view, when mounted, of the pleural sclerites.

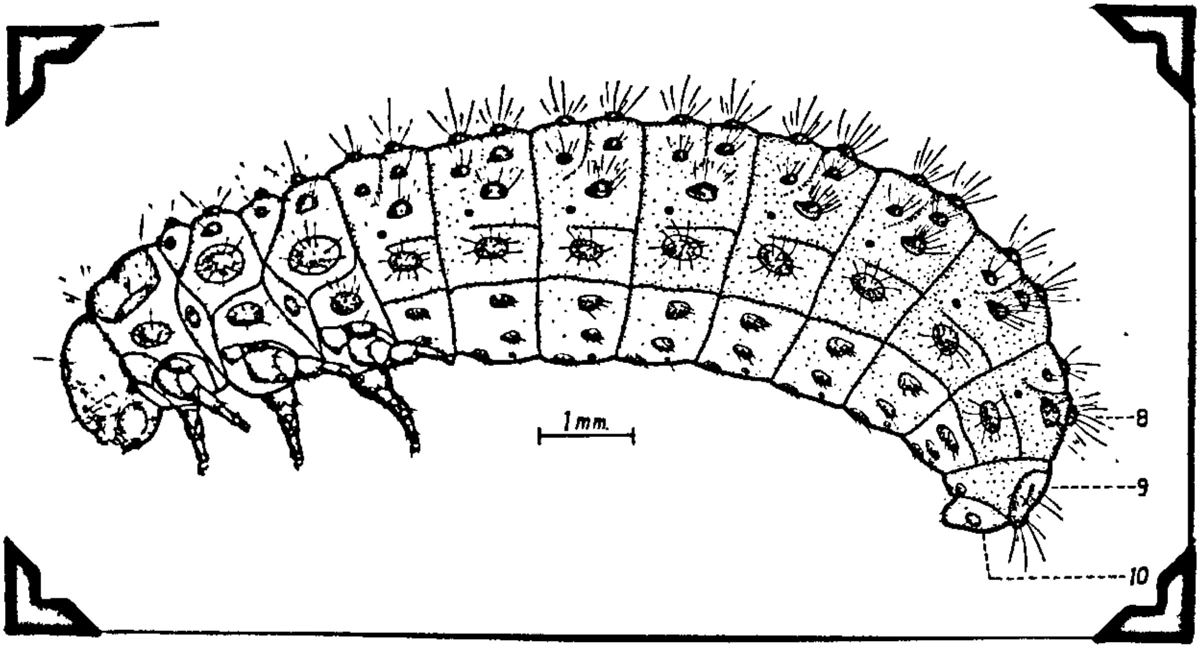

Fig. 1

Galeruca externa

Mature larva

The colour descriptions were made from living specimens. In order to eliminate individual ideas of colour, Windsor and Newton's chart of water colours, as shown by Smith (1906), has been used as a basis for these descriptions.

The terminology of Böving (1929) and Böving and Craighead (1931) was used almost entirely, supplemented to some extent from MacGillivray(1923).

General Description

The mature larvae of Galeruca externa Say (Fig. 1) are subcylindrical in shape, slightly flattened dorso-ventrally, and taper slightly from the middle both ways. They vary in length from 11 to 16 mm., ten of them averaging 12.6 mm. The head capules are from 1.36 mm. to 1.5 mm. with an average of 1.4 mm. The early third instar larvae average about 7.1 mm. in length. The dorsal area being greater than the ventral area, the larvae appear slightly arched when resting. Small, setiferous sclerites, are present on all the body segments. These sclerites are raised but are never higher than their narrowest axis.

In living specimens the head is mostly a shiny black; the prothoracic shield is nearly black, but not shiny; the remaining dorsal areas are a Cologne earth with a suggestion of chrome lemon showing through, especially between segments and along a mid-dorsal line; the dorsal sclerites are even darker than Cologne earth; the ventral area is between chrome lemon and olive green, the sclerites ranging from brown to Cologne earth or darker; the lateral area shades gradually from the dorsal to the ventral colours.

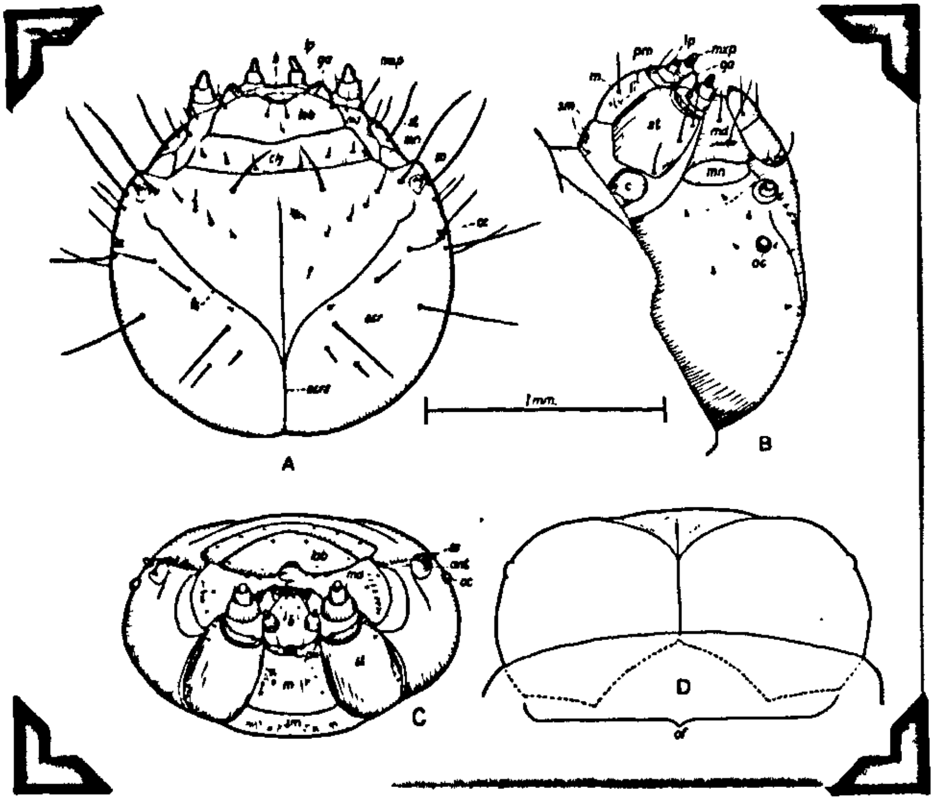

Fig. 2

Galeruca externa

A. Head. Dorsal view.
B. Head. Lateral view.
C. Head. Buccal view.
D, Head. Posterior view.

ant, antenna
c, cardo
cly, clypeus
ecr, epicranium
ecrs, epicranial suture
f, frons
fs, fontal suture
ga, galea
lab, labrum
li, ligula
lp, labial palpus
m, mentum
md, mandible
mn, mandacoria
mxp, maxillary palpus
oc, ocellus
of, occipital foramen
pm, prementum
sm, submentum
so, sensory organ
st, stipes

The setae on each sclerite, especially the dorsal ones, vary greatly in length. The longest setae of the dorsum are approximately half the length of a normal segment; and those of the ventral areas are short, usually shorter than the width of the sclerite on which they are found. The setae of the head, legs, and ventral areas are pointed; the lateral setae and setae of the prothoracic and anal shields are mostly blunt with a few capitate ones; and the dorsal setae are mostly capitate with a few merely blunt. The ventral setae are pale brown, and the dorsal setae almost white. The setae of the body sclerites, except those on the legs, vary considerably in number in different specimens, hence the numbers given later are representative only of the average for the sclerite named.

Head

HEAD CAPSULE (Fig. 2) hypognathous. Epicranial suture extending slightly farther than one-third of distance from occipital foramen to clypeus, yellowish white; frontal sutures similarly coloured and caudolaterally bordered on anterior two-thirds by a yellowish brown streak; blackish brown of epicranium shading to light brown in genal areas; mandibles brown; all membranous parts of head yellowish white. Setae varying in length on different parts of head, but those figured (Fig. 2,A) fairly constant in size and arrangement. Median line of frons not extending to clypeus.

Single OCELLUS (Fig. 2,<u>oc</u>) caudad to antenna by a distance approximately three times its own width.

ANTENNA composed of one segment and a tactile organ (Fig. 2, <u>so</u>), situated just beyond anterior end of frontal suture and posterior to

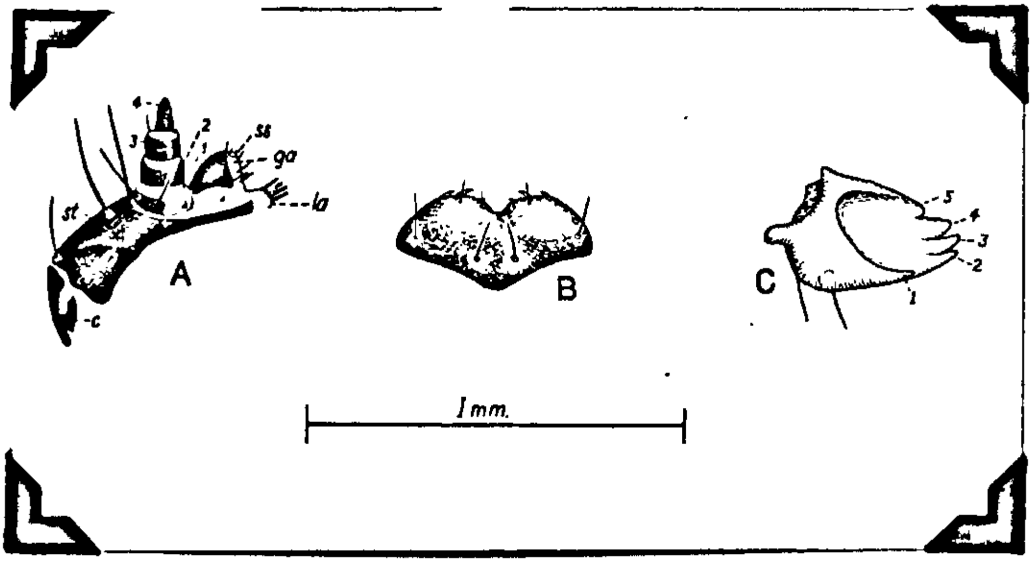

Fig. 3

Galeruca externa

A. Right maxilla
B. Labrum
C. Left mandible

c, cardo
ga, galea
la, lacinia
ss, sensory seta
st, stipes

dorsal end of mandacoria by less than its own diameter. The single segment chitinized except on distal end, and almost completely enveloped by a transparent membrane in all specimens examined.

FRONS obliquely depressed from middle of median line to corner of mandibles and slightly elevated in transverse direction just caudad of clypeus.

CLYPEUS fairly heavily chitinized only at base. Three pairs of small setae on chitinized part.

LABRUM (Fig. 3, B) broad and well-developed, emarginate anteriorly, bearing two pairs of larger discal setae and two pairs of small setae near anterior margin. Three pairs of cephalo-mesally directed spines protruding from beneath anterior margin. Discal setae not always in same ratio, but interior pair usually about three-quarters the length of external pair. A few irregularly spaced depressions present.

MANDIBLES (Fig. 3, C) hollow, palmate, each with five teeth; fourth tooth slightly serrate, second and third seldom so, fifth usually bluntly rounded or even truncate, not pointed like the other four. Two fairly large setae present on exposed basal half of each. Membranous mandacoria (Fig. 2, mn) partly covering base.

MAXILLA composed of usual parts; cardo small and without setae, but stipes strongly developed (Fig. 2, B, and Fig. 3, A), carrying three fairly large setae. Maxillary palpi four-jointed with two setae on first, two small ones on third and one minute seta on fourth segment. Distal area of each segment membranous. Except for the membranous distal surface galea strongly chitinized, carrying about six ordinary setae and one sensory seta (Fig. 3, A, ss), all minute. Lacinia entirely membranous, bearing three to five setae. These setae about twice as heavy as those of galea.

SUBMENTUM largely membranous with a lightly chitinized discal area supporting at least three pairs of setae, other unpaired setae frequently occurring.

MENTUM (Fig. 2, B and C) containing pair of lightly chitinized areas with two comparatively large, and from three to five minute, setae, the latter more usually in row of three near each lateral margin.

PREMENTUM (Fig. 2, pm) fairly heavily chitinized at least at base, mesal portion somewhat extended anteriorly. Setae of prementum about half as long as large pair on mentum.

LIGULA lightly chitinized anteriorly, membranous area containing at least six very small, paired setae, posterior pair slightly larger than others.

LABIAL PALPI two-jointed; distal area of each segment membranous; palpi separated by about their own length.

Thorax

PROTHORAX (Fig 4). Prothoracic shield heavily chitinized and transversely depressed, completely surrounded by narrow membranous margin; setae variable in size and number, averaging about 80, all marginal except three or four. Dorso-lateral sulcus indistinct, hence epipleural area not clearly defined dorsally; epipleural sclerite large, somewhat dome-shaped, carrying about eleven setae. Prehypopleural sclerite (ph) large, raised, bearing about seven setae of various sizes; posthypopleural sclerite

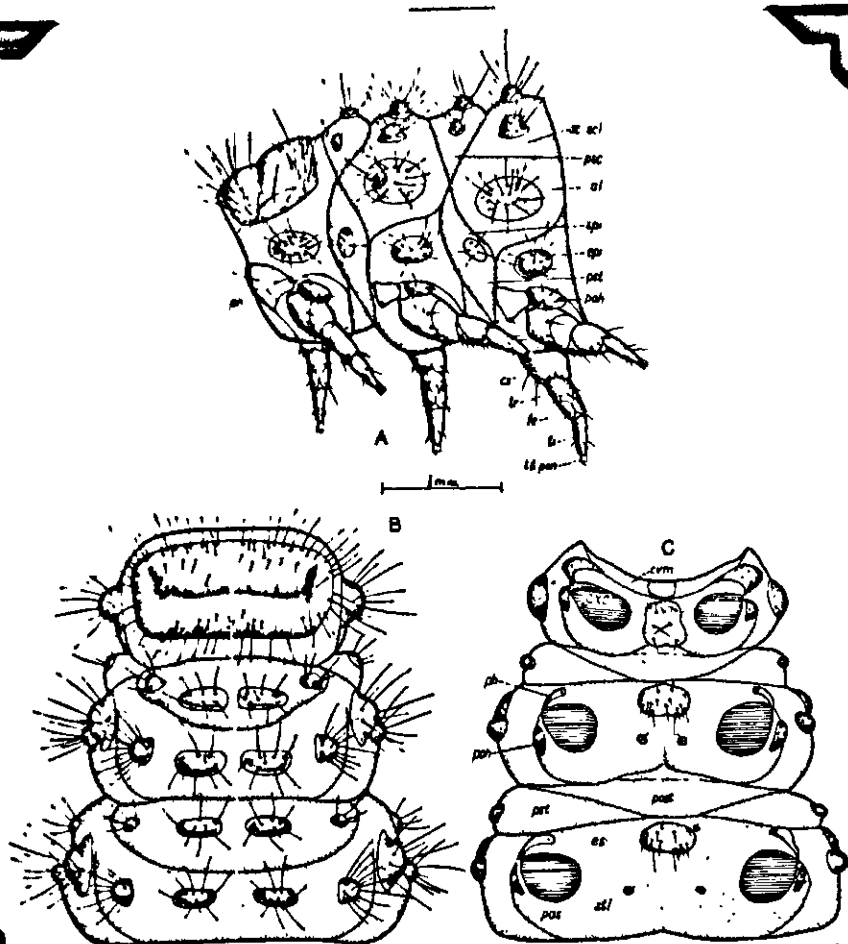

Fig. 4

Galeruca externa

A. Thorax. Lateral view
B. Thorax. Dorsal view
C. Thorax. Ventral view

al, alar area
cvm, cervical membrane
cx, coxa
cxc, coxal cavity
epi, episternum
es, eusternum
fe, femur
pas, parasternum
ph, prehypopleurum
poh, posthypopleurum
pon, paronychial appendix
post, poststernellum
psc, prescutum
pst, presternum
sc-scl, scuto-scutellum
spi, spiracular area
stl, sternellum
t, tarsungulus
ti, tibia
tr, trochanter

(poh) elliptical at base, nearly always with five setae, never less than five. Eusternal, sternellar and coxa-bearing parasternal areas not distinctly separate from each other; eusternal and sternellar sclerites fused, bearing about nine setae, some paired but others irregularly spaced. Poststernellar area well-defined but without either sclerites or setae.

MESOTHORACIC AND METATHORACIC SEGMENTS (Fig.4). Dorsum divided by transverse sulcus anterially curved at ends, completely limiting posterior and lateral margins of prescutum (psc). Scuto-scutellum (sc-scl) partly separated from alar area by an incomplete and indistinct, oblique sulcus. Spiracular area (spi) distinctly separated from alar and epipleural areas (epi) but not from presternal area (pst). No sulci separating eusternum, sternellum, and parasternum; poststernum limited by fairly deep sulci in mesothorax, absent in metathorax.

Inner sclerite of prescutum elongate, carrying about seven setae; outer one dome-shaped with four. Usually eight setae present on elongate inner sclerite of scuto-scutellum, and elven on outer dome-shaped one. Alar sclerite also dome-shaped, with about twelve setae. Spiracle surrounded by a chitinized area bearing about four setae; epipleural sclerite with eight. Prehypopleural sclerite flat and quadrangular with one small seta in anterior ventral corner; posthypopleural sclerite usually with six, never less than five. Eusternal unpaired sclerite flat, not strongly chitinized, carrying about 15 setae irregularly arranged; paired sternellar sclerites similarly chitinized but with only one small seta.

CERVICAL MEMBRANE._An examination of the ventral surface of the prothorax (Fig. 4,C) reveals a well defined area (cvm), extending from one prehypopleural sclerite to the other, which, unless it is the eusternum, has not been included by Böving (1929) in his description of the Galerucinae. The eusternal sclerites of the meso-and metathoracic segments, however, bear numerous setae, while the unpaired sclerite of the area in question has no setae at all. Again, the area immediately posterior to the setaless sclerite, contains a chitinized portion on which setae are numerous, strongly indicating that it is the fused sclerites of the eusternal and sternellar areas. For these reasons the writer assumes that the described area is not the eusternum, and concludes that it is the ventral part of the cervical membrane.

LEGS (Fig. 4,B).- Legs widely spaced, five-jointed, heavy deposits of chitin where that substance is present, chitinized areas fuscous in colour. Coxal cavity sub-elliptical; coxa sessile, with large membranous patch evident distally on exterior side, interior distal margin notched. Trochanter subtriangular, extending from membranous area of coxa, in contact with at least two-thirds of ventral side of femur. Femur slightly longer than trochanter, cylindrical, a small membranous area present ventrally on distal margin. Tibia subcylindrical, tapering slightly from femur to tarsungulus; presence of three weak constrictions giving tibia appearance of being three-jointed. Tarsungulus comparatively short; claw about as long as diameter of basal portion. Small paronychial appendix present.

Except for a few very small ones, setae of legs constant in size, position, and number. Coxa with four setae on anterior distal margin of chitinized area and one similarly placed posteriorly, besides a few minute ones. Trochanter with four ventrally on discal region. Femur with six arranged around distal margin. Tibia bearing six setae in a ring approximately at its middle and three smaller ones on distal margin.

Abdomen

FIRST SIX SEGMENTS.- Abdominal segments one to six divided similarly to second and third thoracic segments, but sulci less distinct. Dorsal area (Fig. 5,A) divided, as in thorax, into prescutum and combined scuto-scutellum. Parascutal area not divided into spiracular and alar regions, no sulcus separating the parascutum from the scuto-scutellum. Dorso-lateral sulcus fairly well defined but anteriorly incomplete (see Fig. 1); epipleurum completely limited ventrally by ventro-lateral sulcus. Eusternum clearly marked (Fig. 5,C,es); no line of demarkation separating the hypopleural (hp) parasternal (pas) and sternellar (stl) areas.

Interior prescutal sclerites elongate, separated by about their narrowest axis, bearing about seven setae; exterior pair removed from interior ones by a distance equalling the long axis of the latter; four setae present. Bases of the two interior scuto-scutellar sclerites fused, the two raised portions occurring on the same sclerite; exterior pair nearer meson than exterior sclerites of prescutum; about eight setae present on each of the four raised areas. No sclerite surrounding

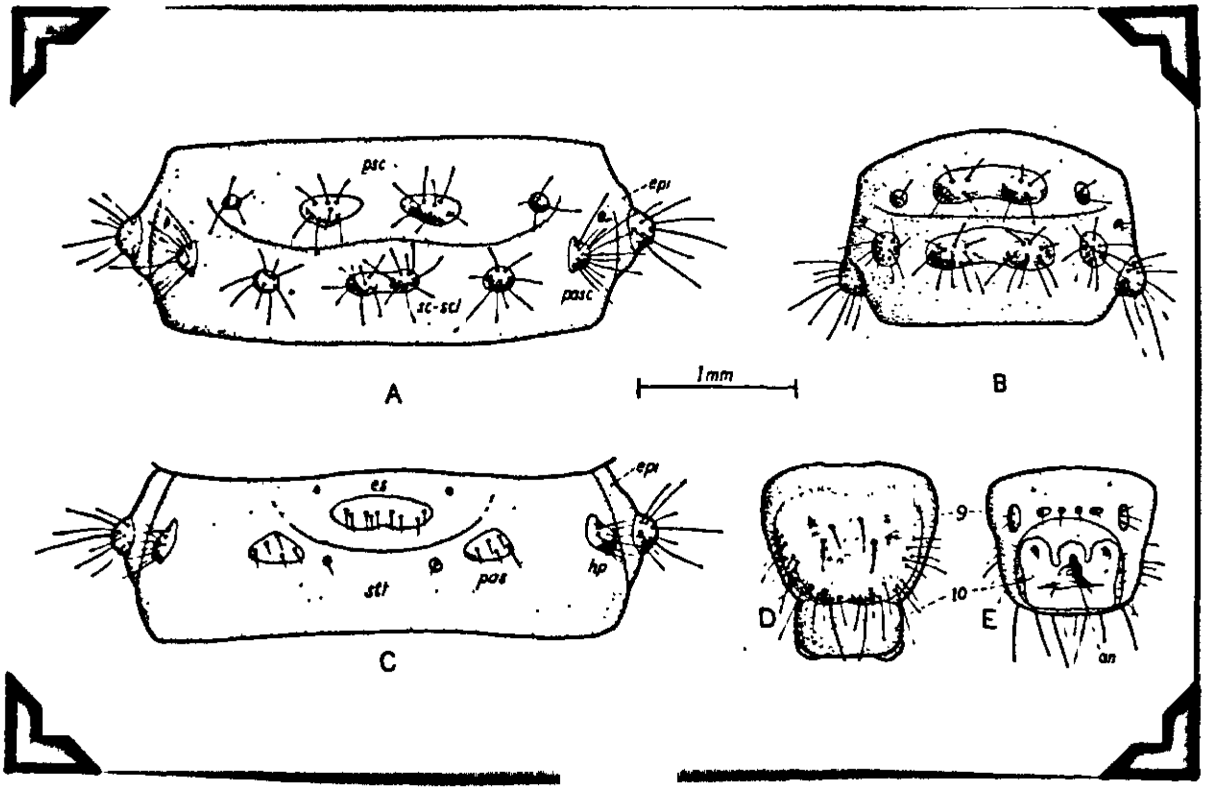

Fig. 5

Galeruca externa

A.	Typical abdominal segment.	Dorsal view
B.	Eighth abdominal segment.	Dorsal view
C.	Typical abdominal segment.	Ventral view
D.	Ninth and tenth abdominal segments.	Dorsal view
E.	Ninth and tenth abdominal segments.	Ventral view

an, anus
epi, epipleurum
es, eusternum
hp, hypopleurum
pas, parasternum
pasc, parascutum
psc, prescutum
sc-scl, scuto-scutellum
stl, sternellum

spiracle; posterior parascutal sclerite shaped like those of thorax but smaller, bearing about eleven setae. Epipleural sclerite sub-circular at base also with about eleven setae. Hypopleural sclerite somewhat less regularly shaped; about seven setae present. Other ventral sclerites flat, not heavily chitinized; eusternal sclerite with about nine setae; sternellar with one, parasternal with five. Two small sclerites, each bearing a minute seta, and possibly representing vestiges of a disappearing preeusternum, located anterior to lateral margins of eusternal sclerite.

SEVENTH SEGMENT.- Seventh abdominal segment similar in every respect to preceding six excepting from one to three fewer setae on all sclerites, the greatest reduction occurring on ventral ones.

EIGHTH SEGMENT (Fig. 5,B).- Interior sclerites of both prescutum and scuto-scutellum fused basally, each retaining its separate raised part. Exterior sclerite of scuto-scutellum absent. [Böving (1929) suggests that it has migrated and fused with the interior sclerite, which, considering the unity of the area, seems most probable.] In other respects eighth segment resembling other segments, except number of setae even less than in seventh segment.

NINTH SEGMENT (Fig. 5, D and E).- Pygidial shield sub-quadrate to semicircular, covering most of the dorsum, and heavily chitinized posteriorly, [illegible] chitin becoming gradually thinner anteriorly, finally blending with [illegible] membrane of [illegible] cephalic border; a semicircular depression present discally; about 28 marginal setae and four discal setae. No other regions of segment defined by sulci. Ventral sclerites thinly chitinized, variable in size, position, and number of setae; a row of four sclerites, each with a single seta, commonly present near posterior margin, though central pair sometimes farther cephalad and bearing three to five setae; minute, paired sclerites present near anterior margin as in other segments.

TENTH SEGMENT.- The tenth segment (Fig. 1), which Böving terms a pygopod, extends in a direction nearly at right angles to the ventral surface of segment nine. Thus looking down vertically on the upturned ventral area of the ninth segment, a very small part of the caudal margin of that segment can be seen projecting beyond segment ten (Fig. 5,E); looking vertically down on the caudal margin of the pygidial shield, however, the dorsal area of segment ten is easily seen (Fig. 5,D). This segment is entirely membranous except for a small sclerite, bearing three minute setae, on the lateral areas. A few very small setae are present here and there on the segment, but a row of six such setae is always present across the middle of the ventral region. The posterior area of the segment is three-lobed anteriorly and forms a sucking disc, which is used in locomotion. The Anus (Fig. 5,E, an) is in the centre of this disc.

SPIRACLES.- Functional spiracles are present in the mesothorax and first eight abdominal segments and a vestigial spiracle is clearly indicated on the matathorax. All subequal, annuliform and laterally located.

Second Instar

The second instar is practically identical with the third, though there are not quite as many setae, especially on the epicranium and the prothoracic and pygidial shields. The setae are comparatively longer but actually shorter than those of the third instar, the longer ones being

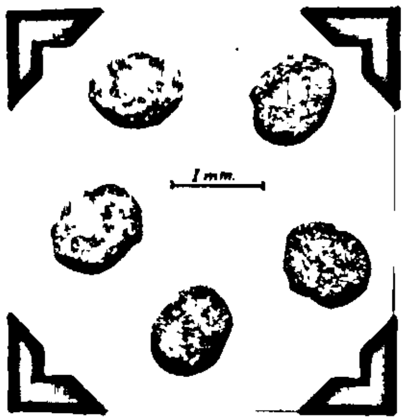

Fig. 6

Galeruca externa

The eggs.

curved slightly toward the rear. The head capsules average 0.87 mm. in width and the body 4.5 mm. in length during the first day of the stadium.

First Instar

This instar is very slightly lighter in color and considerably less heavily chitinized. All the sclerites are present but the setae are greatly reduced in number. The unpaired eusternal sclerite and the epipleural and hypopleural sclerites of the abdomen bear two setae (sometimes only one), while all the other abdominal sclerites bear a single one. The alar sclerite of the thorax also carries two and sometimes three setae, the epipleural sclerite usually carrying two, occasionally one. The body is more nearly cylindrical than in the other two instars, measuring about 1.9 mm. at time of hatching. The head capsule is about 0.58 mm. in width.

The Adult

The adult beetle is black with the exception of a narrow border of yellow on the outer margin of each elytron. In shape it is oval and somewhat flattened, especially as compared to *E. adonidis*. Blatchley (1910) has described the genus and a closely allied species. Say (1824) made the original description of *G. externa*.

The Egg

The eggs measure 0.9 mm. by 1.1 mm. but they are laid in such compact masses as to make them rather irregular in shape. The exposed surface becomes dark brown, but when the cluster is broken open the inner surfaces are shown to be dull yellow. The chorion is rather finely reticulate

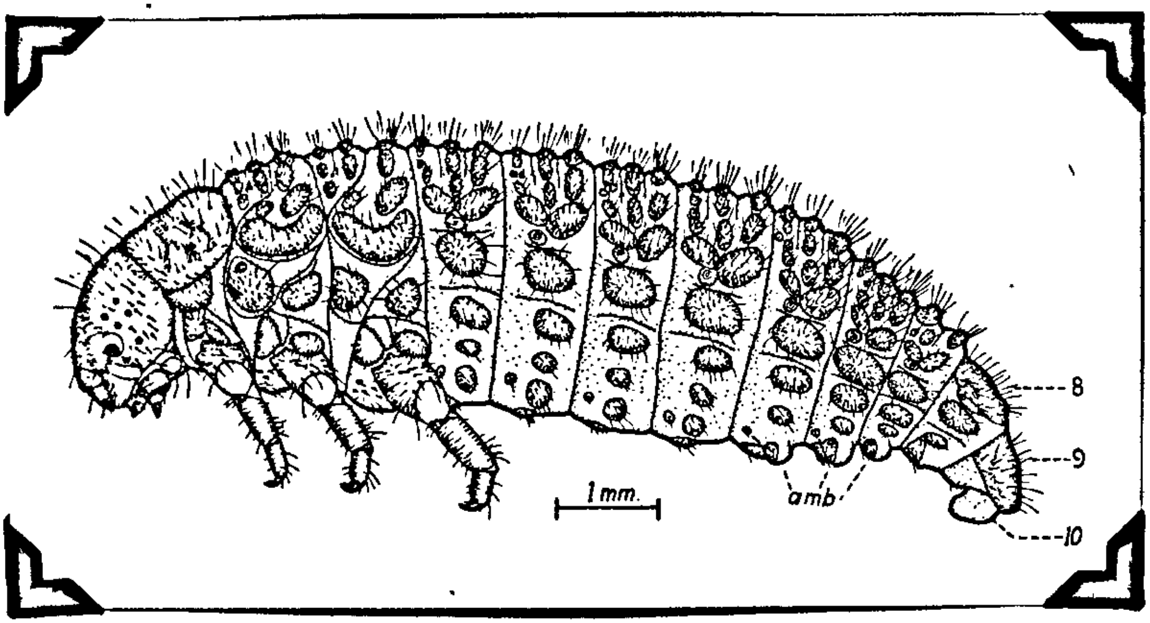

Fig. 7

Entomoscelis adonidis

Mature larva.

amb, ambulatory warts.

(b) Entomoscelis adonidis (Pallas)

The Mature Larva

Methods and Technique

The drawings and descriptions of adonidis were made from one mature larva and modified where necessary from a careful study of one other larva and seven cast skins and mouth parts mounted in gum arabic. Before they were cut and mounted the skins were softened in a 10% solution of potassium hydroxide and washed in distilled water. In all other particulars the methods were the same as those used in the study of externa.

General Description

The mature larva of Entomoscelis adonidis (Pallas), Fig. 7, is superficially similar to Galeruca externa. It is not flattened, however, nor does it taper as greatly toward the head, but the decrease in size caudally is rapid. The sétiferous sclerites are more numerous than in G. externa and are arranged in three rows on the dorsum instead of two. Ambulatory warts are present on the 5th, 6th, and 7th abdominal segments. In the early fourth instar the length varies from 5 mm. when at rest to 7 mm. when fully extended; when mature the larvae average 7.6 mm. when at rest and 10.9 mm. when extended in crawling, the largest specimen being 12.5 mm. long.

Living specimens have the prothoracic shield and most of the head shiny black; the dorsal area of the body, including the sclerites,

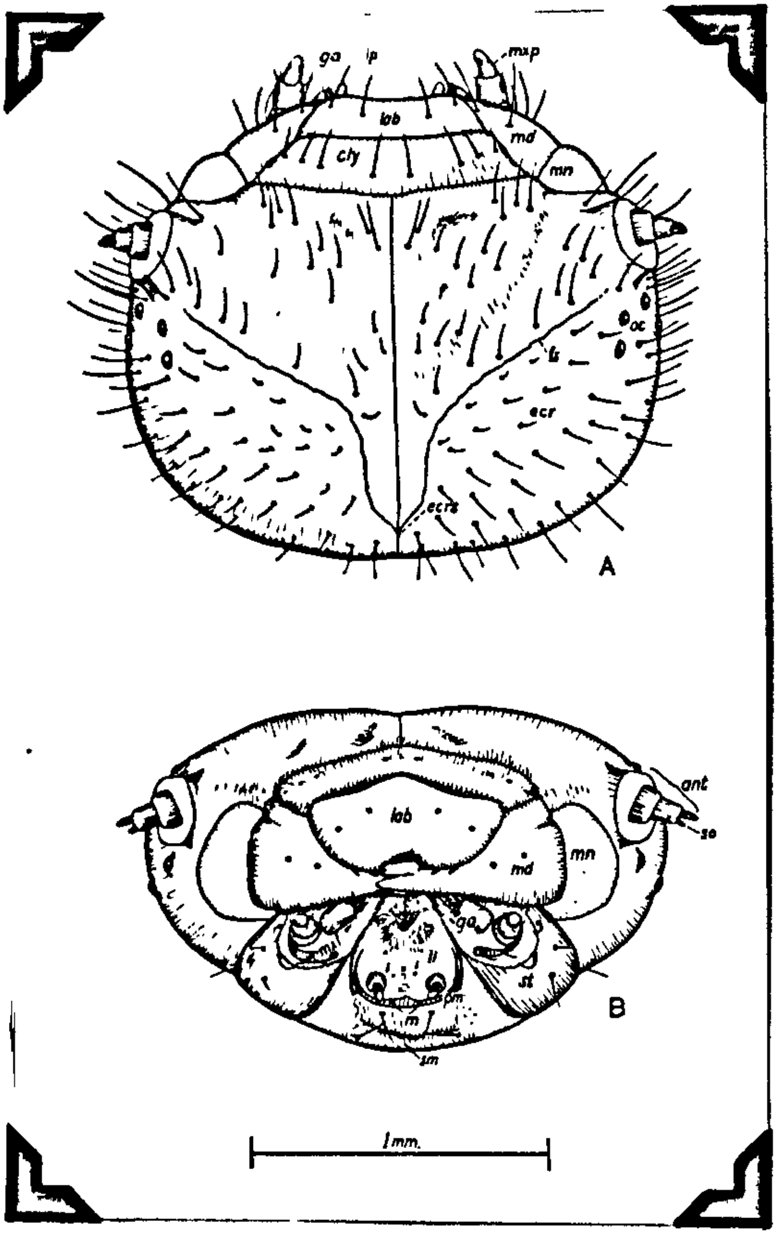

Fig. 8

Entomoscelis adonidis

A. Head. Dorsal view
B. Head. Buccal view

ant, antenna
cly, clypeus
ecr, epicranium
ecrs, epicranial suture
f, frons
fs, frontal suture
ga, mala
lab, labrum
li, ligula
lp, labial palpus

m, mentum
md, mandible
mn, mandacoria
mxf, maxillary palpiger
mxp, maxillary palpus
oc, ocellus
pm, prementum
sm, submentum
so, sensory organ
st, stipes

darker than Cologne earth; the epipleural sclerites close to olive green; the ventral region mostly pale brown with a suggestion of chrome orange on the mid-ventral part of the thorax, this color fading more nearly to pale cadmium yellow on the mid-ventral region of the abdomen; and the ventral sclerites close to Cologne earth.

The setae of the epicranium, and dorsal area of body, including the prothoracic and pygideal shields, are mostly capitate; those of the epipleural area are pointed to blunt; and the remaining setae of the head and those of the ventral area, including the legs, are pointed. The setae are small in diameter, the dorsal setae being fairly uniform in length, about one-third the length of the normal segment, and the ventral setae considerably shorter. The number per sclerite varies from specimen to specimen, the numbers included later representing the average.

Head.

HEAD CAPSULE (Fig. 8) hypognathous, varying in width from 1.47 mm. to 1.94 mm., average for ten specimens 1.81 mm. Black (or sometimes fuscous) of epicranium and frons shading to brown near clypeus, around antennae, and on genal areas. Mandibles brown; clypeus brown near tip; chitinized part of ligula brown, membranaous parts yellowish white; epicranial suture and frontal sutures yellow.

EPICRANIAL SUTURE less than one-quarter distance from occipital foramen to clypeus. Setae of uniform length, capitate, uniformly spaced, about 0.1 mm. apart. Frontal sutures leaving epicranial suture at angle of about forty-five degrees, turning cephalad at about 0.075 mm. from median line, running parallel to median line for about 0.15 mm., hence

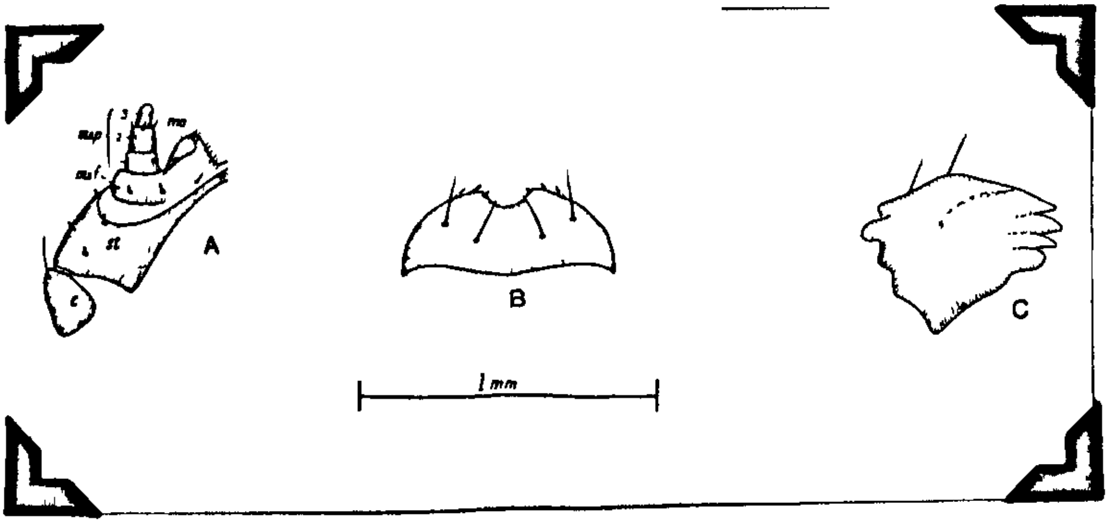

Fig. 9

Entomoscelis adonidis

A. Right maxilla
B. Labrum
C. Right mandible

c, cardo
ma, mala
mxf, maxillary palpiger
mxp, maxillary palpus
st, stipes

curving out again toward antennae.

OCELLI (oc) six on each side, four caudad and two ventrad of antenna, often on slightly raised portions of epicranium.

ANTENNAE (ant) three-jointed, arising from large protruding basal articulating membrane on raised margins of frons and epicranium. Distal areas of first two segments membranous, second segment supporting a conical sensory organ (so) ventrad of narrow third segment. Minute sensory setae present on distal surface of third segment. Basal membrane close to dorsal half of posterior margin of mandacoria.

FRONS wide, apparently fused with epicranial halves at antennae. Slight, V-shaped depression with point on median line just posterior to middle; two other depressions near anterior margin, one on each side of median line. Setae irregularly spaced, a few paired; nearly all capitate. Median line extending to clypeus.

CLYPEUS chitinized throughout, but lightly on anterior half. Four pairs of setae present.

LABRUM (Fig. 9,B) well-developed, emarginate anteriorly, lateral corners of caudal margin extending posteriorly to form short point. Circular depression present in discal surface. Discal setae subequal; no anterior setae present. Six short, stout setae of epipharynx protruding from beneath anterior margin; six minute setae with rounded tips present on anterior emargination of epipharynx but not protruding beyond margin of labrum.

MANDIBLES (Fig. 9,C) hollow, palmate, not nearly as strongly chitinized as those of G. externa. Five teeth present, though first tooth usually so small as to be scarcely noticeable. Fifth tooth well-developed and rounded distally. Two setae on exterior basal half. Mandacoria usually membranous but often chitinized fairly strongly at base.

MAXILLA (Fig. 9,A) strongly chitinized. Palpus three-jointed, with strongly chitinized palpiger (mxf) at base. Mala (ga) present instead of galea and lacinia. Palpiger imbedded in membranous area; mala membranous distally; small cushions of membrane present on distal regions of segments of palpus. Cardo bearing one seta; stipes four; palpiger two, second joint of palpus three; mala with about eleven, none of them appearing to be sensory in function.

MENTUM and submentum somewhat less strongly chitinized than maxillary stipes; line of demarkation indicated by a slight bend in surface, throwing plane of submentum away from that of mentum, in a ventral direction, by an angle of about thirty degrees. Chitinized area of mentum laterally extended cephalad, parallel and in close proximity to lateral extension of maxillary stipes. Pair of strong setae on each area. Lateral areas, in contact with cardo and stipes, membranous.

PREMENTUM (pm) with light chitinization extending cephalad a short distance into ligula (li) from its mesal portion; otherwise as in G. externa.

LIGULA fairly strongly chitinized anteriorly, a trough-like groove running back to hypopharynx; remaining larger area membranous. Setae minute, varied in number and position, frequently three pairs present. Pair of sensory pores situated between anterior sides of bases of labial palpi.

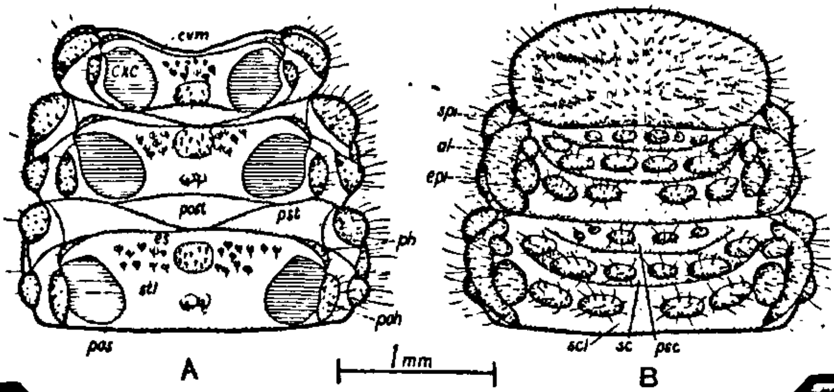

Fig. 10

Entomoscelis adonidis

A. Thorax. Ventral view
B. Thorax. Dorsal view

al, alar area
cvm, cervical membrane
cxc, coxal cavity
epi, epipleurum
es, eusternum
pas, parasternum
ph, prehypopleurum
poh, posthypopleurum
post, poststernellum
psc, prescutum
pst, presternum
sc, scutum
scl, scutellum
spi, spiracular area
stl, sternellum

LABIAL PALPI two-jointed, each segment with small membranous area distally. Palpi separated by about length of one.

Thorax

PROTHORAX (Fig. 10).- Prothoracic shield strongly chitinized, irregular depressions present discally, shield just large enough to obscure, when viewed from above, all lateral sclerites. Epipleural area (epi) with large sclerite filling all anterior part from prothorax to ventro-lateral sulcus. Ventro-lateral sulcus oblique; prehypopleural (ph) and posthypopleural (poh) sclerites almost touching each other. Parasternum, eusternum and sternellum not separated by any line of demarkation. Sternellum and poststernellum separated by distinct sulcus.

Setae of uniform length and spacing, slightly more numerous than on epicranial halves. Epipleural sclerite semicircular, bearing about fifteen setae. Prehypopleural and posthypopleural sclerites both protuberant, the former bearing about five setae and the latter ten. About eleven small, irregularly arranged sclerites, each with single setae, present on eusternum. Sternellum with flat, unpaired sclerite, bearing about eight setae. Parasternal areas bearing the legs.

MESOTHORACIC AND METATHORACIC SEGMENTS (Fig. 10).- Dorsum transversely divided into prescutum, scutum, and scutellum by two transverse sulci anteriorly curved at ends. No line of demarkation between alar region and scutellum. Spiracular area, in front of oblique dorsolateral sulcus, separated from presternum by ventro-lateral sulcus and from alar area by sulcus which follows ventral outline of large alar sclerite. Posterior part of ventro-lateral sulcus horizontal,making epipleural area distinctly triangular. Presternum and poststernellum limited on all sides by sulci; eusternum, sternellum and parasternum not separated from each other.

Sclerites of prescutum irregular in size and number, usually two, often three on each side; interior pair with about seven setae, others with from one to three. The six sclerites of scutum elongate, subequal, outer pair just anterior to a line drawn through cephalic margins of other four; six or seven setae present on each. Scutellum with two pairs of sclerites about same size and shape as those of scutum; about nine setae present on outer pair and eleven on inner ones. Alar region bearing group of three sclerites. Most ventral sclerite sub-lunate, covering almost full length of segment, bearing about twenty-nine setae. Other two sclerites subcircular, dorsad of sub-lunate one, anterior sclerite bearing about six setae, larger posterior one with about fifteen. Spiracular sclerite large, spiracle near its dorsal margin; about twenty-three setae present. Epipleural sclerite slightly smaller than spiracular sclerite, subtriangular, setae about thirteen. Prehypopleural sclerite somewhat flattened, divided into anterior and posterior sections by distinct furrow. Anterior part with three small setae, posterior part devoid of setae. Posthypopleural sclerite ovoid, bearing about ten setae. Eusternum bearing a large flat, unpaired sclerite with from seven to eleven very small sclerites on each side. Large sclerite with about ten setae, smaller ones with a single seta each. Sternellum bearing pair of small sclerites each with one seta.

CERVICAL MEMBRANE (Fig. 10, cvm).- As in G. externa cervical membrane, bearing no sclerites, separated from prothoracic eusternum, especially with larva at rest, by a deep fold.

LEGS (Fig. 11).- Legs five-jointed as in G. externa, heavily

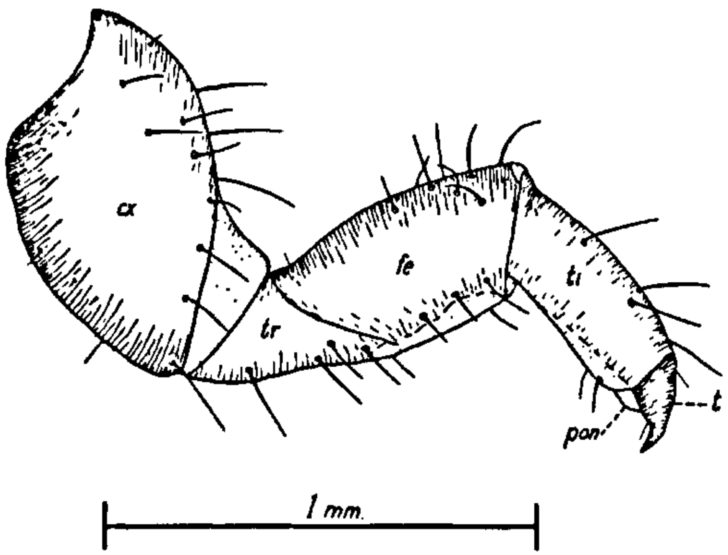

Fig. 11

Entomoscelis adonidis

Left leg of metathorax. Anterior view

cx, coxa
fe, femur
pon, paronychial appendix
t, tarsungulus
ti, tibia
tr, trochanter

chitinized exteriorly and dorsally; large membranous area present distally on coxa, small membrane exposed dorsally on distal margin of femur, ventral areas of femur and tibia so thinly chitinized as to appear membranous; membranous paronychial appendix small. Tarsungulus larger than that of G. externa, claw shorter than conical basal part; trochanter extended along ventral surface of femur little more than half way; other parts as in G. externa.

Setae somewhat irregular, though usually arranged as in figure 11. About eighteen present on coxa; six on ventral region of trochanter; nine dorsally and seven sub-ventrally on femur; regularly five on dorsal area of tibia and about three ventrally; one minute seta always present ventrad of claw on end of basal part of tarsungulus.

Abdomen

AMBULATORY WARTS.- Membrane caudad to paired sclerites of sternellum on fifth, sixth and seventh abdominal segments projecting ventrally to form ambulatory warts (Fig. 7, amb). [Fletcher (1892) named these "pseudopodia" and considered them to be extensile, but the writer has observed nothing to indicate that they are retractile. These ambulatory warts, as well as the sucking surface of the tenth segment, are used in locomotion]

FIRST SIX SEGMENTS (Fig. 12,A & B).- Ambulatory warts described above, segments otherwise practically identical. Dorsum as in metathorax except four to five sclerites present on prescutum and the six of scutum in straight line. Parascutal area not marked off from dorsum; two elliptical sclerites present. Spiracle in a small sclerite adjacent to ventral margin

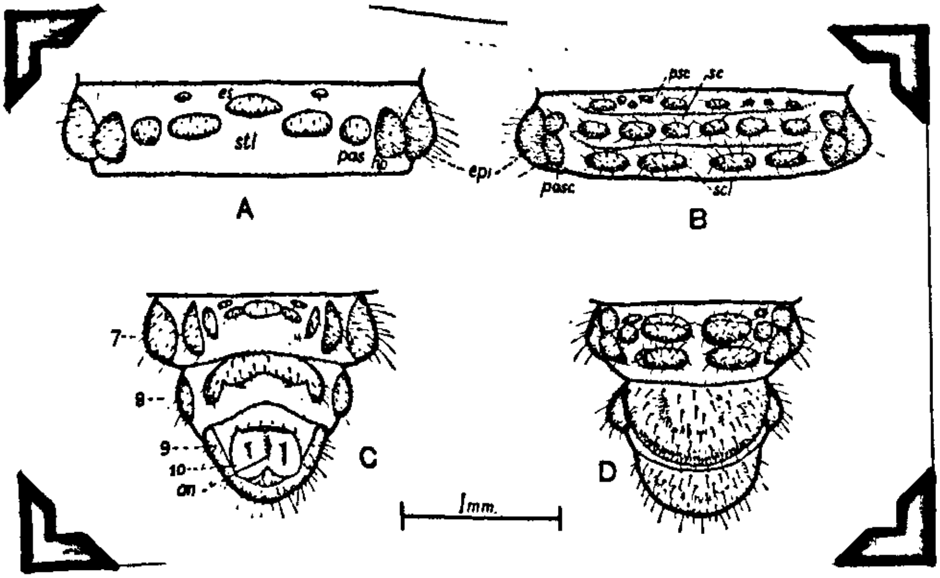

Fig. 12

Entomoscelis adonidis

A. Typical abdominal segment. Ventral view
B. Typical abdominal segment. Dorsal view
C. Abdominal segments 7-10. Ventral view
D. Abdominal segments 7-10. Dorsal view

an, anus
epi, epipleurum
es, eusternum
hp, hypopleurum
pas, parasternum
pasc, parascutum
psc, prescutum
sc, scutum
scl, scutellum
stl, sternellum

of anterior elliptical sclerite. Epipleural area defined dorsally by incomplete dorso-lateral sulcus and ventrally by strongly marked ventro-lateral sulcus; sclerite large, ovoid to elliptical. No lines of demarkation between eusternal, sternellar, parasternal, and hypopleural areas. Hypopleural sclerite ovoid, parasternal dome-shaped, sternellar (one on each side) flat, elongate; eusternum with irregular unpaired sclerite, and pair of small sclerites anterior to sternellar pair.

Setae of dorsal sclerites similar in number to those on dorsum of metathorax. Anterior parascutal with about ten, posterior with fifteen, epipleural sclerite twenty-seven, hypopleural thirteen, parasternal seven, sternellar eight, eusternal unpaired sclerite with about ten, paired with single seta.

SEVENTH SEGMENT (Fig. 12, C and D).- Sulci, except ventro-lateral sulcus, indistinct. All sclerites of prescutum and scutum, except outer pair of each, fused into pair of large sclerites irregular in surface and outline. Sclerites of scutellum also fused to form elongate pair one on each side of median line. Sclerites of parascutal, pleural, and sternal areas as in segment six, except pair of sternellar sclerites touching unpaired sclerite of eusternum. Paired sclerites of eusternum bearing more than one seta; number of setae on other ventral sclerites reduced.

EIGHTH SEGMENT (Fig. 12, C and D).- Dorsal and parascutal areas covered except on the posterior margin by large chitinous shield; spiracle opening in ventrally extended lobe of the shield. Epipleural sclerite as in other segments but smaller. Hypopleural and all sternal sclerites fused, hypopleural sclerites indicated by caudal notch on line of fusion, the whole sclerité ventro-caudally inclined as a result of the slight protrusiòn of membranous area somewhat after the manner of the ambulatory warts of the three preceding segments.

Setae of dorsal shield spaced as on epicranium. About fourteen setae present on central portion of ventral sclerite and seven on hypopleural part; epipleural sclerite bearing about twenty.

NINTH SEGMENT (Fig. 12, C and D).- Dorsal and lateral areas covered by pygidial shield which extends beyond tenth segment. Setae about as numerous as on epicranium; row of six present near posterior margin of ventral region.

TENTH SEGMENT (Fig. 12, C and D).- Plane of anal opening subparallel to ventral surface of segment nine; whole tenth segment dorsally obscured by pygidial shield. Anus (an) opening between two lateral sucking lobes. About six small depressed lobes dorsad of lateral lobes. A very few minute setae scattered over lateral areas but no sclerites present.

SPIRACLES.- Spiracle of eighth abdominal segment little more than half of diameter of those of other segments, spiracles otherwise as in *G. externa*.

Second and Third Instars

The larvae of the second and third instars do not differ appreciably,except in size, from the mature larva, though in the second instar the chitin of the sclerites is slightly thinner and the setae less numerous, there being only one on each side of the unpaired sclerite of the eusternum. Only one or two of the smaller sclerites are present on the eusterna of the thorax in the second instar (seven to eleven present in fourth instar). Larvae on reaching the second instar measure, on the average, about 2.8 mm. in length and 0.89 mm. across the head capsule. On reaching the third instar their length is about 4.2 mm. and the head capsule about 1.39 mm. in width.

First Instar

The larvae at the time of hatching are about 1.7 mm. long and the head capsule measures 0.6 mm. in width. The head is wider than the body which gradually tapers toward the posterior end, the ninth and tenth segments being quite narrow. The antennae are quite conspicuous, being, by comparison with the size of the head, much longer than in the fourth instar. The general colour (as soon as pigmentation is complete) is much the same as in the other instars, but the chitin of the legs and mouth parts is comparatively thin. The sclerites are present as in the second instar, but those of the prescutum are poorly defined and are without setae. On the mesothoracic and metathoracic segments the posterior sclerite of the more dorsal pair of the alar region is quite heavily chitinized and usually is raised to a small point at the centre. The same sclerite on the first abdominal segment is similarly constructed. These are the "egg-bursters" mentioned by Paterson (1931). The unpaired eusternal sclerite of the other instars is sometimes divided into two sclerites in the abdominal segments of the first instar, while the interior sclerite of the scutum is fused with the one adjacent to it on the same side.

The setae are greatly reduced in number except on the mouth parts, but they are constructed the same as in the other instars. The

Fig. 13

Entomoscelis adonidis

The eggs.

lunate sclerite on the alar region of the thorax bears three setae. The larger sclerite on the alar region of the abdomen, and all the epipleural sclerites, carry two setae. There are no setae at all on the parasternal sclerite, but the sternellar sclerite bears three. The remaining sclerites each bear a single seta.

The Adult

Fletcher (1892) describes the adult as "a showy scarlet beetle with three black stripes down its back, a black patch on the collar and black legs; two-thirds the size of the Colorado Potato-beetle, but narrower in outline." The original description is contained in a work of Pallas(1771).

The Egg

The egg of adonidis measures about 1.65 mm. in length by 0.7 mm. in diameter. The colour is burnt sienna and the surface reticulated as in externa.

(c) The Taxonomic Positions of externa and adonidis

The morphological differences between the larvae of externa and adonidis are so obvious as to make comparison unnecessary. Paterson (1931) distinguishes the two subfamilies as follows:-

Galerucinae.- Antenna one-jointed; maxillary palpus short, sometimes two-jointed; one pair of ocelli; clypeo-labral suture curved; no tormae; no egg-bursters; lacinia present.

Chrysomelinae.- Antenna and maxillary palpus three-jointed; six ocelli; clypeo-labral suture straight; tormae present; lacinia absent.

Böving and Craighead (1931) raise Galerucinae to family status, separating it from Chrysomelidae on the number of ocelli and number of antennal joints in the larva. Attention is here drawn to the fact that Paterson did not study larvae of the genus Galeruca. The species externa and all those described by Böving (1929) have four-jointed maxillary palpi, a character which, considering Paterson's description of the group, would place Galeruca outside its true subfamily (or family).

Böving (1929) has described three species of Galeruca. These are tanaceti L., laticollis Sahl., and pomonae Scop. He distinguishes pomonae from tanaceti by the much shorter setae in the former species, and by the greater distance on the abdominal segments of the exterior prescutal sclerite from the interior sclerite of the same region. The main differences between these two species and externa are (1) the fusion in the latter species of the interior sclerites of the scuto-scutellar region of the abdomen and the fusion of the interior pair of the prescutum of the eighth abdominal segment, and (2) the dorsal sclerites do not project to a distance equal to the length of the diameter at the base. The European species laticollis is very similar to externa in this respect, but its exterior prescutal sclerite is separated from the interior sclerite by a distance equal the length of the diameter of the exterior sclerite, while in externa this distance is equal to from two to three times the diameter of the exterior sclerite. Another difference between these two species, though it cannot always be used, is the regular occurrence of five setae on the lacinia of laticollis, there being from three to five present on the lacinia of externa, most frequently four. In addition to these morphological differences and the fact that the one species is found only in Europe and the other in North America, externa has never been recorded as feeding on any other than cruciferous plants while laticollis has never been observed feeding on any members of that group.

Both Paterson (1931) and Böving (1929) are agreed that the presence of three transverse tergal regions appears to be a more generalized condition than a lesser division of that area, and Paterson arranges the two groups according to that character, Galerucinae preceding Chrysomelinae. Böving and Craighead, however, place the family Chrysomelidae before Galerucidae, which, considering adonidis alone, would seem a more natural arrangement. Within the subfamily Chrysomelinae, adonidis comes between Timarchini and Chrysomelini. Paterson identifies Chrysomelini by the presence of eight pairs of abdominal spiracles, five mandibular teeth, indistinct palpigers, at least three pairs of egg-bursters, and the four larval instars. She defines Timarchini as having seven pairs of abdominal spiracles, ill defined mandibular teeth, and distinct palpigers. There is no mention of the number of larval instars. E. adonidis has distinct palpigers as in Timarchini, and though there are eight abdominal spiracles, the eighth pair are only about half the size of the preceding seven. There are five mandibular teeth, but the first is so poorly defined as to be almost indistinguishable. There are three pairs of egg-bursters and four larval instars as in Chrysomelini.

(d) Characters for Rapid Identification of the Larvae

For hasty examination, either in the field or laboratory, with field lens or binocular, the following comparison is very useful for distinguishing between externa and adonidis:-

First Instar

E. adonidis	G. externa
Antennae conspicuous--0.16 mm.	Antennae inconspicuous --0.055 mm.
Hairs about the same length in both the anterior and posterior rows--0.2 to 0.24 mm.	Hairs longer in the posterior row--0.18 to 0.28 mm.
Hairs either straight, or curved slightly backward.	Hairs of anterior row of abdominal segments, and all thoracic hairs, curved slightly forward; hairs of the posterior rows of the abdominal segments curved backward.

Second Instar

E. adonidis	G. externa
Antennae 0.16 mm.	Antennae 0.083 mm.
Hairs straight on dorsal and lateral areas, not over 0.16 mm.	Hairs more or less curved, usually backward, some as long as 0.33 mm.
Tubercles numerous, a suggestion of three rows per segment.	Tubercles more widely spaced, definitely two rows per segment.

Third and Fourth Instars

E. adonidis	G. externa
Antennae 0.27 mm.	Antennae 0.138 mm.
Hairs not visible when magnified 6 X	Rosette of hairs visible when magnified 6 X.
Hairs difficult to see when magnified.	Hairs visible to the naked eye, particularly in sunlight.
Hairs nearly perpendicular--0.11 to 0.22 mm.	Some hairs procumbent--0.28 to 0,47 mm.
Three rows of tubercles per segment, making them very close together.	Two rows of tubercles per segment, tubercles more widely spaced.

SEASONAL LIFE-HISTORY

The only really satisfactory seasonal data on either species were obtained on externa during the 1931 season. Observations were made at least every week, supplemented by intermittent observations at more frequent intérvals under more favourable weather conditions. The larvae were studied on the first-mentioned group of A. saxatile in area A (see section on ecology, page 8), and on nine plants of Arabis in area B. Later in the season a few larvae were recorded on the other two clumps of A. saxatile in area A. The observations on adults were made in Area C, except the three recorded for July 1-7 in Area A. The records are tabulated on the next page.

Table I

Seasonal Observations on G. externa

Date	Time	Temp. Shade	Temp. Sun	Weather notes, etc.	1st	2nd	3rd	Adult	Eggs
Apr. 28				No larvae were discovered during a search of two and one-half hours.					
May 5				The week from Apr. 28 to May 5 was very cold and dull, and no search was made.					
" 12	12.00 noon	63	74	Bright sunshine	3				
" 12	2.15 p.m.	69		" "	7				
" 12	4.15 p.m.	70	74	" "	1				
" 13	8.15 a.m.	55	57	" and calm.	7				
" 13	10.38 a.m.	—	—	" calm; hot.	26	1			
" 13	12.07 p.m.	80	88	" " "	1 - only A. saxatile examined.				
" 14	7.45 a.m.	66	68	Calm; cloudless; smoky	2 - " " " "				
" 15	5.47 p.m.	—	—	- -	20	16	All plants except A. saxatile		
" 18	6.15 a.m.	48		Dull; brisk and cool breeze.	6	15	1		
" 27	6.45 a.m.	—	—	" ; light " " "	1	11	4		
June 2	5.45 a.m.	39	—	Bright; very light breeze.	—	—	5		
" 10	7.50 a.m.	49	—	Slightly hazy; strong breeze.	—	—	3		
" 17	6.30 a.m.	67	—	Bright; brisk breeze.			1	(Adult in lab. June 16)	
" 20	10.45 a.m.	—	—	Many clouds; hot; light cool breeze.	—	—	2	3 (males)	
" 22	12.00 noon	70	—	Clear; rather stiff breeze.	—	—	—	2 (females)	
" 25	6.15 a.m.	57	—	Bright; no wind.	—	—	2	0	
" 25	2.30 p.m.	88	—	Slight haze; light breeze	—	—	—	32	
" 29	Searched in area C at 6.30 a.m., 11.30 a.m., and 3 p.m. but saw no beetles.								

Table I (Con'd)

July 1	6.30 a.m.	Searched in area A and in area C but found nothing.							
" 7	11.30 a.m.	60	—	Bright; windy. (None in area C)	In area A			1	(male)
" 7	2.30 p.m.	63	—	" " (" " " ")	" " B			1	(male)
" 7	2.30 p.m.	63	—	" " (" " " ")	" " B			1	(female)
Aug.10	11.40 a.m.	65	—	" ; slight breeze.	—	—	—	1	
(Two to three surveys were made between July 7 and Aug. 10 but nothing was seen until Aug. 10)									
" 12	10.45 a.m.	70		Smoky.	—	—	—	1	
" 14	11.00 a.m.	68		Bright.	—	—	—	2	
" 18	10.25 a.m.	77		Bright; breezy	—	—	—	4	
" 19	4.12 p.m.	85		Cloudy; breezy - - - - - - - - - - - The first copulation observed - - - -					
" 20	8.40 a.m.	70		Bright; slight breeze.	—	—	—	14	
" 21	6.40 p.m.	85	89	Hazy; almost calm.	—	—	—	83	
" 26	8.30 a.m.	64	73	Bright; good breeze.	—	—	—	116	
" 28	12.00 noon	57	64	A few clouds; moderate wind.	—	—	—	29	
Sept.3	3.00 p.m.	66	78	More clouds; less wind.	—	—	—	15	
" 5		—	—	- - - - - - - - - - - - - -	—	—	—	—	2 groups
" 10	4.00 p.m.	63	68	Cloudy.	—	—	—	13	
" 26	10.00 a.m.	44	60	Bright; slight breeze.	—	—	—	6	

Adults were not seen by the writer or any other members of the staff after Sept. 26 in casual observations, but no more extensive surveys were made after that date because of the small numbers present then.

In addition to the seasonal data given above, it is interesting to note that eggs (from 1930 adults) stored in the unheated insectary from Oct. 18 to January, were brought into the laboratory Jan. 4 and began hatching Jan. 7. They became adults Feb. 10 and had completed aestivation by March 30.

Glancing over table I it will be observed that eggs had hatched by May 12. By June 20 practically all larvae had gone into the soil to pupate, except a few belated individuals in more shaded areas that lagged behind the others (see explanation preceding the table). Adults were first observed in the field June 20, though they began emerging in the laboratory June 16. However, the fact that one of the three first observed in the field was not fully pigmented at that time indicated that emergence was just beginning. Aestivation began shortly after June 25, but a few beetles were observed in the more shaded areas July 7. The next date of importance is Aug. 10 when adults were first observed after aestivation. The greatest number of adults was present Aug. 26. Eggs were first discovered in the field Sept. 5, but they, being difficult to find, were not likely the first laid.

During 1929 and 1930 the seasonal observations were made partly in the field and partly from laboratory material. Regular surveys were not maintained, hence the date given is not necessarily the time of earliest appearance. The table given below includes all the data obtained.

Table II

Seasonal Data on G. externa and E. adonidis, 1928-1931

Species	Galeruca externa				Entomoscelis adonidis			
Year	1928	1929	1930	1931	1928	1929	1930	1931
First larvae seen	—	May 8	May 19	May 12	—	May 2*	Apr. 29*	Apr. 29*
Last mature larvae	—	June 21	June 1	June 20	—	June 5*	—	June 6*
Adults first seen	July 9	(July 4 (June 16*	—	(June 20 (June 16*	—	June 11*	—	June 16*
Adults disappeared	—	—	—	June 25	—	—	—	June 23*
Adults active again	Aug. 22*	Sept. 1	Sept.12	Augl 10	Aug. 16	Aug. 22	Aug. 22	(Aug. 5* (Aug. 18
Eggs discovered	—	Sept.10	—	Sept. 5	Aug. 24*	—	—	Aug. 10*

* Laboratory data.

The outstanding features of the above records may be summarized for both species as follows:-

1. There is only one generation per year.

2. For most of the eggs the incubation period, or more truly the diapause, is fully eight months long.

3. Larvae can be found in shaded locations until after the first appearance of the adults about June 20, though the greater number disappear, of course, early in June.

4. The adults feed for a short period after their emergence from the pupal stage and then go into aestivation, remaining there until near the middle of August when they again become active.

5. Sexual activities are not begun until shortly after the second appearance of the adults.

6. The adults remain active until late September or early October, but their activity is greatly reduced by that time.

7. Judging by the data available, the seasonal life-history of <u>adonidis</u> conforms very closely to that of <u>externa</u>, <u>adonidis</u> appearing a few days earlier in the spring and developing a little more rapidly.

STADIA (SENS. LAT.)

The Normal Stadia

Although the preceding section gives some idea as to the length of the larval period, incubation period, and other phases of the two species, it gives no details regarding the rate of development of the larvae. For this reason this separate section is devoted to the presentation of data on larval instars. It might be well to mention here that eggs of both species can be caused to hatch during the autumn by either desiccation or freezing and subsequent moistening and warming. The possible applicability of this autumn hatching is discussed later in the section on control by weather.

In determining the time spent in their various instars the larvae of both species were reared individually in cylindrical vials measuring 1" by 5". The vials were plugged with cotton batting and kept in the laboratory at ordinary room temperatures. No soil was used. The vials were placed in an upright position in a shallow cardboard box. Blossoms and leaves of Draba nemorosa and Alyssum saxatile were used for feeding externa, only the former plant being used for adonidis. The results for externa are given in detail in table III on the next page, and those for adonidis in table IV immediately following it.

Table III

Time Required to Rear Larvae of *C. externa* During May & June, 1929.

No.	Date Collected	Length of 1st stadia	Changed to 2nd instar	Length of 2nd stadia	Changed to 3rd instar	Length of 3rd stadia
(a)	May 8	—	May 16	9	May 25	10
(b)	"	—	" 14	10	" 24	11
(c)	"	—	" 14	10	" 24	11
(d)	"	—	" 16	9	" 25	11
(e)	"	—	" 16	9	" 25	12
(f)	Date hatched May 9, 2 p.m.	12.5	" 22	9	" 31	—
(g)	" "	12.5	" 22	9	" 31	—
(h)	" "	14.5	" 24	12	June 5	7
Average		13.156 days		9.625 days		10.33 days

No.	Entered pre-pupal stage	Length of pre-pupal stage	Entered pupal stage	Length of pupal stage	Adult emerged
(a)	June 4	7	June 11	9	June 20
(b)	" 4	7	" 11	9	" 20
(c)	" 4	6	" 10	9	" 19
(d)	" 5	6	" 11	9	" 20
(e)	" 6	—	—	—	—
(f)	—	—	" 15	10	" 25
(g)	—	—	" 16	8	" 24
(h)	" 12	5	" 17	12	" 29
Average		6.2 days		9.4 days	

Table IV

Time Required to Rear Larvae of <u>E. adonidis</u> During May & June, 1931.

No. of larva	6	8	9	10	11	12	7	Average
Date hatched	May 11	May 12	May 12	May 12	May 14	May 17	May 17	
Date moulted	May 17	May 17	May 18	May 17	May 22	May 26	May 26	
Time in 1st instar	6 days	5 days	6 days	5 days	8 days	9 days	9 days	6.9 days
Date moulted	May 22	May 23	May 26	May 23	May 26	May 28	May 29	
Time in 2nd instar	5 days	6 days	8 days	6 days	4 days	2 days	3 days	4.9 days
Date moulted	May 26	May 27	May 29	May 26	June 1	June 2	June 2	
Time in 3rd instar	4 days	4 days	3 days	3 days	6 days	5 days	4 days	4.1 days
Date feeding discontinued	June 1	June 1	June 3	June 3	June 6	June 6	June 6	
Time in 4th instar	6 days	5 days	5 days	8 days	5 days	4 days	4 days	5.3 days
Date of final moult	June 6	June 9	June 9	June 10	June 12	June 12	June 14	
Time in pre-pupal stage	5 days	8 days	6 days	7 days	6 days	6 days	8 days	6.6 days
Date adult emerged	June 16	June 17	June 17	June 18	June 18	June 18	June 20	
Time in pupal stage	10 days	8 days	8 days	8 days	6 days	6 days	6 days	7.4 days
Total of larval period	21 days	20 days	22 days	22 days	23 days	20 days	20 days	21.1 days
Total time from hatching to adult stage	36 days	36 days	36 days	37 days	35 days	32 days	34 days	35.1 days
Sex ----------	Male	Male	Male	Female	Female	Male	Male	

The Effect of Temperature on the Stadia

In a series of rearing experiments at different temperatures, a variety of results was obtained. These results are tabulated for comparison in table V. The conditions under which the larvae were reared in each instance were as follows:-

G. externa, Exp. I, 1929.- See the explanation preceding table III.

G. externa, Exp. I, 1931. - This figure was obtained from an examination of the field data given in table I.

G. externa, Exp. II, 1931. - The same as for adonidis, experiment VI, series B, below.

E. adonidis, Exp. I, 1929. - One specimen reared in the same manner as those of experiment II, 1931, below.

E. adonidis, Exp. I, 1930.- The three larvae of this experiment were reared during Nov. and Dec. 1930. The vials were placed in a horizontal position in a shallow cardboard box. During a total of about four hours almost daily they were kept with the near side of the box 2" beyong the end of the bulb of a desk lamp the hood of which was 9" from the surface of the desk pad. The bulb was 100W. power. At all other times the vials were kept at ordinary room temperature, not influenced by the heat and light of the desk lamp. The humidity was not controlled, hence it would be relatively low at all times especially when extra heat was applied. Only three out of seven larvae survived. Young turnip leaves were used as food. Otherwise the method was the same as in experiment VIB,1931, below.

E. adonidis, Exp. II, 1931.- See the explanation preceding table III.

E. adonidis, Exp. VI, 1931.- This experiment was conducted for the purpose of discovering any influence that heat alone, or heat and light combined, might have on the rate of development of larvae and pupae of adonidis. Three series of larvae were reared, each series being kept under a condition of heat and light differing to some extent from the other two. One series (A) was kept in almost complete darkness; another series (B) was subjected at intervals to a fairly high intensity of light; the check series (C) was placed, during the day, on a shelf near a window and shaded from artificial light, but during the hours of natural darkness it was placed where artificial light would not reach it. As for temperatures, series A and B were both subjected nearly every day to a temperature of between 91°F. and 93°F. for one or two periods of approximately two hours each, the total time being 44.25 hours. To obtain the desired heat it was necessary to conduct a fairly lengthy test of temperatures within the vials, the vials being placed at varying distances from the source of heat. The details of these tests, as well as the complete results of each experiment, are contained in the writer's report to the Dominion Entomologist at Ottawa.

Each larva was kept in a vial 5" x1" placed horizontally in a very low cardboard box. Cotton batting plugs about one inch in length and wrapped with cheese cloth, were used to prevent the escape of the larva. Leaves of seedling turnips, cut into discs 18 mm. in diameter, were fed to the larvae morning and evening. No soil or any other material was put into the vials except a small piece of paper bearing the experimental number of the larva. Additional small pieces of folded paper were placed in the vials when the larva was ready to enter the prepupal stage.

Table V

Average Results of Rearing Experiments with Larvae of Both Species.

(Results given in days)

Species	*Galeruca externa* Say			*Entomoscelis adonidis* (Pallas)					
Year	1929	1931		1929	1930	1931			
Exp. No.	I	I	II	I	I	II	VI	VI	VI
Series							A	B	C
Days 1st instar	13.17	---	6.0	10.0	5.2	6.9	4.5	4.0	4.0
" 2nd "	9.62	---	4.0	6.0	2.0	4.9	3.0	3.0	3.0
" 3rd "	10.33	---	9.0	5.0	2.2	4.1	3.0	3.0	3.0
" 4th "	---	---	---	7.0	3.5	5.3	5.5	4.0	4.0
" pre-pupae	6.20	---	3.5	6.0	4.2	6.6	3.0	4.0	4.0
" pupae	9.40	---	8.5	6.0	6.2	7.4	6.5	7.0	6.5
Larval period	33.12	---	19.0	28.0	11.7	21.1	16.0	14.0	14.0
Total "	48.72	39.0	31.0	40.0	22.0	35.1	25.5	25.0	24.5

Discussion of Rearing Experiments

COMPARISON OF THE TWO SPECIES IN REGARD TO TIME.- From the results given in table V above, it is obvious that larvae of <u>externa</u> require more time to reach maturity than those of <u>adonidis</u>. Of those reared at the normal time of the year, in an unheated laboratory, larvae of <u>externa</u> averaged nearly 49 days (1929, I) while those of <u>adonidis</u> required 40 days (1929, I) and 35 days (1931, II). Of those reared during the winter at either constant room temperatures, or room temperatures with occasional period of increased heat, <u>adonidis</u> required from 22 to 25.5 days and <u>externa</u> 31 days. These results are fairly conclusive as to the difference in time requirements of the two species.

DIFFERENCES DUE TO SEX.- As indicated in table IV and supported by the detailed results of all the other experiments, there is no reason for believing that the rate of development is influenced by sex.

INFLUENCE OF TEMPERATURES ON <u>adonidis</u>.- On examining the results of the experiments on the larvae in series A, B, and C, it is at once apparent that the periods of increased heat and light did not cause any appreciable difference in the rate of development of these larvae. Just why there should have been no difference between the check series (C) and the series subjected to increased heat (series A and B) is only a matter of conjecture. There are three possible explanations.- (1) The periods of increased heat and light may have been of insufficient duration to give significant results. (2) The higher temperatures may have caused a condition of stupor during which time both activity and metabolism were arrested. (3) The food of series C remained fresh for a longer period than that of the other two. Of these possible explanations the first seems unsatisfactory because the rate of mortality was considerably higher in A and B, especially the latter, than in C, thus indicating that the higher temperatures were having no small influence on the larvae. Considering the second hypothesis, it is a question whether or not such comparatively moderate temperatures would so influence <u>adonidis</u>, though field observations on <u>externa</u> have shown that that species is inactive at temperatures little higher than those in the vials. If such was the case, then, the inactivity during the highest temperatures would counteract the more rapid development during the time that the heat was increasing from, and decreasing to, room temperature. This explanation may be correct, but it is certain that the drying of the food would contribute largely to counteracting any beneficial effects that the higher temperatures might have.

In the other two experiments (I of 1930, and II of 1931) there are slight differences in rate of development that suggest an approach to the optimum condition. Those of experiment I, Nov. and Dec., 1930, developed more rapidly by an average of three days than those of series A, B, and C, while those of experiment II, May and June, 1931, required an average of ten days longer. It has already been pointed out, in the introduction to table III, that those reared during May and June were kept in the unheated laboratory where the temperature frequently fell well below normal room temperature. The temperatures to which those of Nov. and Dec. were subjected at intervals are believed to have been lower than those used in A and B, though the degree of heat was not actually measured. This being the case we have a gradation of temperatures up to a point where development averaged 22 days and then taking longer (25.5 days) as the temperature was increased. These results are not conclusive, of course, but they do suggest an optimum growth temperature slightly above 70°F. They indicate, too, that during warm springs the rate of development would be correspondingly greater. It would be of considerable interest to repeat the experiment on a larger scale, with more uniform gradations of temperature, and with the humidity controlled.

AESTIVATION AND OVIPOSITION

Aestivation

Indications that adults of externa go through an aestivation period were first observed by the writer in 1929. Adults during that year were seen in the field July 4, and no more were discovered until September 1. It was not until 1931, however, that the occurrence of aestivation was definitely established, as shown in table I. An examination of this table shows that the aestivation period was approximately 42 days in length, beginning about June 29 and ending Aug. 10. Adults from larvae reared indoors were also inactive for several weeks. A single male reared during Jan., 1931, emerged

Feb. 5, began feeding the next day, and ceased feeding about Feb. 14. It was inactive from then until it resumed feeding March 31, a period of 44 days. Adults from larvae reared during May and June, 1931, and retained in the laboratory, aestivated for about 34 days.

Crosby and Leonard (1918) claim an aestigation period for adonidis in Austria and suggest that a study of its habits in Canada might reveal a similar period of quiescence. Not having had an outbreak at hand for observation, the writer has not proved definitely that such is the case. However, reports received by Mr. King of the Saskatoon laboratory and Professor Mitchener of the Manitoba Agricultural College, during years when several reports were made, indicate that the beetles probably do aestivate. These reports came in as follows:-

To Professor Mitchener -

1922	June 11, 1 report	Aug. 3 to Sept. 30, 4 reports
1927	July 4, 1 "	Aug. 21, 1 report
1928	June and July, no report	Aug. 12 - 25, 5 reports
1930	June 27, 1 report	

To Mr. King -

1925	June 18 and 22, 2 reports	July 25, 1 report
1927	June 19 - July 2, 4 "	July 18 - Aug. 30, 9 reports

The above data are insufficient to prove definitely the occurrence of an aestivation period, but the gaps between the earlier and later reports suggest it rather strongly. It is true that the reports to Mr. King in 1927 leave a gap of only 16 days, but these reports were received from widely separated points, differing sufficiently in soils and climate to cause differences in the time of appearance and disappearance of the beetles.

Adults of adonidis in captivity undoubtedly passed through a period of aestivation. Those from larvae reared during Nov. and Dec., and held constantly at room temperatures aestivated for approximately 45 days. Adults from larvae reared in the unheated laboratory during the normal season were inactive from June 30 to Aug. 5, a period of 37 days.

From the above data, assuming that the habits of captive specimens of adonidis closely approximate field habits (and such an assumption seems to be justified), it appears that beetles of both species spend very nearly the same length of time in aestivation.

Just what purpose aestivation serves has not been established. Mating, however, has never been observed prior to aestivation. It is evident, then, that sexual maturity is not reached until near the end of that period. Mr. King has suggested, also, that this adaptation prevents the beginning of a second generation most of which would perish before reaching maturity.

Oviposition

The act of oviposition has never been observed by the writer for either externa or adonidis, but eggs of the former have been discovered in the field occasionally. They are laid most commonly just below the surface of the soil. Loose soil, around the bases of food plants and among fallen stems, etc., seems to be favoured most. The writer has never seen eggs of adonidis in the field, but in rearing cages they were usually found under bits of wood, cardboard, and leaves. Fletcher (1892) quotes one of his reporters to the effect that they were found "on the surface of the ground under some dried up radishes......

under almost any slight covering, and sometimes only under a shade that did not amount to an actual covering. I also found them a quarter of an inch or so under the surface of the ground by the roots of rough-leaved turnips and radishes." They are usually laid in loose masses of from 1 to 40 eggs, while externa females laid theirs in compact masses of about 40 eggs, from which the individual eggs could be separated only with difficulty.

Some idea of the rate of oviposition and number of eggs laid by females of externa can be obtained by a study of table VI below. Five five-ounce, glass-topped salve tins and a quart size glass fruit jar were used as oviposition cages. About half an inch of cotton batting was placed in the bottom of the sealer and a small quantity of soil, about a quarter of an inch altogether, was sifted onto it through a 40 mesh screen. Soil was similarly sifted into the bottom of the salve tins, and small cardboard trestles were used to hold up the leaf so that the beetles could feed in a more natural position. Three or four small squares of cardboard were dopped into each cage to assist the beetles in turning over when they fell on their backs. The food, Lepidium apetalum, was changed daily.

Table VI

Eggs Laid by Adults of G. externa During Autumn, 1931.

Cage No.	1	2	3	4	5	6
Date collected						
Aug. 23	0	0	0	0	0	0
" 25	34	40	38	0	0	0
" 31	41	39	44	0	0	0
Sept. 4	0	46	42	0	0	0
" 8	108	45	83	102	46	47
" 10	58	52	0	0	0	0
" 12	57	48	46	57	57	47
" 15	0	0	44	0	53	0
" 19	106	45	45	115	48	Below
" 23	0	0	39	58	53	136
" 26	55	---	0	0	50	0
" 29	54	---	0	0	0	44
Oct. 2	55	---	---	105	---	0
" 26	---	---	---	43	---	92
Total	568	315	381	480	307	366
Daily Ave.	14.2	11.7	12.3	9.2	14.0	7.0
Average of totals for group - 402.8 eggs.						

The females died as follows:- No. 1, about Oct. 26, No.2, Sept. 24; No. 3, Sept. 30; No. 4, about Oct. 26; No. 5, Oct. 2; No. 7, about Oct. 26.

Adults of adonidis were caged at the same time as those of externa. Pairs 1 and 3 were in 5-oz. salve tins; female No. 2 had four males with her; cage No. 4 was a quart glass sealer and contained one pair. Young turnip leaves were used as food. In all other particulars the beetles were treated in the same manner as those of externa. The results are given in detail below.

Table VII

Eggs Laid by Adults of E. adonidis During Autumn, 1931

Cage No.	1	2	3	4
Before Aug. 12	193	0	0	0
" " 15	151	0	0	0
" " 18	144	0	0	0
" " 20	97	36	0	0
" " 25	Female dead	141	0	75
" " 31	---	74	0	112
" Sept. 4	---	0	0	106
" " 8	---	0	0	3
" " 10	---	Female dead, male destroyed	76	Female dead
" " 12	---	---	0	---
" " 15	---	---	111	---
" " 19	---	---	151	---
" " 23	---	---	123	---
" " 26	---	---	69	---
" " 29	---	---	122	---
" Oct. 2	---	---	63	---
" " 26	---	---	0 Female dead	---
Totals	585	251	715	296

Another female adonidis, one from a larva reared during Nov. and Dec. 1930, began ovipositing Feb. 12 and continued until Mar. 31, laying an average of 20.6 eggs per day, a total of 991. The first male died Mar. 25 and another was put in with her immediately. The female died April 6.

With such high fecundity it is little wonder that outbreaks, especially of adonidis, come almost from no apparent source. Why these outbreaks are not maintained is a question that is discussed in the section on control by weather.

FOOD AND HABITS OF FEEDING

Food Plants

The plants listed below are those upon which larvae or adults of adonidis or externa have been observed by either Mr. Criddle or the writer.

Alyssum saxatile -- externa only

Arabis brachycarpa -- " "

Arabis holboellii -- " "

Brassica oleracea -- adonidis only

Brassica oleracea caulo-rapa -- adonidis only

Brassica rapa -- both species

Capsella bursa-pastoris -- adonidis only

Crambe pinnatifida -- " "

Draba caroliniana -- externa only

Draba memorosa -- both species

Erysimum asperum -- externa only

Erysimum cheiranthoides -- adonidis only

Lepidium apetalum -- ~~adonidis~~ externa only

Matthiola incana -- externa only

Raphanus sativus -- adonidis only

Sisymbrium altissimum -- externa only

This list is not likely complete, but at the present time the writer is not prepared to say that the species feed on all cruciferous plants. An extract from the original notes of A. P. Arnason of the Saskatoon laboratory reads, — "Mr. Pavlochenko reports this species" (adults of <u>adonidis</u>) "very thick on the wormseed mustards (and a few on the tumbling mustards) in his weed experimental plots (Saskatoon U.), but not on the following plants that were growing in close proximity to the wormseed mustard: Hare's ear, ball, false flax, and other mustards." In some reports to the Saskatoon laboratory <u>adonidis</u> has been said to feed on potatoes and nasturtium, while other reports mention this species as feeding on "everything but potatoes." Lettuce has been included as a food plant in reports to Professor Mitchener, and Crosby and Leonard (1918) have listed beans for the same species. Of these four (nasturtium, potatoes, beans,and lettuce) the writer is of the opinion that the last three, at least, have not been used as food by either <u>adonidis</u> or <u>externa</u>. Fletcher (1892) says that "the insect takes its name <u>adonidis</u> from one of its food plants in Europe, <u>Adonis</u> <u>autumnalis</u>, a plant belonging to the Ranunculaceae." He is of the opinion that it may feed in Western Canada on members of that group as well as Cruciferae. His prediction has apparently not been fulfilled.

In 1928 the writer found adults of <u>externa</u> collected on a turnip plant of second year growth with well-developed flowers and seed pods. Since that time it has frequently been observed that both adults and larvae, of <u>externa</u> at least, seem to prefer the blossoms of the plants as food.

Feeding Habits of Larvae in the Field (G. externa)

A series of field observations on larvae of externa were made during several days for the purpose of securing information that might be used as a guide in applying artificial control.

The larvae were present in area B described on page ~~20~~ 9. Nine plants were selected and marked and the number of larvae feeding on them was recorded at the intervals given in the table VIII. In making the observations it was necessary to approach the plants slowly else the larvae dropped to the ground and could not be recorded correctly. Neither could the plant be touched because of the same tendency of the larvae, hence the examination was made only by sight, from as low an angle as possible. All larvae seen were recorded in the notes, but only those either feeding or moving about actively are included in the totals of table VIII. During observations of very early morning and late evening it was necessary to use a flashlight, but this did not seem to disturb the larvae. The hour given in the table is that at which observations were begun.

The temperatures given in the fourth column of the table are those recorded by the thermograph which was mounted in a regular Stevenson temperature screen about fourteen feet south of the laboratory. Those in the third column, for May 15-18 inclusive, were taken in the field at a point three inches south and half way down the six inch stem of plant No.7; but those beginning May 19 were taken from the standard thermometer of the Treesbank meteorological station, located about 100 yards from, and several feet higher than, the thermograph.

Table VIII

Time and Temperatures at Which Larvae of *G. externa* Feed.

Date	Hour	Temps.		Weather Notes	Instars 1st	2nd	3rd	Total
May 15	4.40 a.m.	59	60	Slight breeze; cloudless; sun not risen.	3	4		7
"	5.40 "	57	55	" " ; " ; but smoky.	9	6		15
"	7.05 "	62	57	Strong cool breeze; cloudless, smoky.	9	4		13
"	8.18 "	66	59	" " " ; " , " .	9	3		12
"	9.07 "	66	61	" " " ; light, broken clouds.	7	2		9
"	10.07 "	71	60	" " " ; cloudless but smoky.	4	4		8
"	11.09 "	74	62	" " " ; " " "	3	5		8
"	12.03 p.m.	77	65	" " " ; " " "	1	1	1	3
"	1.05 "	76	66	" " " ; " " "	2	2		4
"	2.05 "	77	68	" " " ; light film of clouds.	3	6		9
"	3.03 "	78	68	" " " ; cloudless but smoky.	3	2		5
"	4.06 "	77	67	" " " ; " " "	3	4		7
"	4.58 "	72	66	Slightly less " ; " " "	2	5		7
"	5.55 "	68	65	Somewhat more smoke than before.	7	3		10
"	6.51 "	63	62	Breeze still fairly strong; still smoky.	3	5	1	9
"	8.07 "	55	56	Still a breeze; sun almost set.	2	6		8
May 16	3.55 a.m.	28	28	Cloudless; no air movement.				0
"	5.40 "	34	30	Sun well up; smoky; no wind; small amount of white frost on some plants.				0
"	7.31 "	54	39	Bright; light, cool breeze.	3	6	2	11
"	8.51 "	63	51	" " , " "	3	8		11
"	12.17 p.m.	76	61	" " , " "	1			1
May 17	9.53 a.m.	56	56	Light rain falling-has been raining 20".				0
"	2.10 p.m.	67	60	Strong breeze; sun shining through thin clouds.				0
"	4.50 "	67	66	" " ; " " " " " "		4	1	5
"	8.20 "	58	59	Sun down; light breeze; very thin clouds.		12		12
"	9.30 "	58	54	Light breeze; cloudy; twilight.				0
May 18	6.15 a.m.	48		Brisk, cool breeze; thick, broken clouds; smoke.	1	8	1	10

Table VIII (Con'd)

May 18	9.05 a.m.	60		Sun just visible through film of clouds and dust; occasional gusts of wind.	2	3		5
"	2.47 p.m.	68		Just a breeze; less dust; sun and occasional clouds.	1	2	1	4
"	4.18 "	60	61	Wind almost nil; heavy, broken clouds.	1	8	1	10
" 19	3.35 "			A heavy snow (6-8") fell during the night. By 3.35p.m. the meteorological thermometer registered 38.5^{o}F., but the sun was shining. There was still some snow. A 2nd instar and a 3rd instar larvae were feeding on No.10.		1	1	2
May 31	3.45 a.m.	49	46	Clear but dark; light but rather chilly breeze.		1	1	1
"	5.00 "	49	46	Temperature was one degree lower during previous hour; sun just up; breeze stronger.	~~3~~	~~12~~1	12	13
"	6.00 "	57	50	Still a brisk breeze; bright.		1	10	11
"	7.15 "	58	58	Light breez e; slightly cloudy.			7	7
"	11.15 "	84	75	" " ; slight cloud haze; hot sun.			1	1
"	1.30 p"m.	86	82	" " ; " " " ; " " ; soil hot under foot. An unusual number of larvae inactive on the plant in shade of leaves, stem, etc.; soil probably too hot.			1	1
"	8.10 "	68	65	Light, cool breeze; sun near setting.			4	4
"	9.45 "	63	59	" " " ; still a little light.			3	3
June 1	5.30 a.m.	51	44	Slight air movement; slightly hazy; a little dew.			12	12
"	8.15 "	60	56	" " " ; cloudy, but sun still visible			3	3
"	12.20 p.m.	79	77	Brisk breeze; sun shining warmly through slight haze.				0
"	5.45 "	79	78	Light " ; " bright and rather hot.			1	1
"	7.30 "	72	70	" " ; sun nearly set; pleasantly cool.		1	4	5
"	10.00 "	59	59	Very slight breeze; clear and almost dark.			2	2
June 2	3.45 a.m.	43	38	" " " ; clear; moon still well up.				0
"	5.45 "	39	39	" " " ; bright sunshine.			5	5
"	9.15 "	73	72	More breeze; bright but a few clouds about			1	1

An examination of table VIII shows that during nearly every day most of the feeding was done in the early morning; during days of average weather there was less feeding at noon and another period of nearly optimum feeding during the late afternoon; during very warm days a period of dormancy occurred from late morning until late afternoon, following which fairly heavy feeding occurred again.

In studying the temperatures in the table it must be borne in mind that beginning May 19 those in the third column are shade temperatures, and they are from five to fifteen degrees lower than the temperature in the sun, the difference depending on the time of day. The sun temperature for optimum morning feeding is close to 60°F., the evening temperature seeming to be slightly higher. The range is from 48°F. to 86°F., though very little feeding was done after the thermometer (in the sun) registered 75°.

The inactivity of the larvae during the very early morning and late evening indicate that they do not feed during the night. Only one larva (May 31) was observed feeding before daylight, but a few sometimes continued feeding at dusk (June 1 especially). Temperature probably plays the greatest part in influencing the time of feeding, but on June 1 the temperatures were more nearly optimum at 10.00 p.m. than during the early morning, yet twelve larvae were feeding at 5.30 a.m. as compared with two at 10.00 p.m., suggesting that light intensity has some influence. It is likely, too, that the condition of the larva, as regards quantity of food previously consumed, is another cause of the early morning voracity and late evening inactivity.

Larvae seek shelter under the plant when either rain or snow is falling, but begin feeding again as soon as there is sufficient warmth (May 17 and 19). They also crawl down to the soil under the basal leaves when temperatures are too high for feeding, though the excessive heat during May 31 apparently forced them to forsake the hot soil for the shade of the stem and upper leaves of the plant. Wind and dust (May 18) seem to cause delayed feeding even when temperatures are optimum.

Feeding Habits of Adults in the Field (*G. externa*)

Field observations similar to those above were also made on the adults, during the autumn, in area C described on page 9. Only the adults in sight were counted, even though searching for a few minutes under *Taraxacum*, *Artemisia*, etc., usually revealed considerable numbers. They are recorded as "feeding" or "crawling" or "inactive," but those feeding and crawling are considered as practically in the same category because those crawling were usually either searching for food or else had just ceased feeding. Care had to be taken not to move abruptly, otherwise the beetles ceased feeding and dropped to the ground.

Temperatures were recorded from three thermometers.— The shade temperature is that of the thermograph at the laboratory. The sun temperature was obtained from a Tycos pocket thermometer hung vertically with the bulb six inches from the surface of the ground. A soil thermometer lay horizontally with the bulb half buried in the soil among the stems of a clump of grass. Some of the temperature records are tabulated in auxiliary table IX to facilitate examination.

Table IX

Time and Temperatures at Which Adults of G. externa Feed.

Date	Hour	Temperatures Shade	Sun	Soil	Weather Notes	Active Adults Feeding	Crawling	Total	Inactive
Aug. 21	6.55 a.m.	64	73	73	Clear; calm; warm.	2		2	
	7.15 "	65	77	74	" ; slight breeze.	4		4	
	7.30 "	66	78	75	" ; " "	5		5	
	7.45 "	67	81	76	" ; " "	7		7	
	8.00 "	70	82	78	" ; " "	12	1	13	
	8.15 "	73	83	79	" ; " "	15	18	33	
	8.30 "	75	87	81	" ; breeze increased slighty	20	15	35	
	8.45 "	77	88	82	" ; " the same.	17	9	26	
	9.00 "	79	88	83	" ; " " "	16	13	29	
	9.15 "	81	90	85	" ; " " "	10	6	16	
	9.30 "	82	91	86	" ; " " "	8	5	13	
	9.45 "	84	94	87	" ; " " "	3		3	
	10.00 "	86	95	89	" ; " " "	2		2	
	11.00 "	89	99	93	" ; " " "	1	1	2	
	12.00 noon	95	102	98	" ; " " "			0	3
	1.00 p.m.	98	103	103	" ; strong breeze.			0	9
	1.05 "	The soil thermometer placed in soil surface with no vegetation near it rose to 124°F. by 1.13 o'clock (104° in sun air). Then brought down to 100° in moist cloth and placed under dump of Artemisia where two beetles were hiding, inactive, it rose to 102° (sun = 106°) by 1.20. Back in original grass clump it rose to 103° by 1.25 (sun = 105°).							
	2.00 p.m.	98	104	104	Bright; strong breeze.			0	14
	3.00 "	99	104	104	" ; " "			0	16
	4.00 "	98	103	104	" ; " "			0	15
	5.00 "	95	102	101	Slightly hazy; breeze moderate.	3		3	10
	5.30 "	95	97	97	Quite hazy ; " "	8	7	15	2

Table IX 'Con'd)

Aug. 21	6.00 p.m.	91	96	97	Quite hazy; breeze moderate	19	12	31	1
	6.40 "	85	89	91	" " ; almost calm.	56	27	83	0
	7.30 "	79	78	86	Sun just setting; calm.	14	9	23	
Aug. 26	7.00 a.m.	57	64	65	Hazy; light breeze.	22	2	24	
	8.00 "	66	72	73	Brighter; light breeze.	73	28	101	
	8.30 "	64	73	75	The same; stronger breeze.	89	27	116	
	9.00 "	66	78	79	The same; breeze the same.	73	21	94	
	9.30 "	72	79	81	Still somewhat hazy; strong breeze.	48	9	57	
	10.00 "	73	82	82	" " " ;mod. breeze.	26	8	34	
	11.00 "	76	86	87	" " " ; " "	2	1	3	
	12.00 noon	81	91	90	" " " ;strong "	6		6	3
	2.00 p.m.	87	93	92	" " " ; windy.		-	0	7
	3.00 "	85	89	91	Very hazy; moderate breeze.			0	9
	4.00 "	86	88	89	" " " "	28	8	36	6
	4.30 "	84	87	87	Clouds over sun; moderate "	42	30	72	0
	5.00 "	83	85	85	" " " ; " "	62	15	77	
	5.30 "	81	84	84	" " " ; " "	59	32	91	
	6.00 "	80	83	83	" " " ; " "	70	38	108	
	6.30 "	80	83	82	Sun shining through haze; slight breeze.	59	39	98	
	7.00 "	79	81	80	Sun behind cloud, almost set; slight breeze.	71	22	93	
	8.00 "	75	77	77	Almost dark; slight breeze.	22	8	30	

Table IX (Con'd)

Sept.10	7.00 a.m.	45	50	53	Bright; heavy dew; light breeze.			0
	8.00 "	48	54	56	" ; " " ; " "	1		1
	9.00 "	52	60	61	A few clouds about. " "	2	2	4
	10.00 "	56	62	63	Mostly cloudy; light breeze.	5	5	10
	11.00 "	58	63	65	" " ; " "	2	7	9
					Two dead ones discovered at this time.			
	12.00 noon	60	65	69	Same weather.	3	3	6
	2.00 p.m.	61	65	68	" "	2	1	3
	3.00 "	64	68	69	" " , but some sunshine dur. hour.	4	3	7
	4.00 "	63	68	68	Continuously cloudy;	7	6	13
	5.00 "	63	67	68	Still cloudy; moderate breeze.	4	1	5
	6.00 "				More dead beetles discovered.			
		62	62	63	Sun momentarily; moderate breeze	3	3	6
	7.00 "	60 ~~48~~	62 ~~54~~	63 ~~49~~	Still cloudy; almost dusk. ~~Cloudy; free~~		3	3

Auxiliary Table IX

Comparison of Sun, Shade, and Soil Temperatures.

Time / Date		7.00	8.00	9.00	10.00	11.00	12.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00
Aug. 21	Shade	64	70	79	84	89	95	98	98	99	98	95	91	85	76
	Soil	73	78	83	89	93	98	103	104	104.5	104	101	97	91.5	--
	Sun	73	82	88	95	99	102	103	104	104	103	102	96	89	--
Aug. 26	Shade	57	61	67	73	76	81	85	86	86	86	83	80	79	75
	Soil	65	73	79	81	87	90	--	92	91	89	85	83	80	77
	Sun	64	72	78	79	86	91	--	93	89	88	85	83	81	77
Aug. 28	Shade	42	46	50	54	57	59	61	63	62	59	58	59	54	49
	Soil	--	--	--	54	56	58	60	61	59	59	--	--	--	--
	Sun	--	--	--	60	62	64	69	69	64	63	--	--	--	--
Sept. 3	Shade	48	51	56	61	64	65	67	67	66	68	68	66	61	55
	Soil	55	59	62	67	68	72	--	75	72	72	71	68	--	--
	Sun	55	59	66	70	72	76	--	74	78	72	73	70	--	--
Sept. 10	Shade	45	48	52	56	58	60	61	61	64	63	63	62	60	58
	Soil	53	56	61	63	65	69	--	68	69	68	68	66	63	--
	Sun	50	54	60	62	63	65	--	65	68	68	67	66	62	--

Though the observations were limited, table IX shows fairly clearly the reaction of <u>externa</u> adults to various temperatures. The range of feeding is very great, being from 48° in the shade and 54° in the sun to 95°in the shade and 102°in the sun. On hot days (Aug. 21 and 26) especially, two periods of feeding occurred. The first feeding was done during the morning, reaching a maximum between 8 and 9 o'clock when the thermometer registered between 73° and 87° F. in the sun. The second period of feeding took place at slightly higher temperatures during late afternoon or early evening. Between these two periods of feeding the beetles either crawled under <u>Taraxacum</u>, <u>Artemisia</u>, and other plants, or climbed the shady side of blades of grass, etc., and remained inactive. Most of the beetles ceased feeding and began seeking shelter when the morning temperature reached about 88°F. in the sun, or a little lower, and a few began climbing into the shade of the plant just before the soil reached 100°. On cooler days a few beetles could be observed feeding throughout the day (Sept. 3 and Sept. 10), and on Aug. 28 the greater number were feeding at noon, a complete reversal of the activity observed on hot days.

The tendency to leave the soil and seek shade temperatures is probably due to the excessive heat at the soil surface. On bright days the air warmed more rapidly than the soil (Aug. 21, Aug. 28, and Sept. 3), but the soil temperature eventually rose above that of the air, except on Aug. 28 which had been preceded on the previous evening by almost an inch of rain. On Aug. 21, when many beetles were inactive in the shade of the plants, the temperature in the sun was 104°F., the surface of the bare soil was 124°, and the soil in the original location of the thermometer was 103°.

That the shade temperatures were lower than any of these is shown in auxiliary table IX. However, the soil under Artemisia, etc., must not have been too uncomfortable because only a small proportion of beetles climbed the grass blades.

Feeding Periods of Larvae in the Laboratory.

Crosby and Leonard (1918), Lochhead (1919), and Essig (1926), state that the larvae of adonidis are nocturnal feeders. Since it was impossible to learn the field habits of this species the writer observed and recorded the habits of a few specimens under somewhat unnatural conditions. Larvae of externa were reared at the same time under identical conditions for purposes of deduction, it being hoped that the habits of adonidis in the laboratory might indicate probable field activity.

The larvae of both species were placed in the Stevenson temperature screen in glass-topped salve tins containing moist soil. The food was changed at the intervals shown in the table below, externa being fed on leaves of Arabis and adonidis on leaves of Draba. The quantity eaten was carefully estimated and recorded in square millimeters. The first instar larvae were fed individually in two-ounce salve tins for a period of four days; the larvae of the final instars, reared nearly two weeks later than those of the first instar, were all caged in the same five-ounce salve tin (one tin per species) and fed for three days only. The first instar larvae of both species were the same age, but those of externa moulted early in the experiment while those of adonidis remained in the first instar throughout.

It was occasionally impossible to change the food at the desired hour, and at such times it became necessary to apportion the quantity for each period according to the amount of time. These calculations did not interfere in the least as far as direction of the results were concerned, though they may have slightly reduced the degree of significance. Only the totals of the experiment are given here.

It is of significance that the temperature never rose above 80°F. except during the first day of the experiment, and only once did it fall below 32°. The average temperature for the first instar larvae was a little above 60° and for the older larvae it was almost 70°F. In every instance the greatest total heat occurred between 12 noon and 4 p.m., the maximum being reached at, or maintained until, 4 p.m.

Table X

Feeding Period of Larvae of *G. externa* and *E. adonidis* in the Laboratory.

Period No.	1	2	3	4	5
Time	4 a.m.- 8 a.m.	8 a.m.- 12 noon	12 noon - 4 p.m.	4 p.m.- 10 p.m.	10 p.m. -4 a.m.
G. externa, 1st inst.	13.3	36.5	9.6	22.8	7.2
E. adonidis, " "	2.6	7.7	9.2	11.7	3.3
G. externa, 3rd "	93.6	271.4	230.0	560.0	23.0
E. adonidis, 4th "	172.7	292.3	320.0	445.0	93.0

Reducing the figures of period No. 4 by one-third to make the interval correspond to that of periods 1-3, there is little of significance left except that none of the larvae fed to any appreciable extent during the hours of darkness. It appears, too, though the experiment was too small to be conclusive, that the larvae of adonidis feed under very nearly, if not altogether, the same conditions as those of externa.

That the newly hatched larvae of both species quickly respond to light was observed while measuring larvae under a microscope, the light stimulus coming alternately from the window and the desk lamp. The larvae were first observed to move steadily in the direction of the desk lamp. When the lamp was turned off, however, the larvae almost immediately turned in the direction of the window. This led the writer to try a few experiments at night with only a single source of light stimulus, all surfaces reflecting white light having been removed from the desk. The larvae were placed on a sheet of paper which was pivoted around, to change the direction of the source of light, at intervals of three minutes. The larvae invariably, with but momentary hesitation, turned and again crawled toward the light. Heat may have formed part of the attraction, but there was certainly no heat coming from the window in the first instance, light evidently being the only stimulus.

Quantity of Food Required to Bring Larvae of E. adonidis to Maturity

The quantity of food eaten by the larvae of experiment VI, 1931 (see table V), was estimated and recorded for use in calculating possible injury to crops. The results, however, suggested an interesting problem deserving of future study. By using a uniform disc of food 18 mm. in diameter (or 254.57 sq. mm. in area), the estimates of food consumed could be made with a fair degree of accuracy. The totals were as follows:

The three larvae of series A,- 301.0, 300.8, and 339.9 sq. cm.

The one larvae of series B,- 297.0 sq. cm.

The two larvae of series C,- 370.4 and 378.9 sq. cm.

The third larva of series A consumed somewhat more than the larva of series B, but the first two ate almost exactly the same amount as that of series B. Those of series C, however, each ate very nearly the same amount, that quantity being considerably more than the quantities consumed in the other two series.

An examination of table V shows that these differences were certainly not due to differennes in time required to mature. Nor could they be attributed to sex, all being males except No. 1 of series C. However, the differences do exist in this one small experiment, and it would be interesting to discover (1) if they would occur, and be significant, in an experiment on a larger scale, and (2) what the effect would be on the sexual activities in the different groups.

CONTROL

None of the publications deal with control measures for _externa_, and no data have been discovered showing the results secured by the methods advocated for the control of _adonidis_. The following spray is recommended by several authors for the control of the turnip beetle:-

2 lbs. arsenate of lead

40 gallons of water

4 lbs. of soap if used on cabbages or cauliflower.

In addition to this, King (1927) recommends the destruction of cruciferous weeds, thus reducing the food supply.

1. Natural Control

Disease

Three larvae of _externa_ in the third instar were found dead in their cages June 13, 1931. The bodies were soft and considerable liquifaction had occurred. Death was believed to have been caused by bacterial organisms. Another larva of the same species was apparently killed by a fungous disease, the body being covered by white fungous growths. Mr. Criddle has informed the writer that in 1913 the larvae of both species were greatly reduced in number by a fungous disease.

Parasites

Dr. Paterson (1931) reared Braconid parasites of the species

Sigalphus luteipes Thoms. from an adult female of Tamarcha tenebricosa, but neither parasites nor predators have been observed to attack either externa or adonidis.

Weather

(a) Entomoscelis adonidis

The occurrence of fluctuations in the population of adonidis was discussed in the section on the economic importance of the species. Considering the enormous number of eggs laid, it is not difficult to understand an outbreak occurring, under favourable conditions, from the progeny of a very few pairs of adults. Just why they should disappear so suddenly is more difficult to explain. Fletcher (1892) includes in his report a passage from the "Annales de la Société Entomologique de France" which states that in Europe, where the beetle does serious injury to rape, droughts favour its multiplication and cold rainy weather greatly retard it. In Western Canada drought appears to have the opposite effect.— As previously discussed there were very few outbreaks reported to entomological authorities in the dry year of 1930, and only one outbreak (Therien, Alta.) was reported during the still dryer year of 1931. How drought may decrease the numbers is suggested in the two paragraphs below.

LARVAL MORTALITY.- The rate of larval mortality in artificial rearing is high (60%-80%), but it was especially high in experiment VI, 1931, series A and B, where the larvae were subjected to increased heat. The extreme heat and lack of humidity, as well as rapid drying of food and possible injury due to handling, must certainly increase the rate of mortality. There is every likelihood that considerable mortality occurs during warm dry springs owing to the failure of the larvae to reach food and shelter before being affected by the dryness and heat.

AUTUMN HATCHING OF EGGS.- Though the larval mortality in the spring may reduce the population to some extent, autumn hatching and subsequent death of the larva, or death of the embryo by desiccation, is more likely to seriously affect the numbers present the following season.

Eggs laid during September, 1930, were allowed to dry until November and then were moistened. There were 105 eggs in the group and 17 of them hatched. The others soon grew mouldy and were discarded. Other groups were dried for different intervals up to five weeks during the fall of 1931. Only those dried for five weeks had any percentage of hatch (12%), the total time from oviposition to hatching being 43 days.

The results of these experiments suggest a possible cause of the disappearance of the infestation at Dropmore. As previously mentioned, the adults were numerous during the autumn of 1929 and again in 1930. The autumn of 1930 was extremely dry for over a month. A heavy fall of snow came Oct. 16 and this was followed by another period of mild weather. The period of drought was of sufficient length to cause hatching of the eggs when the moisture came during October. A similar hatching was made possible by the warm weather of February. Either of these periods may have caused the disappearance of the beetles. The crops affected were largely perennial and the soil was seldom disturbed by cultivation.

(b) Galeruca externa

Aweme is the only place that externa has been reported as being present in large numbers, being first mentioned in 1905. During the writer's observations, 1928 to 1931, the beetles were present every year, gradually increasing until they were fairly numerous in a few small areas in 1931. This evident stability of numbers may be partly explained by the smaller number of eggs laid and a greater larval mortality counteracted by a greater resistance of the eggs to conditions tending to cause autumn hatching. A few larvae were reared to maturity during the winter of 1930-31, but the eggs had to be frozen before they would hatch and the larvae were reared with difficulty, the mortality being extremely high.

2. Artificial Control

The Effect of Poisoned Dusts on Larvae

The poisoned dust commonly recommended for the potato beetle, 1 part Paris green to 19 parts hydrated lime, was found ineffective against larvae of externa and adonidis.

Four larvae of each species were placed in two-ounce, glass-topped salve tins, one larva to a tin. An area of two square yards in which plants of Arabis brachycarpa were growing was marked off and dusted with the poison at the rate recommended, 50 lbs. per acre. Leaves were removed from the dusted plants and placed in the tins with the larvae. The larvae fed, but they avoided the more heavily dusted parts. Only one larva died, the others seemingly remaining perfectly healthy.

The Effect of Poisoned Dusts on Adults of G. externa

No adults of adonidis being available, an experiment was conducted on adults of externa for the purpose of obtaining information as to the strength of poison, type of carrier, and rate of spreading of the dust, necessary to bring about a kill of 100%.

<u>Nos. of tins and strength and quantity of poison</u>.-

1. One part poison to 19 of lime at 50 lbs. per acre.
2. " " " " 19 " " " 100 " " "
3. Two parts " " 18 " " " 50 " " "
4. " " " " 18 " " " 100 " " "
5. (Check) Lime alone " 100 " " "

6-10. A repetition of the above with flour in place of lime.

<u>Beetles</u>.- The beetles were collected four days previous to poisoning and were all kept in one 2 qt. fruit jar containing soddy soil and a screen top. The day before poisoning, 3♀'s and 2 males were placed in each of ten 5-oz., glass-topped salve tins and given turnip leaves which they ate quite readily.

<u>Procedure</u>.- The food, both turnip leaves and pepper-grass, was poisoned Sept. 2 soon after 8.00 a.m. Plots, 3 sq. yrd. in area, were marked out on a well-clipped tennis court. A piece of turnip leaf and another of pepper-grass was laid on each plot and the dust screened on through a 40 mesh screen. The poisoned food was left there for 48 hours and then removed and fresh leaves put in in their stead.

Table XI

Adults Killed by Various Poisoned Dusts.

No.	After 48 hours	After 72 hours	After 144 hours	Total
1	0	0	1♂ & 2♀; other 2 quite active.	3
2	0	1♂	1♀; other 2♀ active but crippled; other ♂ quite active.	2
3	1♂	2♀	0; two left are crippled.	3
4	0	1♂ & 2♀	1♂; other ♀ slightly crippled.	4
5	0	0	0	0
6	0	1♂	3♀; other ♂ quite active.	4
7	2♂	0	3♀	5
8	0	0	3♀ & 1♂; other ♂ active.	4
9	0	1♂ & 2♀	0; 1♀ crippled; ♂ active.	3
10	0	0	0	0

The results as far as rate of spreading and strength of poison are concerned, are too varied to be conclusive. The flour, however, gave slightly better results than the lime, though the latter was also reasonably effective.

If beetles are sufficiently congregated during the early summer attack, poisoning at that time would prevent oviposition. It appears, however, from table I, that the greater concentration occurs during the autumn, and if control measures are applied early in August, the numbers could be greatly decreased before many eggs had been laid. Dusting is best done during early morning of a warm day when the beetles are just beginning to feed and while the dew is present to hold the particles of dust. Spraying could be done as effectively during the late afternoon on a day when the temperature (in the shade) has reached a maximum of at least 80°F.

The Effect of Plowing Down the Eggs of E. adonidis.

In a laboratory experiment, larvae from eggs buried even as deeply as one inch did not reach the surface of the soil. Eggs of adonidis, 200 in number, were placed in each of seven tins and left in a well-protected location in the woods throughout the winter. In the first tin the eggs were barely covered with soil, in the next they were buried to a depth of one inch and successively one inch deeper in each of the remaining five tines. The next spring larvae hatched from 171 of the eggs buried at the surface, but no larvae were discovered in any of the other tins. In a similar experiment using eggs of the red-backed cutworm, Euxoa ochrogaster Gn., the newly hatched cutworms reached the surface from a depth of four inches. It may be concluded, then, that thoroughly plowing down the eggs of adonidis would result in the destruction of practically all of either the eggs or the larvae. This may be the major reason for the disappearance of infestations from fields in which annual crops are grown.

SUMMARY

From the studies made by the writer the following facts have been established:-

1. Crops usually are not attacked by the larvae, this stage appearing very early in May and reaching maturity early in June, adonidis preceding externa by just a few days. Two attacks are made by the adults, one for a short period during the latter part of June and the other beginning about Aug. 10 and continuing until late autumn. The beetles aestivate for a period of about five weeks between these two attacks, sexual maturity being reached during that time. Eggs are laid during the autumn but do not hatch until spring, this diapause lasting fully eight months for the first eggs laid. There is, as the above statements indicate, only one generation per year.

2. Outbreaks of adonidis appear with little warning and disappear as quickly. The increase is easily accounted for under favourable conditions by the enormous fecundity, the females being capable of laying over 500 eggs, one in captivity having laid 991. The rapid decrease may be due to the hatching or desiccation of eggs during the autumn, aided by larval mortality in the spring. Autumn or very early spring plowing is believed to account for the checking of many outbreaks.

3. The population of externa changes much more gradually. This appears to be due to the smaller number of eggs laid (an average of about 400) and to a greater rate of larval mortality counteracted by a greater resistance of the eggs to conditions causing autumn hatching.

4. Only cruciferous crops are attacked. Both larvae and adults of externa have two periods of feeding on warm days, one during early morning and another during late afternoon. Temperatures of feeding are given. Larvae of adonidis are believed to feed at about the same temperatures as externa. They are NOT nocturnal feeders.

5. A poisoned dust composed of 1 part Paris green to 19 parts flour, spread at the rate of 100 lbs. per acre, was the most effective against adults of externa. Lime can be used instead of flour but is slightly less effective. A dust of 1 part Paris green to 19 parts lime at 50 lbs. per acre was ineffective against larvae of both species, the lime appearing to act as a deterrent.

6. A fungous disease destroyed a larva of externa in the laboratory in 1931 and three died of a bacterial disease. Predators and parasites have not been observed to attack either species.

7. There are three larval instars of externa and four of adonidis. The larvae of both species are figured and described in detail. The larvae of the two species are very similar in superficial appearance, but can easily be distinguished by a comparison of the antennae, those of externa being one-jointed and those of adonidis three-jointed. Other important differences between these species and other more closely allied species are included in the section on morphology.

LITERATURE CITED

Blatchley, W. S. (1910). "An Illustrated Catalogue of the Coleoptera or Beetles (Exclusive of the Rhyncophora) Known to Occur in Indiana." Nature Publishing Co., Indianapolis.

Böving, Adam G. (1929). "Beetle Larvae of the Subfamily Galerucinae." No. 2773; Proc. U. S. Nat. Mus. Vol. 75, Art. 2, pp.1-48.

Böving, Adam G., and Craighead, F. C. (1931). "An Illustrated Synopsis of the Principal Larval Forms of the Order Coleoptera." Brooklyn Entomological Society, Brooklyn, N. C.

Crosby, C. R., and Leonard, M. D. (1918). "Manual of Vegetable-garden Insects." MacMillan Co., N. Y. p. 50.

Criddle, Norman (1911). "Insect Pests of Manitoba." Jour. Ec. Ent. Vol. IV, p. 24.

Criddle, Norman (1913). "Insect Pests of Southern Manitoba." Ann. Rep. Ent. Soc. Ont., Toronto, Ont. pp. 97-100.

Essig, E. O. (1926). "Insects of Western North America." MacMillan Co. N. Y. p. 469.

Fletcher, J. (1892). "Report of the Entomologist and Botanist." Dom. of Can. Dept. of Agric., Ottawa, Ont. p. 10.

Fletcher, J. (1906). "Report of the Entomologist and Botanist for the Year 1905." Can. Exp. Farm Bul. 52, p. 42.

Gibson, Arthur (1921). "Common Garden Insects and Their Control." Dom. of Can. Dept. of Agric. Ent. Branch Cir. 9.

Gibson, Arthur (1923). "Report of the Dominion Entomologist for 1919 and 1920." Can. Dept. of Agric. Ent. Branch, Ottawa.

Hewitt, C. G. (1915). "Report of the Dominion Entomologist for the Year Ending March 31, 1915." Dom. of Can. Dept. of Agric. Ottawa. 40 pp.

Hewitt, C. G. (1917). "Report of the Dominion Entomologist for the Year Ending March 31, 1916." Dom. of Can. Dept. of Agric.,Ottawa. 70 pp.

Hewitt, C. G. (1920). "Report of the Dominion Entomologist and Consulting Zoologist for the Two Years Ending March 31, 1919." Dom. of Can. Dept. of Agric., Ottawa, 25 pp.

King, K. M. (1927). "The Red Turnip Beetle (Entomoscelis adonidis (Pallas)." Dom. Ent. Lab., Saskatoon, Sask. Leaflet 21.

Leng, C. W. (1920). "Catalogue of the Coleoptera of America, North of Mexico." John D. Sherman, Jr., Mt. Vernon, N.Y.

Lochhead, William (1919). "Class Book of Economic Entomology.". P. Blakiston' Son & Co., Philadelphia, Pa. p. 309.

MacGillivray, Alex. D. (1923). "External Insect-anatomy." Scarab Company, Urbana, Ill.

Pallas, Peter S. (1771). "Reisen durch verschiedene Provinzen des Russischen Reiches." I, 463, St. Petersburg.

Paterson, Nellie F. (1921). "Studies on the Chrysomelidae.-Part II. The Bionomics and Comparative Morphology of the Early Stages of Certain Chrysomelidae (Coleoptera, Phytophaga)." Enc. of the Zool. Soc. of London, Sept. 30.

Say, Thomas (1824). "Academy of Natural Sciences of Philadelphia." III, 222, Philadelphia.

Smith, John, B. (1906). "Explanation of Terms Used in Entomology." Brooklyn Entomological Society, Brooklyn, N. Y.

Treherne, R. C. (1914). "Report from Vancouver District: Insects Economically Important in the Lower Fraser Valley." Proc. Ent. Soc. Br. Columbia, No. 4, N.S., pp. 19-33.