AN INTENSIVE STUDY OF THE GRASSHOPPERS OF ECONOMIC IMPORTANCE AT ARNAUD, MANITOBA, 1935.

BY

H. W. MOORE, B.Sc. (Man. 1934)

ZOOLOGY DEPARTMENT, UNIVERSITY OF MANITOBA.

A THESIS PRESENTED TO THE COMMITTEE OF POST GRADUATE STUDIES OF THE UNIVERSITY OF MANITOBA, IN CANDIDACY FOR THE DEGREE OF MASTER OF SCIENCE, APRIL, 1936.

The data presented in this paper were accumulated while employed by the Entomological Branch, Department of Agriculture, during the summer of 1935 and have been officially released for thesis purposes.

AN INTENSIVE STUDY OF THE GRASSHOPPERS OF ECONOMIC IMPORTANCE AT ARNAUD, MANITOBA, 1935.

CONTENTS

AN INTENSIVE STUDY OF THE GRASSHOPPERS OF ECONOMIC IMPORTANCE AT ARNAUD, MANITOBA, 1935.*

1. Review of the development of the conception of grasshopper study centres.

Arnaud is the first study centre established in Manitoba by the Entomological Branch, Dominion Department of Agriculture, to be dealt with as an "Intensive Study of the Economic Grasshoppers in Typical Environments Where Previous Extensive Outbreaks Have Been Known to Occur." (Leth. Rept. 1935, App. 4, P. 1). The study of this area is intended to be a long term project, the object of which is "To determine the biological and environmental factors which cause extensive fluctuations in grasshopper populations, with the practical end in view of being able to predict or prevent grasshopper outbreaks." (Leth. Rept. 1935, App. 4, P. 19).

It has long been recognized that grasshoppers must not be forgotten in the years of least abundance of their kind. In the report on the Rocky Mountain Locust in 1877 it was pointed out that "The danger is that during periods of immunity, indifference and forgetfulness intervene until another sweeping disaster takes us by surprise." (Rept. U.S. Ent. Comm. 1877, P. 420). The danger of this lack of preparation was well known to the late Mr. Norman Criddle who drew the following tentative conclusion from his work in Manitoba (1919-'23 outbreak) and British Columbia (1925), "There is a reason to suspect that the Camnula outbreak might have been prevented had the insects been attacked on their egg beds when they first showed indications of multiplying and it is believed that they may yet be checked by careful attention to the breeding areas in spring and autumn." (Criddle 1925, P. 6). If for no other reason than the above recognized fact the study of such an area during the next few years of dwindling grasshopper populations would be of great value from the economic standpoint of forecasting the next outbreak. There are, however, other reasons, both practical and scientific, for this intensive study. (Leth. Rept. 1935).

Mr. Norman Criddle, who was the first professional Entomologist to be present during a grasshopper outbreak in Manitoba (1919) stated that "Any evidence which would help us to forecast grasshopper outbreaks, or to anticipate and check them before they become acute, is worth considering and on this account the recently announciated "phase" theory,

*The data presented in this paper was accumulated while employed by the Entomological Branch, Department of Agriculture, during the summer of 1935 and has been officially released for thesis purposes.

should secure the careful consideration of American entomologists." (Criddle 1933). The present study at Arnaud is one of the phases of research established in view of the two above theories.

Prof. B. P. Uvarov's "Phase Theory" 1921 (Uvarov 1921, 1928) points out that Locusts, or gregarious Acrididae, are a phase in the development of the species and that the opposite phase of the same species is a solitary grasshopper. It is possible, according to this theory, for the gregarious phase, or the true Locust, to give rise to the solitary phase, or the true grasshopper. All intermediate stages of the transition from one phase to the other may occur. This gives rise to the "Phase Theory of Periodicity". According to this theory periodicity in Locusts is due to ideal conditions for the extremely rapid increase of the locust on their breeding grounds and the consequent development of the gregarious phase, due to crowding and perhaps other factors. (Faure 1932, 1933). These true locusts migrate to other areas normally free from the pest. In this invaded area the following year the progeny of these locusts may develop into the gregarious phase and fly out of the area or, if the conditions are not suitable for the perpetuation of the species, the locust may revert back to the solitary phase and remain in the area. Once this solitary phase is developed the complete disappearance of the species may be rapid. Sometimes the disintegration of these swarms takes two or three seasons and other times only one generation. The invasion area is subject to periodic locust invasions which will be repeated when the conditions in the customary breeding grounds of the locust are favourable to the development of the gregarious phase. (Uvarov 1928).

Uvarov (1929) summarizes the phase theory saying, "The original theory recognized the fact of the existence in swarming locusts of two extreme forms, or phases, connected by a continuous series of transitional ones. The phases differ from each other in morphological and colour characters, on the one hand, and in biological peculiarities (mainly behaviour), on the other. Biological differences are, of course, of primary importance..(Uvarov 1929 P. 261).

The phase theory soon gave rise to the conception and the division of locust infested areas into, "invasion areas" and "reservation areas". Uvarov (1932) defines indirectly "reservation area" in the following words, "It is a well established fact that within the area subject to invasions by various locusts there are certain definite localities in which the locusts find the conditions suitable for the production of the swarming phase. In such localities the insects survive in sufficient numbers even during the years of minimum, when there are no swarms present, and from these localities new invasions start again." (Uvarov 1932 P. 274) and "The name

reservations appears more suitable for those localities, since the term "permanent breeding-places" commonly used to designate them implies that the locust cannot breed permanently elsewhere." (Uvarov 1932, P. 274).

This theory does not apply directly to the solitary grasshoppers, as found in Manitoba, which never develop a true gregarious phase. It has, however, been shown in studies of Manitoba grasshoppers that some of them have a tendency to form a transition to a form resembling the gregarious phase of locusts during mass outbreaks. Rubtzov following his studies of Chorthippus albomarginatus De G., a non-swarming grasshopper of the Old World, in comparison with Locusta migratoria L. states, "The degree of phase variability is very different according to the species and varies from the striking structural and biological transformation in Locusta migratoria L., to the small, but wholly analogous, changes in non-swarming grasshoppers." (Rubtzov 1935, P. 519). In 1935 M. bivittatus and C. pellucida with a few M. mexicanus were present in the Arnaud area. Concerning C. pellucida Criddle states, "The individuals in the concentrated gatherings of Camnula pellucida Scud. are much yellower in colour than the solitary forms of the same species." (Criddle 1933, P. 97). This change in colour, as mentioned above, is one of the indications of the change from the solitary to the gregarious phase in locusts. Criddle also says of M. bivittatus Say. that "the paler colours of the migratory phase are not so noticeable but what is more striking is the very appreciable greater percentage with longer wings.", furthermore, "we can discern, in the swarming phase, a distinctly more slender body which is associated with an agility unlike the rather clumsy solitary form." (Criddle 1933, P. 97). M. mexicanus is of particular interest because it is believed that it can develop a migratory phase known as Melanoplus spretus (Walsh). Hebard (1928) states that "It is quite possible, as we have already stated, that spretus is not a distinct species but a migratory phase of mexicanus." (Hebard 1928, P. 281).[A] Swarms of M. spretus have been known to occur in Manitoba as far east as the Red River Valley but not since 1875. (Macoun 1882). Although flights are known to occur among grasshoppers and are much more extensive during mass outbreaks than in normal years, flights of swarms, comparable to those of the gregarious phase of locusts in the Old World, do not occur.

It is now recognized that, in Manitoba, grasshoppers undergo a transition, under the conditions of mass outbreaks, that resembles somewhat the formation of transition stages or phases in the locusts of the Old World. Criddle (1933) suggests that, "Perhaps our grasshoppers are less susceptible to change than are those of other countries and on this account a longer time is required to bring out the abnormal characters present in the extreme migratory form. Or perhaps there is some condition of the atmosphere which is less rarely present in North America and more so in those countries where the change from one phase

---

[A] See also Hebard 1935, Parker 1935, Uvarov 1928.

to another seems so easily brought about." (Criddle 1933, P. 98).

In regards the "reservation theory" Criddle (1933) says, "We have not been able to fit the evidence obtained from observing our local grasshoppers, into such a theory but it does not follow that more exact observation may not provide a different conclusion, or that it may not be applicable to the grasshoppers in other parts of the country." He further points out that, "There is no doubt that all our outbreaks of grasshoppers have their inception in local areas. On the other hand, there is always a marked increase of the insects over all suitable places. Thus while certain favoured sections produce outbreaks first, others may do so the following year until finally the spread of the original concentrations, the formation of new ones and the more steady rise elsewhere, leads to a general epidemic." (Criddle 1933, P. 99). In this way it can be understood how the Camnula outbreak in Manitoba in 1919 originated in the southwest corner of the province while in 1931 it began in the Red River Valley about 200 miles east of the former.

It is perhaps impossible to have "reservations" in Manitoba according to Uvarov's definition of them as "localities in which the locusts find the conditions suitable for the production of the swarming phase." (Uvarov 1932, P. 274). However, it may be possible to think of "permanent breeding areas", where grasshoppers occur in non-outbreak years, which act as nuclei for future outbreaks.

In Manitoba it is hoped to find these "breeding areas" as they are called, by means of nymphal, adult and egg surveys of grasshoppers during the years of dwindling grasshopper population, the intervening years of comparative scarcity and the building up of the population at the commencement of the next outbreak, and by means of tracing the history of past grasshopper conditions in different areas. It is hoped that by these surveys and from the history of the province to be able to pick out certain areas termed "focal points" in Manitoba. ("permanent breeding areas" are also referred to as "hot spots" and sometimes as "reservations".) It will then be possible, if these breeding areas are found, to study the grasshoppers, to determine the causes for the increase to outbreak proportions and to forecast the coming of future outbreaks.

It was thought inadvisable to wait until definite permanent breeding areas were found before beginning the intensive studies. It must be remembered that there may not be definite breeding areas in Manitoba. It may be that in non-outbreak years there will be a general light infestation in all suitable sections which may include nearly the whole of southern Manitoba. Even if this is found

to be the case it is hoped by the use of intensive study areas, like the one established at Arnaud, that it will be possible to follow the trend of the population from year to year. By following this trend in different representative areas it will be known when the grasshopper population begins to build up for the next outbreak. At the same time studies will be made to determine the influence of weather, ecological factors, parasites and cultivation of crops on the different species of grasshoppers.

2. Review of work on study centres.

Uvarov and his co-workers have done a considerable amount of work on "reservations" of locusts in the Old World. It is reported that Prof. Uvarov insists that it would be impossible to solve the grasshopper problems, unless they could centralize the accumulated information in each of the infested countries. (Uvarov 1934). Although our conditions, in Manitoba and the rest of Canada and the United States are not comparable to those of the Old World, it has been recognized both by the Canadian and United States Governments that we can accomplish much more by following a uniform plan in our studies so that data will be interchangeable and comparable between the two countries. With this end in view a meeting of the Dominion Entomological Branch Committee on Grasshopper Research met at Lethbridge, Alberta, in April, 1935 at which members of the United States Department were present. At this meeting there was a mutual exchange of ideas with the aim of standardizing the methods to be used in future work on grasshoppers both in the provinces of Canada and in the United States. At this meeting one of the research projects for which an outline of the method of study was drawn up, was that of Intensive Study Areas. The detailed outline and the discussion of this project is reported under appendix 4, of the second report of the Entomological Branch Committee on Grasshopper Research.

"The only work conducted along this line up to the present time has been done by the U. S. Bureau of Entomology and Plant Quarantine. The project is new and of unquestioned importance in the study of the entire grasshopper problem." (Leth. Rept. 1935 App. 4, P. 1).

According to Dr. Parker's outline of the work that they have done, presented at the Lethbridge meeting (Leth. Rept. 1935 App. 1), the first area of this type was established by them in 1930 in the Centennial Valley. Four years' work did not yield very definite results on these areas but from this work they were able to tell where the grasshopper population was building up. In 1934 ten more intensive study areas were established and in the spring of 1935 they planned on adding more areas of a similar nature.

In Canada E. R. Buckell has been working along this line in

British Columbia since 1926 and in the case of the Nicola Valley has found reservations to exist. He states that "It would appear that this annual poisoning of reservations actually prevented an outbreak from forming....." (Buckell 1935, P. 5). It was found that although there was a general building up of grasshopper populations in the district in 1932-33-34, it was only a few isolated pockets in little side valleys which had been missed in the poisoning campaign, that built up a heavy population. (Buckell 1935, P. 5) and (Buckell and Treherne 1924).

3. Objects of the study.

Work on a study area for the "Intensive Study of the Economic Grasshoppers in Typical Environments Where Previous Outbreaks Have Been Known to Occur." (Leth. Rept. 1935, App. 4, P. 1), was started as a long term project.

The object of this long term project is "To determine the biological and environmental factors which cause extensive fluctuations in grasshopper populations, with the practical end in view of being able to predict or prevent grasshopper outbreaks." (Leth. Rept. 1935, App. 4, P. 19).

The immediate objects at Arnaud were,

(1) To start the work on the long term project.

(2) To make estimates of the population and graph the seasonal fluctuation.

(3) To gather phenological and meteorological data for the different nymphal and the adult stages.

(4) To record the length of the egg laying period, the weather condition under which oviposition occurs, and the habitats selected by the different species for oviposition.

(5) To record the conditions and seasons when flights occur.

(6) To make a fall egg survey in order to forecast the number of grasshoppers expected the following year, to check the accuracy of the forecast and to determine the destruction of the eggs, due to parasites, predators and weather conditions, in the spring.

(7) To determine the effect of weather conditions on the general activity of the grasshoppers in their different stages of development.

(8) To determine the effect of different bordering crops and the treatment of these crops in the grasshopper population.

(9) To determine the environment and plant associations preferred by the various species of grasshoppers during their different stages of development.

(10) To determine the differences in behaviour of the various grasshoppers, especially M. bivittatus and C. pellucida.

(11) To estimate at different seasons the damage done to crops, gardens and native vegetation by the grasshoppers.

(12) To determine to what extent the grasshoppers are diseased and parasitized and to determine the rate of mortality due to these causes.

(13) To determine the area that one investigator could study to advantage in a project of this type.

(14) To test out the methods suggested and to improve on them if possible.

4. Advantages of the Arnaud area.

Arnaud was selected as a satisfactory area for intensive study because of the history of the grasshopper outbreak in this area, the present infestation, and because it was representative of a large portion of the Red River Valley. Although the Arnaud area was not recorded as infested with grasshoppers during the outbreak of 1919-1923 it was one of the first areas infested in the 1931 outbreak. There was no organized grasshopper control campaign in Manitoba until 1932 but bait was shipped to certain areas in 1931 and Arnaud was one of these areas. In all forecasts for grasshopper infestations from 1932 to 1935 Arnaud has been the centre of one of the severe areas. The infestation consisted of Melanoplus bivittatus Say. and Camnula pellucida Scud. The egg survey in the fall of 1935 indicates that this will be one of the most heavily infested areas in Manitoba next spring.

According to Mr. H. Lilliford, one of the leading farmers in this community, there were grasshoppers present on Sec. 13, T. 4, R. 3E. and the adjoining part of Sec. 12, T. 4, R. 3E. during the years previous to the outbreak in 1931. This was virgin land and is still unbroken. Mr. E. Linklater, also a farmer in this district, reports that there are certain sections south of the Roseau River which have always had grasshoppers. Thus the history of Arnaud, although sketchy, points to the suitability of the area for the study and might even indicate that this will be found to be a permanent grasshopper breeding area. This area is representative of a large portion of the Red River Valley and as such can be studied as indicative of conditions in this section of the province.

An additional advantage of the Arnaud area was that Camnula pellucida Scud. had died out almost entirely throughout the rest of Manitoba from Empusa grylli (Fr.) while at Arnaud it was chiefly Melanoplus bivittatus Say. that was dying of this fungus disease.

GENERAL DESCRIPTION OF THE ARNAUD AREA.

1. Geology.[A]

The town of Arnaud is situated in the so-called "Red River Valley" on the east side of the river about fifty miles south of Winnipeg. The "Red River Valley" is an extensive lacustrine plain which was formerly part of the bed of glacial Lake Agassiz. The river flows in a general northerly direction from south of the international boundary to empty into the southern end of Lake Manitoba.

During the glacial period successive ice sheets covered Manitoba and extended into North Dakota and Minnesota and further south. As the glaciers receded northward, due to the melting of the ice, the boulder till or glacial drift was deposited over the underlying deposits and was subsequently covered by water forming a glacial lake known as Lake Agassiz. The lake in turn receded northward as the glacier melted. As it retreated different shore lines or beaches were formed, and deltas, deposited by the rivers draining into the lake, were exposed. One of these beaches may be observed at the town of Riverville, immediately north of the Arnaud area. The fine lacustrine sediments, from which the soils of the "Red River Valley" have developed, were left as the lake was finally drained to the north by the Nelson River.

2. Soils.[AA]

The Red River Valley is in the soil zone of the black earth or "Chernozems". The soils of the Red River Valley combination have the lacustrine deposits left when Lake Agassiz was drained. Prof. Ellis divides the lacustrine sediments deposited on the glacial drift in Manitoba into six types of surface deposits. On each of these types of deposit a different soil association has developed. The soil of the Arnaud area has been formed on the fine lacustrine deposits which are designated as the Red River Association. The soils of this association lying to the east of the Red River differ mainly from those to the west in not having been salinized or alkalinized. The different soil associations occurring in this area are indicated on the map (Plate I).

In the Arnaud area three associates of the Red River Association are present, the boundaries of which are indicated on the map (Plate II).

The first of these associates is termed "McTavish Clay" or the Red River "phyto-hydromorphic" associate. It is defined as the meadow-prairie or immature phase of Red River Clay. It is the better drained phase of transition from the wet meadows to the well drained prairie. It is characterized by "a black A horizon, tongued into an olive drab clay subsoil". Lime carbonate concretions are present in the olive drab clay.

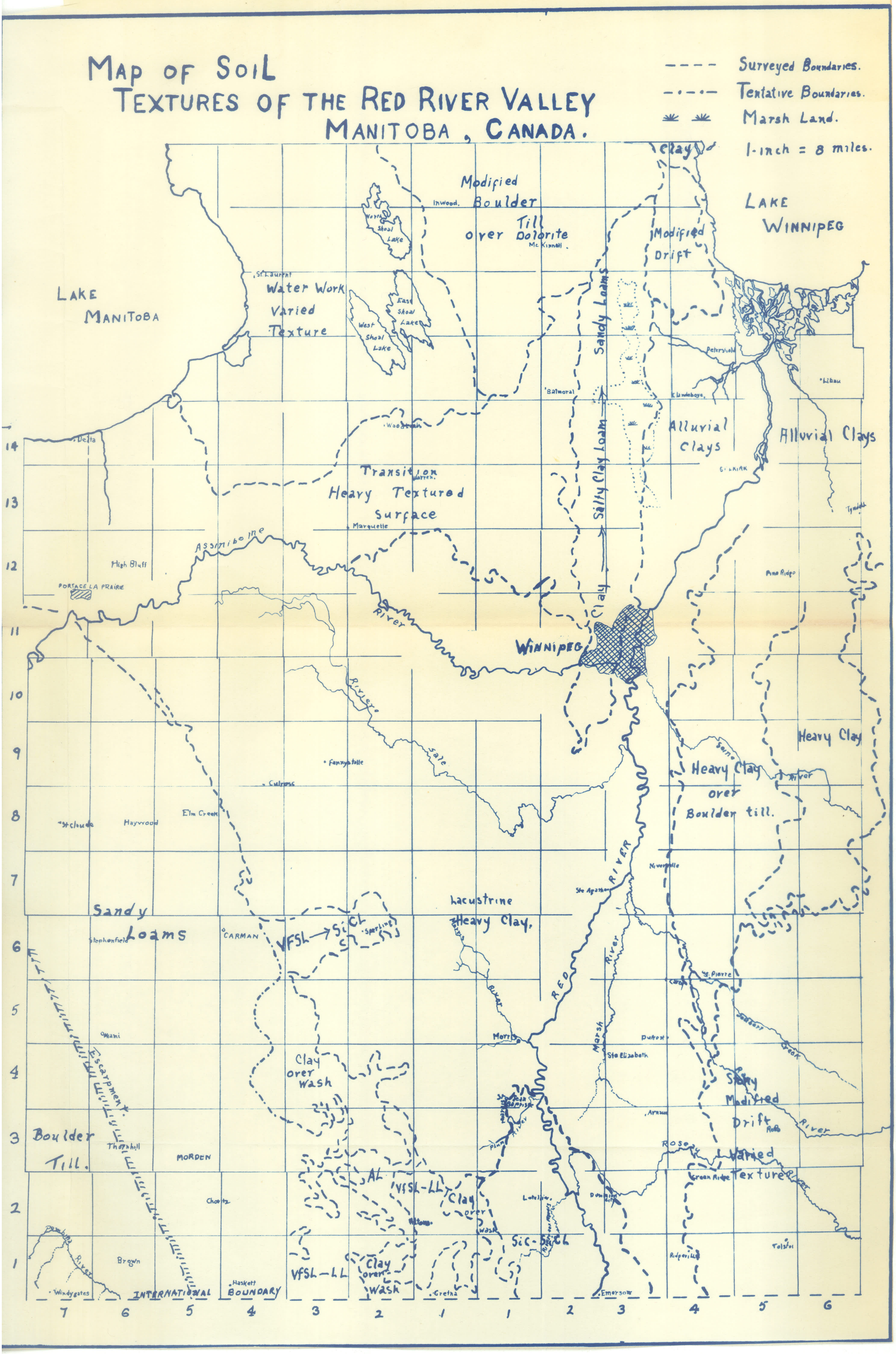
A Upham 1895; Ellis 1935; Ellis (unpublished)

AA Ellis (unpublished)

Plate I

Soil Associations of the Red River Valley Soil Combination.

(Ellis, unpublished)


Map of Soil
Textures of the Red River Valley
Manitoba, Canada.
Surveyed Boundaries.
Tentative Boundaries.
Marsh Land.
1-inch = 8 miles.
Lake Manitoba
Lake Winnipeg
Modified Boulder Till over Dolorite
Inwood.
McKinnell.
North Shoal Lake
East Shoal Lake
West Shoal Lake
St. Laurent
Water Work Varied Texture
Clay
Modified Drift
Sandy Loams
Silty Clay Loam
Clay
Petersfield
Balmoral
Libau
Alluvial Clays
Alluvial Clays
Selkirk
Tyndall
Delta
Transition Heavy Textured Surface
Warren.
Marquette
Assiniboine River
High Bluff
Portage La Prairie
Pine Ridge
Winnipeg
Riviere Sale
Fannystelle
Culross
Elm Creek
St. Claude
Haywood
Heavy Clay
Heavy Clay over Boulder till.
Seine River
Niverville
Ste Agathe
Red River
Lacustrine Heavy Clay.
Sandy Loams
Stephenfield
Carman
VFSL → SiCL
Sperling
Morris River
St. Pierre
Marsh River
Ste Elizabeth
Dufrost
Morris
Miami
Escarpment.
Clay over Wash
Arnaud
Stony Modified Drift
Rat River
Joubert Creek
Roseau River
Varied Texture
Green Ridge
Boulder Till.
Thornhill
Morden
St. Jean Baptiste
Plum River
AL
VFSL-LL
Clay over wash
Letellier.
Dominion City
Chortitz
Altona.
SiC-SiCL
Ridgeville
Tolstoi
Pembina River
Brown
VFSL-LL
Clay over Wash
Haskett
Windygates
Gretna
Emerson
International Boundary
7 6 5 4 3 2 1 1 2 3 4 5 6
14 13 12 11 10 9 8 7 6 5 4 3 2 1

The second associate is named "Osborne Clay" or the Red River "hydromorphic" associate. It is a "non-salinised" meadow associate. It has a"shallow black A horizon over a grey gleilike clay horizon with more or less profuse iron specks or streaks and concretions. It may have a thin deposit of muck or peaty material on the surface in the virgin condition."

The third soil is an intermediate type between the above two associates. It is termed "McTavish Clay (low phase)". This soil is similar to the "McTavish Clay" in character but is poorer drained. However, it is better drained than the "Osborne Clay".

The "Osborne Clay" forms natural hay meadows. "When newly broken, the surface is friable because of the organic sod mat but, after a few years of fallow and cropping, the soil becomes tough, waxy and difficult to work." The "McTavish Clay" has a more friable surface.

In the virgin condition the soils of the Arnaud area were under grassland which was broken between 1905 and 1920; some of it is still unbroken. The better drained soils were broken first and now due to drainage, the more humid associates are being brought under cultivation. The drainage problem has been improved somewhat by the deep ditches which have been installed along some of the roadallowances (Plate XX). The spoil banks of these ditches have been converted into high graded roads.

The district is a grain growing area, but in wet years the soils of the poorer drained associates tend to be too wet and it is impossible to work the land in the spring. In normal or dry years good grain crops are grown.

The area is settled chiefly by Russian Mennonites established on rented farms which formerly constituted three syndicate farms; the Emmert Ranch Foundation, the Kaewani Ranch and the Lyman Ranch.

3. Topography.

The area around Arnaud is a very flat, level plain. The altitude at Arnaud is 794 feet above sea level with a fall to the west of 0.43 feet per mile and to the north of 0.07 feet per mile (Ellis). The drainage is in a north-westerly direction by means of the Marsh River which enters into the Red River. There is a general absence of macro- and meso-relief. There is some micro-relief represented by shallow low areas. It is in these low areas that the hydromorphic soil associates have developed. Despite this micro-relief and the gradual slope to the north-west the general impression recieved by a casual observer is that of a flat level plain as illustrated in Plates III, IV and V. These photographs were taken from the top of the Ogilvie Grain Elevator at Arnaud.

Plate II

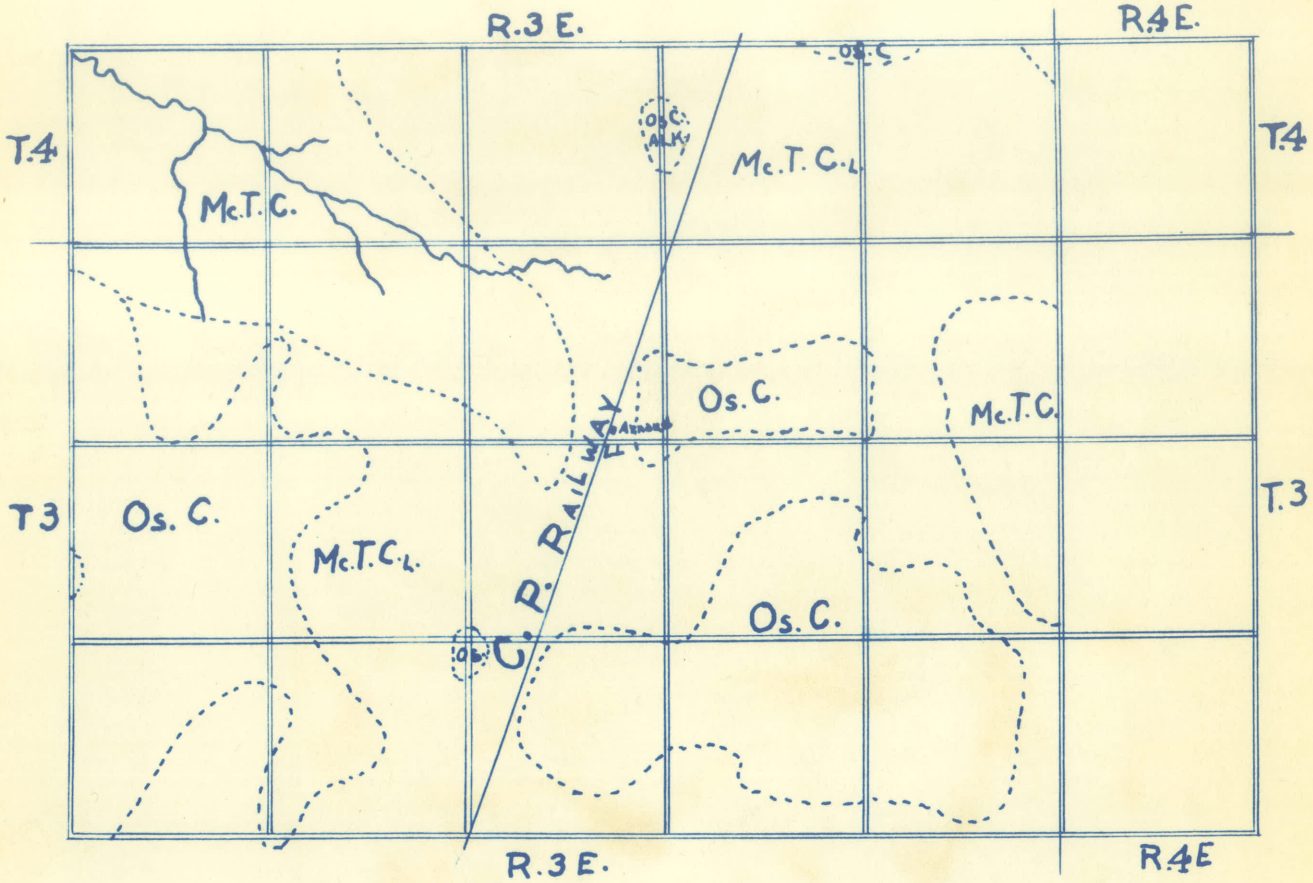
Soil Associates of

the Armand area.

(Ellis, unpublished)

Soil Survey Arnaud, Man.

J. H. Ellis (Unpublished).



McT.C. - McTavish Clay. Os.C. - Osborne Clay.

McT.C.L. - McTavish Clay (Low Phase).

Alk. - Alkalinized Phase.

Plate III

View from the top of the grain elevator at Arnaud, Man. Looking south-west towards Plots III & IV.

Plate IV

View from the top of the grain elevator at Arnaud, Man. Looking west along the Arnaud grade. The building in the foreground is the church with the Lyman Ranch building behind it and other farm buildings on the north side of the road. This view shows the area covered by Plots I & II.

Plate V

A panoramic view taken from the top of the Ogilvie grain elevator, looking east along the Arnaud grade over the area in which are plots V, VI, VII, & VIII.

4. Plant communities and cultivated crops.

1. Plant communities. The native vegetation of the Arnaud area is a tall prairie formation. (Weaver and Clements 1929). This is the eastern edge of the tall prairie formation in Manitoba and at the present time appears to be undergoing a woodland invasion from the east. The first stage of this invasion is represented by the occurrence of Symphoricarpus occidentalis in the intermediately dry positions with several species of Salix in the low, wetter positions. When the shrubs become established then aspen and poplar gradually pushes in. There is also an ecotone, or area of stress, separating the prairie from areas of invasion by poplars and willows. The poplars are confined to groves on areas of slightly better drainage and are mainly Populus tremuloides with a few Populus balsonifera. Associated with these are several species of willow of which Salix species are common. In the ecotone Elaegnus argentea, Symphoricarpus occidentale are common shrubs. There are many herbs both in the prairie and ecotone area. Sunflowers, asters and golden rods are conspicuous.

The crops for the 1935 season are mapped. The chief native plants and ruderal invaders collected on the areas studies are listed below.

2. List of native plants collected in the Arnaud area.

Timothy	Phleum pratense L.
x Canada blue grass	Poa compressa L.
x Giant blue stem	Andropogon furcatus Muhl.
Brome grass	Bromus inermis Leyss
x Slough grass	Spartina michauxiana Hitch.
Wild barley	Hordeum jubatum L.
Couch grass	Agropyron repens (L.) Beauv.
Lamb's quarter	Chenopodium album L.
Dandelion	Taraxacum officinale Weber
x False rag weed	Iva xanthifolia Nutt.
x Giant rag weed	Ambrosia trifida L.

Plate VI

Map of the area east of Arnaud showing the crops for 1935 on the sections adjacent to the study areas.

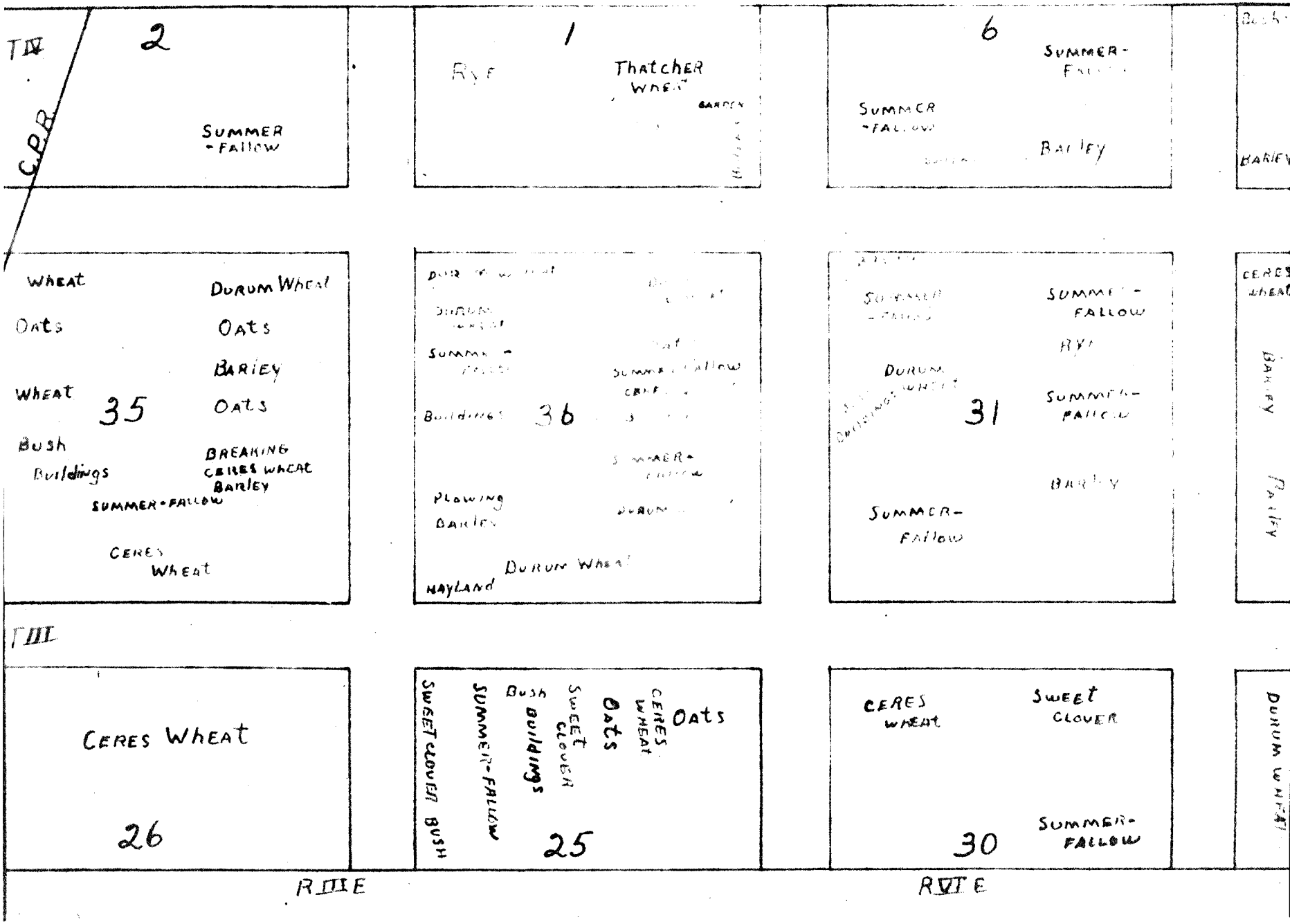
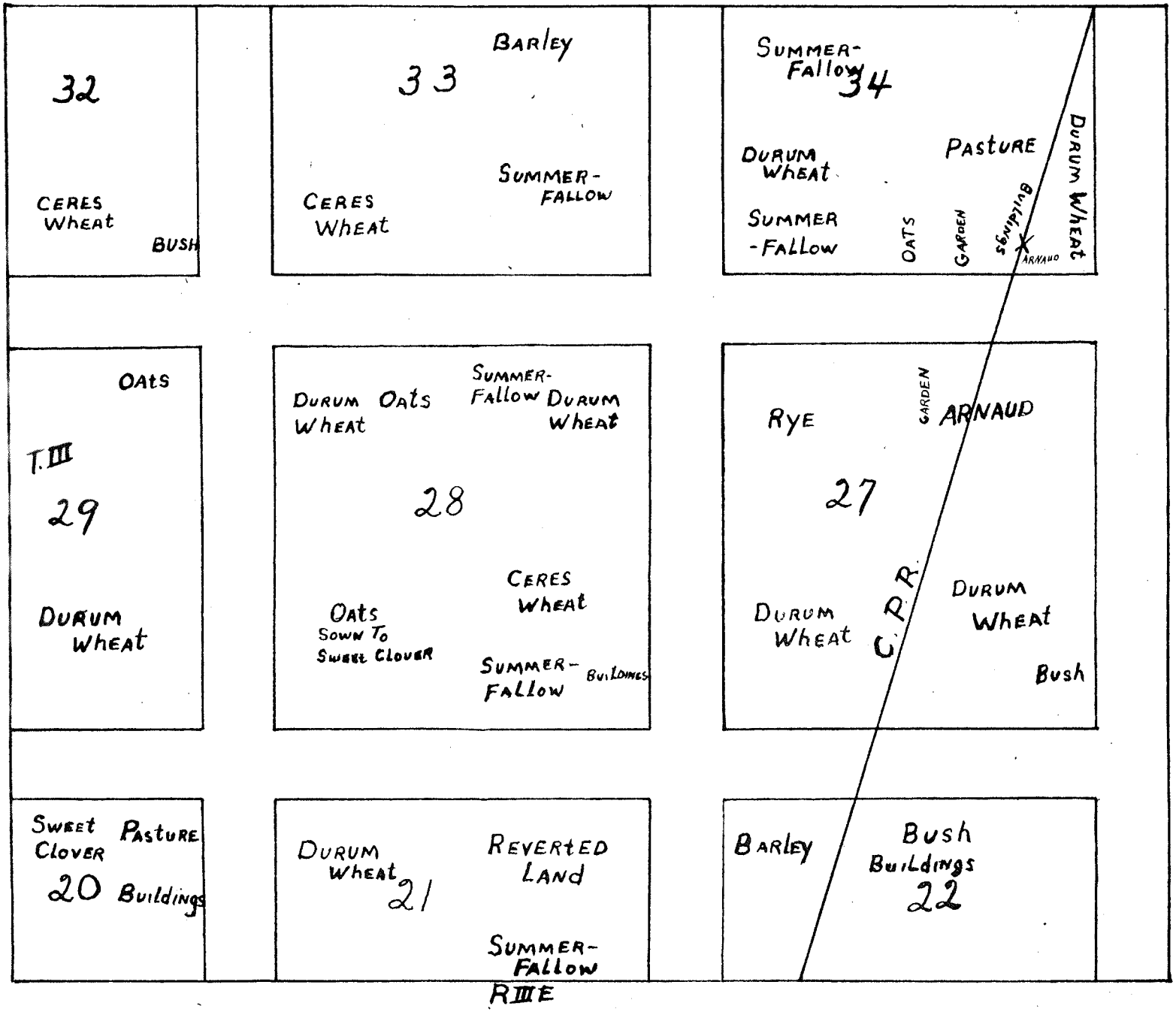

T IV
C.B.R.
2
SUMMER - FALLOW
1
RYE
THATCHER WHEAT
6
SUMMER - FALLOW
BARLEY
WHEAT
OATS
WHEAT
35
BUSH
BUILDINGS
DURUM WHEAT
OATS
BARLEY
OATS
BREAKING
CERES WHEAT
BARLEY
SUMMER-FALLOW
CERES WHEAT
BUILDINGS
36
PLOWING
BARLEY
DURUM WHEAT
HAYLAND
SUMMER - FALLOW
RYE
DURUM
BUILDINGS
31
SUMMER-FALLOW
BARLEY
SUMMER-FALLOW
T III
CERES WHEAT
26
SWEET CLOVER BUSH
SUMMER-FALLOW
BUSH
BUILDINGS
SWEET CLOVER
OATS
CERES WHEAT
OATS
25
CERES WHEAT
SWEET CLOVER
30
SUMMER-FALLOW
R III E
R VI E

Plate VII

Map of the area west of Armaud showing the crops for 1935 on the sections adjacent to the study areas.


32
CERES Wheat
BUSH
BARLEY
33
CERES Wheat
SUMMER-FALLOW
SUMMER-Fallow
34
DURUM Wheat
PASTURE
SUMMER -FALLOW
OATS
GARDEN
BUILDINGS
ARNAUD
DURUM Wheat
OATS
T. III
29
DURUM Wheat
DURUM Wheat
OATS
SUMMER-Fallow
DURUM Wheat
28
OATS Sown To Sweet Clover
CERES Wheat
SUMMER-FALLOW
BUILDINGS
RYE
GARDEN
ARNAUD
27
C.P.R.
DURUM Wheat
DURUM Wheat
Bush
SWEET Clover
PASTURE
20
Buildings
DURUM Wheat
21
REVERTED Land
SUMMER-FALLOW
BARLEY
Bush
Buildings
22
RIII E

x Western rag weed	Ambrosia psilostachya DC.
x Tumble weed	Amaranthus graecizans L.
Red root pig weed	Amaranthus retroflexus L.
x Knot weed	Polygonum aviculare L.
x Spurge	Euphorbia serpyllifolia Pers.
x Golden rod	Solidago canadensis L.
x Golden rod (2)	Solidago rigida L.
x Purple aster	Aster laevis L.
x White aster	Aster multiflorus Ait.
x Maximilian sunflower	Helianthus maximiliani Schrad.
x Indian hemp	Apocynum cannabinum L.
x Gum weed	Grindelia squarrosa (Pursh) Duval.
x Artemisia (White sage)	Artemisia ludoviciana Nutt.
x Wild rye	Elymus canadensis L.
x Anemone	Anemone canadensis L.
x Rose	Rosa blanda Ait.
Wild buckwheat	Polygonum convolvulus (Linn.) Dumortier
Stink weed	Thlaspi arvense L.
White sweet clover	Melilotus alba Desr.
Yarrow	Achillea millefolium L.
Strawberry	Fragaria virginiana Duchesne
x Long leafed willow	Salix longifolia Muhl.
x Peach leaved willow	Salix amygdaloides Andersa.
x Wolf willow	Elaeagnus argentea Pursh.
x Willow	Salix bebbiana Sarg.
x Prunus	Prunus pennsylvanica (L.)

Poplar	Populus tremuloides Michx.
Poplar	Populus balsamifera L.
Cottonwood	Populus deltoides Marsh.
Snow berry	Symphoricarpus occidentalis Hook.
Bidens burr	Bidens (frondosa?) L.
Canadian thistle	Cirsium arvense (L.) Scop.
Called orchard grass	Not identified

x Identified by Prof. Lowe, Botany Department, University of Manitoba.

3. Grasshoppers and predators present. The grasshoppers occurring in this area and the predators on them are listed below with their complete scientific names so that in the ensuing discussion where the names are repeated abbreviations may be used.

The two economically important grasshoppers in this area were:

Melanoplus bivittatus (Say) - The two-striped grasshopper

Camnula pellucida (Scud.) - The clear-winged grasshopper

The other grasshoppers that were collected and identified were in order of their abundance:

Melanoplus femur-rubrum femur-rubrum (DeG.)

Melanoplus dawsoni (Scud.)

Melanoplus mexicanus (Saus.)

Chorthippus curtipennis (Harr.)

Dissosteira carolina (Linn.)

Arphia pseudonietana (Thom.)

Encoptolophus costalis (Scud.)

Orphulella pelidna (Burm.)

Orphulella speciosa (Scud.)

Chloealtes conspersa(Harr.)

Melanoplus gracilis (Scud.)

Camptocerus clavatus (Thom.)

Spharagemon collare (Scud.)

There was also a species of Tettigoniidae, Conocephalus sp. present.

The fungus that killed off the grasshoppers to some extent was Empusa grylli Fr. This fungus causes the grasshopper to climb and cling to the stems of grasses and weeds to die. There was another disease present which caused the grasshoppers to die on the ground but the organism causing their death was not identified.

The egg predators present were:

x Pterostichus obesus (Say) - Carabid beetle

x Macrobasis subglabra Hall. - Blister beetle

x Systoechus vulgaris Loew.

Eutrombidium locustarum (Walsh) Red mite

Unidentified - Wire worms

Unidentified - Red ants

x Identified by W. Brown, Entomological Branch, Ottawa.

III WEATHER.

1. The relationship of weather to grasshopper abundance.

One of the objects of this study is to determine the effect of climate on grasshopper abundance but this is a long term project. We may define climate as "The complex of meteorological factors prevailing throughout the year in the area dealt with". (Wardle 1929, P. 41).

Weather may be defined as "the meteorological complex prevailing at some particular point of time". (Wardle 1929, P. 41). In the study of the effect of weather on grasshoppers, especially on their activity, some data have been obtained. These results are reported under the sections on oviposition (P.187), flights (P.182), and under the plots as general observations. These

results are not complete or in any way firmly established but offer leads to be further investigated and proven or disproven.

It has long been recognised that climate has a great deal to do with grasshopper abundance. In the grasshopper report of 1877 it was stated that, "If we could foretell the character of the seasons for the coming years, we could then predict with more certainty the movements of the locusts." (Rept. U. S. Ent. Comm. 1877, P. 125). Many entomologists have tried and are trying to connect the periodicity of grasshopper and locust outbreaks with sunspot cycles and weather cycles. Criddle (1932) stated "That there is a correlation between sunspot minimum, or decline, and rise in the number of grasshoppers seems evident, but the presence of a number of other factors greatly complicates the problem and often obscures what might otherwise be plain." (Criddle 1932, P. 196). Uvarov, on the other hand, claims that the outbreaks are not periodic but are merely irregular fluctuations and that, although weather is one of the chief factors instrumental in bringing outbreaks to a close, he sees no way in which weather could bring about the sudden rise of grasshoppers to outbreak proportions. (Uvarov 1928). Many workers are, however, studying the effect of climate on grasshopper abundance and Uvarov in recent years recognises climatic areas where his reservations occur. (Uvarov 1932 and 1933). This, however, is a study which it will take a number of years of intensive work to investigate.

It is hoped that by collecting weather data and making graphs of grasshopper populations we shall be able in a few years to state whether such periodicity does occur and if there is a correlation with weather cycles just what the connection is. In other words, to have data on the complicating and obscure factors which Criddle speaks of (Criddle 1932) and their effect on the periodicity.

2. Meteorological observations at Arnaud.

It is pointed out in all the outlines for the study of these intensive study areas that weather records are of utmost importance. Parker suggests that the intensive study areas should be chosen in proximity to weather record stations of fifteen to twenty years standing. (Leth. Rept. 1935). In Canada, where weather stations are not so numerous, this is not so readily carried out as in the United States but is likewise desirable. Meteorological stations at Emerson and at Morris within a radius of 20 miles of Arnaud, have accumulated broken series of records but the conditions are not exactly

comparable to those at Arnaud. We have, therefore, established a small meteorological station on the study centre. The instruments were operated this year only while the investigator was located there. It may be found advisable in later studies to have the instruments operated by an inhabitant of the area throughout the entire year.

At Arnaud a weather shelter containing a maximum thermometer, a minimum thermometer, and a hygrothermograph, a home-made rain recorder, a sun recorder, a sling psychrometer, an egg beater psychrometer (Gray 1929), a soil thermometer, a fan anemometer, and a sunshine recorder was set up on July 17 and operated until September 20. Pocket thermometers were used to measure soil surface temperatures during the field trips. The sling psychrometer was used to measure the relative humidity at forty inches from the ground and then the egg beater psychrometer, which was used to take the relative humidity in the shelter, was checked against it. In this way the hygrograph was checked by the sling psychrometer. The psychrometer readings were converted to relative humidity by the (Table' Marvin 1915). . The standard maximum and minimum thermometers were used to check the thermograph. The readings were taken every morning and every evening and the hygrothermograph set every Monday morning. The graph on the sunshine recorder was changed every evening.

Every morning at eight o'clock and in the evening at six or seven o'clock the following readings were taken:

(a) Maximum temperature.
(b) Minimum temperature.
(c) Standard temperature.
(d) Temperature at the surface of the soil.
(e) Thermograph reading.
(f) Hygrograph reading.
(g) Sling psychrometer at 40 inches.
(h) Egg beater psychrometer at 40 inches.
(i) Egg beater psychrometer in the temperature screen.
(j) Egg beater psychrometer at 6 inches from the ground in the grass.
(k) The direction and velocity of the wind.
(l) Cloudiness. (1-10)
(m) Rain in inches.

The weather shelter was placed standing on the ground as this was believed to be the most satisfactory position for the record of the conditions in the grasshopper environment. Uvarov (1928) pointed out that "Meteorological stations observe temperatures, humidity, etc., in special screens at a definite height above the ground and at definite hours of the day - these all being conditions that are clearly not the same as those under which animals have to live." (Uvarov 1928, P. 91) Several United States investigators

in the last few years have been placing the weather shelters on the ground in order to overcome this objection to some extent. It has now been realized that as the data collected is to be used for practical purposes our data should be in terms of the standard meteorological data. Therefore, in future studies the temperature screen will be placed at the standard height of forty inches. If possible, it would be most satisfactory to have two sets of instruments, one on the ground and one at the standard height. The standard maximum and minimum thermometers were hung on the south wall of the weather shelter as is the common practice.

The thermograph readings are easily corrected to correspond with the maximum minimum and hourly readings taken from the standard thermometers. In the case of the hygrograph, corrections are not so easily applied. It is impossible to take the humidity inside the temperature screen with the standard sling psychrometer. In order to overcome this difficulty an egg beater psychrometer was constructed which could be used in the screen. (Gray 1929). This egg beater psychrometer was checked each time by the sling psychrometer at the standard height. Even then, the correction of the readings taken from the graph is difficult unless the graph is adjusted at the time that the readings are taken. This difficulty arises in the steepness of the rise and fall in the graph making it impossible to get the exact reading at a definite time from the graph. As the graph was corrected when the readings were taken, the readings used for the calculations of mean humidities are those read as closely as possible from the graph with minor corrections.

Inthe case of the sunshine records the only difficulty experienced was in setting the instrument so that the readings corresponded to the time. Although this was correct in the morning it would not necessarily be correct in the afternoon. It was found that the record was most correct when the graph was put on and adjusted at noon. As the investigator was very seldom at the meteorological instruments at noon this method of adjusting the instrument was of little value at Arnaud. The graph was, therefore, adjusted as closely as possible from the results of the readings of the previous day.

Soil temperature recordings were taken at eight A.M. and six P.M. but were of little value as a continuous record was not kept. On the field trips the soil temperature at the surface was taken in connection with field observations and was found to be of considerable value. Continuous records of the temperature below the surface of the soil, as well as the surface temperature, should have been taken but the instruments were not available. Because of the incompleteness of the soil temperature data they are not presented but temperatures recorded during field observations, especially in connection with oviposition (p.190) are given along with the observations made.

The velocity of the wind was taken in the morning and the evening and the direction noted. Changes in the velocity and the direction of the wind were also noted during the day while on the observation trips. In the field observations the velocity of the wind was not recorded as miles per hour but merely as a wind, breeze, slight breeze, air movement, etc. It is believed that this method of recording the velocity of the wind is sufficiently correct for this type of study unless a continuous record of the velocity could be kept. (See tables P. 25).

The rainfall was recorded by means of a home-made rain gauge made after the "Snowden" pattern.

The cloudiness was recorded in the field by the following method. The cloudiness is represented by numbers from 0-10. Thus, a completely overcast sky is assigned the value 10 and a perfectly clear sky 0. If the sun is shining only half the time the value given is 5 and so on. Plus and minus signs may also be used, for example, if the sky is hazy around the horizon but not clouded over enough to be given the value 1 the cloudiness might be recorded as one minus. This method of recording cloudiness was found to be quite satisfactory for field observations.

No record of atmospheric pressure or rate of evaporation was kept. In the case of the atmospheric pressure, it is quite generally recognized that a record is of very little value in biological work. The rate of evaporation, however, may be more important as it is a measure of a combination of the effect of many other factors. For example, the rate of evaporation depends on the temperature, the wind and its velocity, the relative humidity, radiation and to some extent the atmospheric pressure. J. J. de Gryse in his paper on climatic factors does not consider that it is of any great significance. (de Gryse 1932). However, a measure of the evaporation rate might be of value in a long term project of this type.

Dr. Parker proposed the following readings be taken on the study centres:

(a) Rainfall.
(b) Standard air temperature.
(c) Standard soil temperature.
(d) Soil temperature at one inch.

In addition to these he considers a record of the hours of sunshine and of the relative humidity to be of value. (Leth. Rept. App. 4, P. 13).

The weather data obtained in the Arnaud area are summarized in the following tables and graphs. The mean temperatures and humidities are calculated from Geddes formula (deGryse 1932). The data at Emerson is so incomplete that it is of little value but a summary of the Morris data follows.

Table I

Date	Max. T.	Min. T.	Mean T.	Range T.	Max. Hum.	Min. Hum.	Mean Hum.	Range Hum.	Ppt. in.	Wind 8 A.M.	Sunshine Hours
July 18	86°	56°	71.81°	30°	97%	55%	76.48%	42%		S.E. breeze	11
July 19	90	66	76.96	24	97	58	79.23	39		S. very slight	12
July 20	89	66	74.75	23	100	64	83.66	36		N.W. sl. breeze	
July 21	89	55	72.56	34	100	39	70.19	61		S.W. breeze	12.5
July 22	88	55		33	94	42		52		S.W. very slight	7.5
July 23	88.5	62	73.77	26.5	98	41	73.25	57	0.35	N. slight breeze	11.5
July 24	93	56	74.46	37	100	39	71.56	61		W. breeze	13
July 25	93	61	76.50	32.	95	47	70.00	48		S.E. breeze	10
July 26	93	70	80.29	23	97	55	77.79	42	0.244	S. sl. breeze	8.5
July 27	87	65	76.25	22	100	48	74.89	52	0.035	N. sl. breeze	13
July 28	91.5	51.5	75.89	40	100	38	68.19	62		S.E. breeze	
July 29	90	54		36	100	54	76.38	46	0.03	S. 8.5	6.5
July 30	90	52	74.79	38	100	24	62.12	76		W. sl. breeze	13.0
July 31	84	52	72.10	32	100	38	68.75	62		N.W. breeze	13.5
Aug. 1	70	52	60.21	18	99	70	90.12	29	0.05	E. very slight	0.25
Aug. 2	84	60	68.48	24	100	39	74.02	61	0.70	S. breeze	8.0
Aug. 3	73	54	60.71	19	97	43	71.25	54	sl. shower	W. 5.5 gusty	6.0
Aug. 4	82	43	62.48	39	100	36	68.92	64		N. sl. breeze	11.5
Aug. 5	76	50	65.83	26	98	74	83.48	24	0.63	E. sl. breeze	1.0
Aug. 6	89	55	72.69	34	97	30	63.10	67	some	N. sl. breeze	10.0
Aug. 7	92	61	76.85	31	95	30	58.17	65	some	N.W. sl. breeze	9.0
Aug. 8	91	64	74.46	27	96	41	67.81	55	0.42	N.W. sl. breeze	10.0

Table I (Con'd)

Date	Max. T.	Min. T.	Mean T.	Range T.	Max. Hum.	Min. Hum.	Mean Hum.	Range Hum.	Ppt. in.	Wind & A.M.	Sunshine Hours
Aug. 9	85°	60°	70.14°	25°	100%	42%	67.75%	58%	0.017	N. sl. breeze	10.25
Aug. 10	88	47	69.06	41	100	34	63.29	66		S. breeze	7.00
Aug. 11	84	65	66.89	19	90	51	74.50	39	Storm after 4 P.M.		5.00
Aug. 12	77	53		24	89	40	66.62	49	1.653	N. 7.	9.45
Aug. 13	86	57	72.12	29	93	37	61.46	56		S.W. sl. breeze	11.5
Aug. 14	96	62	78.25	34	82	34	57.29	48		S. 7.6 & 9.2	3.33
Aug. 15	92	61	75.73	31	82	44	63.46	38	some	S. 10.8	5.00
Aug. 16	61	51	54.37	10	99	86	92.64	13	0.66	N.E. sl. breeze	0.00
Aug. 17	74	48	59.29	26	96	56	78.64	40	0.03	N.E. sl. breeze	10.00
Aug. 18	67	57	61.56	10	96	73	91.83	23	Rain	E.	
Aug. 19	64	55	60.12	9	98	70	90.77	28	0.066	N. sl. breeze	
Aug. 20	70	47	59.94	23	97	46	76.33	51	0.122	N. 12.7	10.5
Aug. 21	82	46	63.96	36	96	42	70.77	54		S. sl. breeze	13.0
Aug. 22	83	56.5	69.56	26.5	98	53	73.46	45		S.E. breeze	12.0
Aug. 23	85	62.5	74.37	22.5	98	58	77.33	40		S.E. 11.5	4.5
Aug. 24	77	59	68.77	18	100	56	75.19	44	0.66	S. 12.4	1.25
Aug. 25	79	46	64.39	33	100	36	68.56	64			12.5
Aug. 26	68	49	56.25	19	90	41	64.56	49	0.035	N.W. cool	
Aug. 27	60	43	50.27	17	94	49	70.69	45	some	N.W. 11.4	6.0
Aug. 28	62.5	37	51.12	25.5	100	43	71.50	57		N.W.	2.25
Aug. 29	64	36	49.56	28	100	39	80.21	61	0.035	N.W. sl. breeze	8.00
Aug. 30	62.5	36	48.91	26.5	100	37	71.37	63	0.038	S.E. sl. breeze	
Aug. 31	64	31	47.62	33	100	39	70.12	61			8.00
Sept. 1	72	32	53.52	40	100	32	60.90	68			10.00

Table I (Con'd)

Date	Max. T.	Min. T.	Mean T.	Range T.	Max. Hum.	Min. Hum.	Mean Hum.	Range Hum.	Ppt. in.	Wind 8 A.M.	Sunshine Hours
Sept. 2	79°	48°	58.35°	31°	100%				Rain 4 P.M.		
Sept. 3	60	48	51.17	12	100	64%	89.37%	36%	0.52	N.W.	4.0
Sept. 4	57.5	46	50.19	11.5	98	55	78.19	43	0.07	N. strong cold	1.0
Sept. 5	66	36	49.81	30	100	39	74.12	61		N. al. breeze	9.0
Sept. 6	64	33.5	49.19	30.5	100	58	85.31	42	0.05	S. al. air mov.	1.0
Sept. 7	67	42	51.67	25	100	47	82.81	53		N.W. " " "	2.5
Sept. 8	62	36	48.98	26	100	45	80.25	55	some	S. al. breeze	6.0
Sept. 9	67	28	49.17	39	100	40	66.92	60		S.E.	10.0
Sept. 10	65	43	54.21	22	95	47	67.58	48		N. 7.8	7.0
Sept. 11	52	40	46.46	12	100	53	84.92	47	0.07	N.W.	0.0
Sept. 12	58	40	46.29	18	100	53	78.79	47	0.09	S.E.	3.0
Sept. 13	52	44	47.92	8	100	85	92.44	15			0.0
Sept. 14	71	37.5	52.37	33.5	100	52	78.58	48			8.5
Sept. 15	72	48	59.19	24	95	47	78.02	48			4.0
Sept. 16	83.5	47	66.58	36.5	100	25	66.00	75		W. al. breeze	10.0
Sept. 17	74	47	59.96	27	100	37	72.65	63	0.017	N.W. al. breeze	10.0
Sept. 18	73	38.5	54.58	34.5	100	29	66.60	71	0.40	S.W. breeze	9.0
Sept. 19	80	36	56.77	44	95	19	63.62	76		S. al. breeze	7.0
Sept. 20	68	40	55.02	28	95	30	71.06	65	0.205	N. al. breeze	9.5
Sept. 21		40								S.W. breeze	

Total rainfall 6.582 inches

Table II

Weekly Figures

Week beginning	Mean Temp.	Mean Hum. %	Max. Temp.	Min. Temp.
July 22	76.42° *	72.61 *	93.0°	51.5°
July 29	66.46 *	73.39	90.0	43.0
Aug. 5	70.26	68.30	92.0	47.0
Aug. 12	66.88	73.13	96.0	48.0
Aug. 19	65.87	75.63	85.0	46.0
Aug. 26	51.03	69.91	72.0	31.0
Sept. 2	51.34	81.67 *	79.0	33.5
Sept. 9	50.80	78.18	72.0	28.0

* Calculated.

Plate VIII

Graph

Weekly Mean Temperature.

Weekly Mean Humidity.

Table III

Summary of Morris Meteorological Data

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
No. Years Records	19	18	18	18	17	17	17	18	18	19	19	19
Monthly Mean Temperature	18	5.3	19	38.6	53.3	63.3	68.5	66	55.8	40.8	24.3	7
No. Years Records	16	16	14	23	23	22	23	23	22	22	18	18
Average Monthly Precipitation	.73	.64	.90	1.12	1.63	2.61	2.48	2.35	2.22	1.33	1.11	.56

Plate IX

Monthly Mean Temperature, Morris.

Average Monthly rainfall, Morris.

THIS MARGIN RESERVED FOR BINDING.

IF SHEET IS READ THE OTHER WAY (VERTICALLY), THIS MUST BE LEFT-HAND SIDE.

Table IV

Morris

Yearly Winter and Summer Precipitation and Mean Temperatures.

Year	Previous Winter Ppt.	Summer Ppt.	Mean Yearly Temperature
1916	5.75	14.12	33.2
1917	4.10	9.01	32.5
1918	3.15	14.34	35.7
1919	6.0		
1920	5.84	11.58	36.7
1921	5.66	19.09	38.1
1922	4.06	15.73	38.3
1923	10.95	10.36	37.5
1924	3.81	18.8 5	35.8
1925	1.70	14.66	
1926	1.15	14.17	36.1
1927	0.70	19.36	35.2
1928	1.94	13.30	38.4
1929	2.40		
1930			39.2
1931			42.0
1932			39.0
1933			38.5

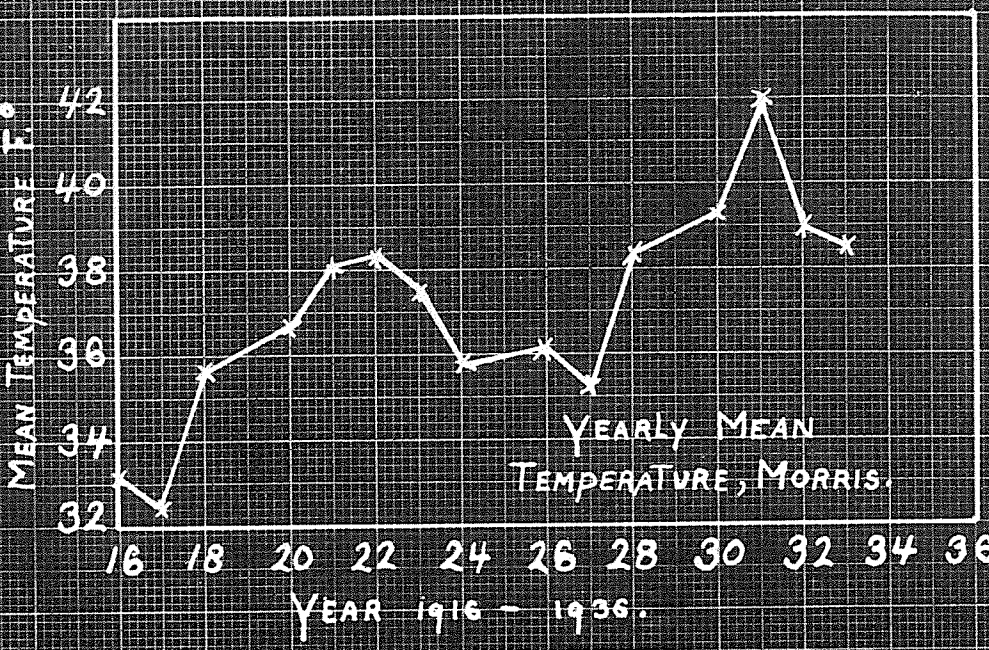
Plate X

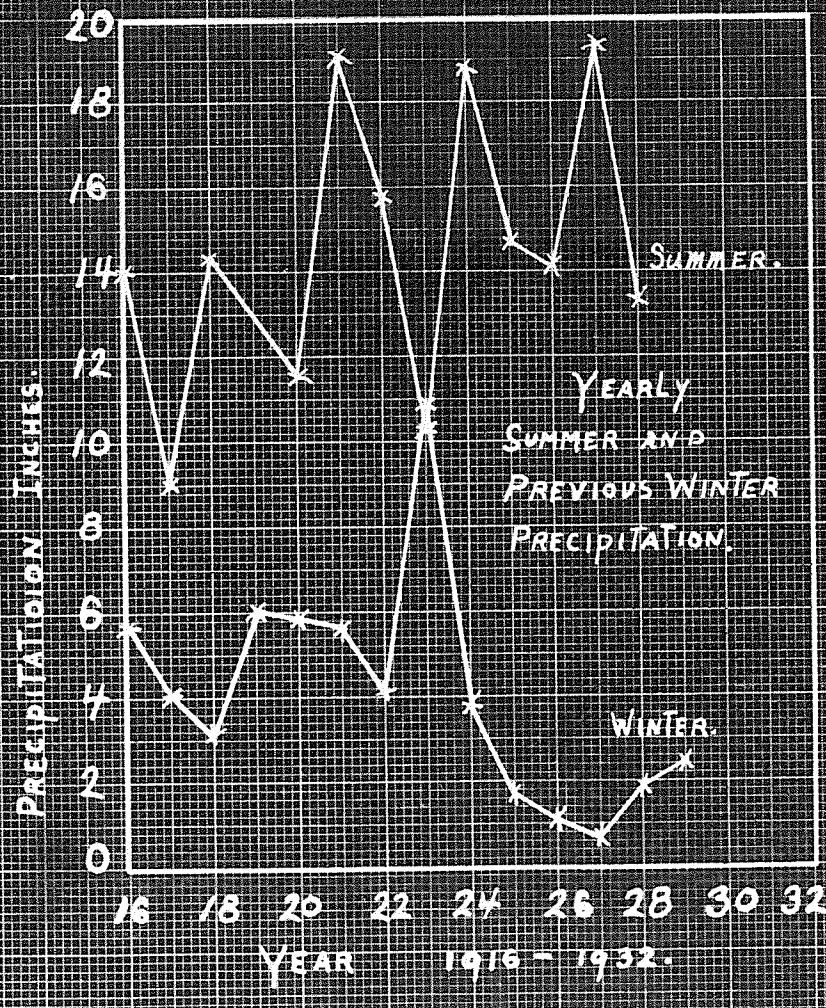
Morris

Yearly Mean Temperature.

Average Yearly Winter Precipitation.

Average Yearly Summer Precipitation.





IV METHODS

1. Observations were made at Armaud between July 17 and September 21.

The area was first surveyed for adult grasshoppers in order to determine the extent of the infestation. It was found that, taking the village of Armaud as the centre, an area six miles square, at least, could be taken as an intensive study area. Mr. H. W. Moore was then established in the town and proceeded to survey the area in detail on foot. This was done by taking round trips of eight to nine miles every day. In this way the area was covered and the study centres selected. These study centres were each chosen individually for certain interesting characteristics. Two trips of eight and six miles respectively were mapped as a day's trip each (Plate XI). The observational areas were then chosen on this route for the study of population changes. It was planned to make the two trips on two successive days and to spend the third day on general survey work, more detailed examination of certain areas or the writing up of notes. The investigator presumably walked over the area twice a week. This program was difficult to follow because of adverse weather conditions. The location of the study plots and observational areas is shown on the map (Plate XII).

2. Estimates of grasshopper populations.

The best method to be adopted for the recording of grasshopper populations was thoroughly discussed at the Lethbridge meeting. (Rept. 2: App. 4, Ent. Br. Com. Rept. Leth. 1935). It was agreed that the best and quickest method is to estimate the number per square yard. With training very close estimates of the population can be made by walking over the area. Comparable results can be obtained between various observers with a little training and the method can be adapted to changes in weather conditions. Therefore, the grasshopper population was estimated by walking over the area and recording the population for each eighth of a mile on each side of the roadallowance. When the work was first started estimates were made only every quarter of a mile, but it was found that the density of the population often varied considerably in an area of this size. Therefore, for the remainder of the period the estimates were made every eighth of a mile and recorded on a map ruled with squares representing one sixty-fourth of a square mile in area. This was found to be the most satisfactory method of recording the population changes and shifts in population in an area of this size.

In an attempt to improve on this method of studying changes in population, large quadrats were marked out on the roadallowance south of Sec. 1, T.4, R.3E. Plots twelve yards long and extending from the road into the crop about six yards were staked out. It was believed that in a small area of this type more detail could be determined regarding the shifts in population. It was found

that they were too detailed for the study and that the population on such a small area was easily disturbed and often left the area almost entirely on the approach of the observer. For minor detailed movements this plot method would prove very satisfactory but in studying a large area for seasonal and yearly population changes, the time required for these more detailed studies is too great. It was found that the less detailed estimates of every eighth of a mile gave almost as much information and as a larger area could be covered was more representative of the area.

It is recommended that in our future studies the estimates should be made in the same manner for areas of a sixty-fourth of a square mile. Instead of recording the estimates on a map it is believed that it would be more satisfactory to have a card for each area with a table on which the estimates could be inserted. It would be necessary to have a key map with the areas where the estimates were made, indicated and referred to the table.

3. Field Observations.

While walking over the areas making the estimates of population, certain general notes were made. Observations were made on the maturity of the grasshoppers, the distribution of the different species, mortality due to disease, occurrence of flights, and the temperature reactions of the different species. These notes were made on sheets kept for each day. It is recommended that in future studies, tables will be used for each of the major activities as well as the keeping of general daily notes.

The chief activities reported on were flights, oviposition, and beginning and cessation of activity. When records were made of the occurrence of the activities the soil temperature was taken with a pocket thermometer, the cloudiness, the direction of the wind and the time of the observation recorded and general notes made. The cloudiness was expressed by a number representing the condition of the sky as explained under the section on weather (p. 24).

In the case of flights, the intensity was recorded as the number of grasshoppers that could be seen at one time within the field of vision near the sun. Flights are best observed by standing so that a building or some other object just obscures the sun. Grasshoppers can then be seen as white objects drifting by in the halo of light next to the sun.

Some difficulty was found with the method of recording the occurrence of oviposition. It was assumed that when a female grasshopper had her abdomen extended and pushed into the soil she was ovipositing. In one area where records were made under many abnormal conditions it was found during the egg survey that very few

eggs had been deposited. Evidently, this criterion that oviposition is taking place is not to be depended upon.

4. Estimates of mortality due to disease.

Mortality due to disease was recorded by estimating the number of dead per square yard at the same time that the estimates of population were taken. In several locations grasshoppers were dying up the stems of grasses while in others they were dying on the ground. In some places they were dying both on the ground and up the stems. There were apparently two types of disease present.

Besides these estimates, quadrats for the counting of the dead were established. In all cases quadrats a square yard or less in area were measured out and counts of the dead made on each visit, the dead being removed each time from some of the quadrats but left on others. Besides this type, large quadrats several yards in area were measured out and the stems to which the dead were clinging marked with gauze. In this way it could be determined where the fresh dead occurred and it was unnecessary to remove the dead each time. In another case, quadrats were not staked out but the plants with dead clinging to them were marked with gauze and the area visited from time to time to record any fresh dead.

It is believed that the best method was that of taking large quadrats and marking the stems of the plants with a marker when the grasshoppers were dying up the stems of plants. This is more satisfactory as the large area takes in more specimens and as the dead are not necessarily found close together but are often found dying in different places on different days, there is a better chance of finding additional dead on the plot on future visits. In the case of the specimens that are found dead on the ground, the small quadrat proved very satisfactory as the number of dead in a small area was greater in most cases.

5. Method of egg survey.

The method of egg survey was the same as that used in the general grasshopper egg survey of the province except that it was more intensive. A square foot of soil was examined for the number of grasshopper egg pods by progressively scraping layers off the surface of the soil, exposing the egg pods, or by digging up a square foot of soil to a depth of two inches and passing it through a sieve, eighth inch mesh, counting the egg pods in the sieve and estimating the eggs which pass through. The second method is much easier and quicker than the first in drift, loose or light soil, but in the clay soil of the Armand area it is useless except for summer fallow or drift soil. In the survey of the Armand area a plasterer's trowel was used for scraping off the soil in layers as described above. The edges of the trowel were sharpened and a file carried to keep them sharp. When the soil was very hard the back of the

trowel was used as an axe to cut the soil into narrow strips which could then be examined by breaking these strips by hand.

The method of sampling was to take strips across the road-allowance at four or five different places in each mile. The first strip was taken about a sixteenth of a mile from the corner and the second just after the quarter mile line. One was taken just at the half mileline, one at the three quarter mile line and one just before the end of the mile. In each strip the following samples were taken: two in the field on each side of the road, two in the field but near the edge, some just outside the field in the different types of vegetation, some on the level part of the roadallowance, along the top of the ditch, on each slope of the ditch and along the edge of the road.

The number of samples varied somewhat depending on the number of eggs found in the most typical situations and the number of different types of vegetation. The results were placed on the map as the number of pods per square foot and at the same time the type of vegetation, the slope and other details were recorded on another page. On the map the numbers representing pods per square foot were followed by a letter indicating the species. Thus, a number followed by "B" was used to indicate pods of M. bivittatus per square foot while "C" indicated C. pellucida. When pods of M. bivittatus and C. pellucida or any other species were found in the same square foot sample an addition sign was placed between the two counts which were indicated as above, for example, 2 B + 3 C. In the case of a sample containing no egg pods the record was indicated as zero. Combined maps of the egg survey, native vegetation and cultivated crops have been prepared for each study plot and observational area. Each sample was recorded with details of slope, type of soil and vegetation. From this data information was secured concerning the selection of egg laying sites by the different species of grasshoppers.

A record was made of the number of predators found in each square foot sample examined. The species of the pod attacked, the species of the predator and the amount of damage that had been done was noted. If any egg pods were found in poor condition, this was also recorded.

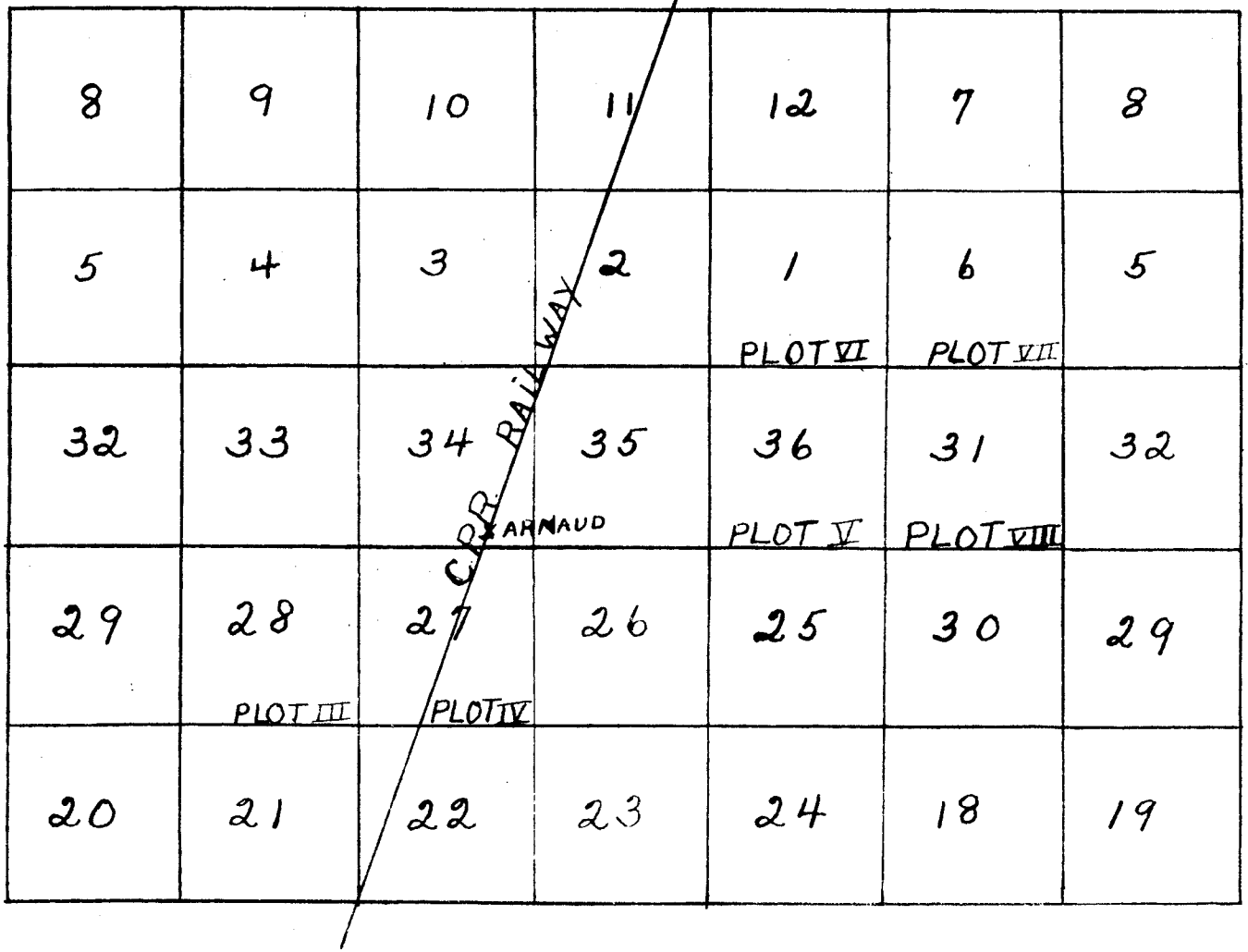
V DETAILED STUDY PLOTS

1. Treatment of the detailed study plots.

The detailed study plots were selected, not only on the basis of the grasshopper population, but also with some regard to the plant communities represented, the direction of the roadallowance, whether east and west or north and south, the topography, the adjoining crops, the presence or absence of disease among the grass-

Plate XI

Map of the area immediately surrounding Arnaud showing the sections and the location of the study plots.


8
9
10
11
12
7
8
5
4
3
2
1
PLOT VI
6
PLOT VII
5
32
33
34
35
36
PLOT V
31
PLOT VIII
32
C.R.R. RAILWAY
ARNAUD
29
28
PLOT III
27
PLOT IV
26
25
30
29
20
21
22
23
24
18
19

hopper population, and also the proximity of the area to the daily route of travel. These plots were chosen, then, because of certain interesting features which they possessed and were studied in reference to these characteristics. It is unfortunate that in some cases the factors for which a plot had been chosen disappeared before they could be thoroughly investigated.

The population was estimated and recorded on these areas as described under methods (P. 35), every time that these plots were visited. At the same time general notes of conditions were made and filed under the heading of that plot. In these notes the population was compared with the conditions for the previous day without reference to the notes. This served as a check on the estimates. The frequency of oviposition and the effect of farming practices in the adjoining fields on the grasshopper population was recorded. During the season the vegetation on each area was mapped in detail and photographs taken to illustrate the general character of each plot. During the fall egg survey special attention was paid to the number of predators present and to the habitats in which eggs were found.

Plate XII

Photograph of part of the general observational area V on the west roadallowance of Sec. 36, T. 3, R. 3E. This is the ditch on the east side of the road at the north end of the mile. An idea of the height of the vegetation can be obtained from the height of the observer standing in the foreground. The vegetation is described under the general observational area (P. 157) and is under the location XI on the map on Plate XXXVII.

Plate XIII

A view of part of Study Plot I showing the strip of drift soil a quarter of a mile north of the half mile line on the west side of the road on the roadallowance west of Sec. 34, T. 3, R. 3E. The vegetation is described in detail (P. 47) under Plot I as indicated on the map on Plate XXII under location XI.

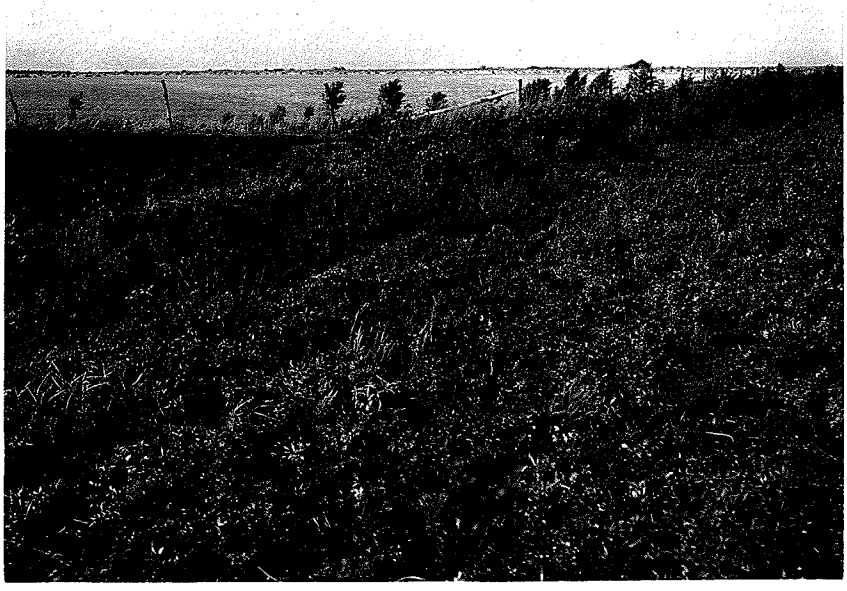


Plate XIV

A portion of Study Plot II which is described for this Plot (P. 58) under location XVI on the map on Plate XXIII. This strip of soil on the north side of the south road-allowance of Sec. 33, T. 3, R. 3E. is the most heavily egg infested area in the district and probably in Manitoba this year. Pods of M. bivittatus eggs run as high as 65 pods per square foot.

Plate XV

Photograph showing portion of the reverted land on the northwest quarter of Sec. 28, T. 3, R. 3E part of the Study Plot III. The vegetation is described from this plot (P. 67) under location III on the map shown on Plate XXIV.

Plate XVI

A part of Plot IV is shown in this photograph. It is the north side of the south roadallowance of Sec. 27, T. 3, R. 3E., the vegetation of which is described for Plot IV (P. 78) under locations I and II shown on the map on Plate XXV. This roadallowance had a heavy population of C. pellucida but they moved out and the majority of the eggs deposited were those of M. bivittatus except for some C. pellucida along the fence.

Plate XVII

This photograph shows the old buildings described under Plot V, an area of hayland infested with C. pellucida and M. bivittatus. The vegetation is described for Plot V under locations II, III, VI and VII shown on the map (Plate XXVI).

Plate XVIII

Part of Plot V showing location I as indicated on the map (Plate XXVI) and the vegetation of which is described under Plot V (P. 84). The investigator is shown in the act of examining a clump of pea sod for grasshopper egg pods. The type of plasterer's trowel used in the egg survey can be seen.

Plate XIX

Part of Plot VI, the west end of the north side of the south roadallowance of Sec. 1, T. 4, R. 3E. This roadallowance borders a field of rye and at the east end a crop of thatcher rust-resisting wheat. The row of white buildings in the distance are the granaries of Mr. H. Lillijord and contain the thatcher wheat sold to the Provincial Government for seed to be distributed among the farmers in Manitoba. The vegetation is described for Plot VI (P. 91) under location V as indicated on the map (Plate XXVII).

Plate XX

A portion of Plot VII the vegetation of which is described for the plot (P. 100) under location VII indicated on the map (Plate XXVIII). The level area was thought to be C. pellucida egg bed at the first of the season but the C. pellucida later left the area and the population became mainly M. bivittatus. An idea of the height of the grades and the depth of the ditches can be arrived at by the comparison with the height of the investigator who is standing in the ditch.

Plate XXI

Portion of Plot VIII showing the pasture field, the poplar and willow bluff, and part of the Armand grade running west toward town. The vegetation is described under locations VIII, IX, and XI, of Plot VIII (P. 111) as indicated on the map on Plate XXIX.

2. Detailed study plot I.
(The west roadallowance of Sec. 34, T. 3, R. 3E.)

(1) Reasons for selection.- The plot was selected because of the heavy population of M. bivittatus and the high mortality due to Empusa grylli Fr.

(2) General description.- This plot was established on July 22 and consisted at first of the south half mile of the east side of the roadallowance where there was a heavy mortality due to Empusa grylli Fr. On August 9 it was extended to take in the whole south three-quarters of the mile because of the high population and the presence of a bank of drift soil extending for a quarter of a mile north of the half mile line on the west side.

The roadallowance was bordered (Map, Plate XXII) on the east, starting from the south, by a field of summer-fallow, a field of durum wheat and another field of summer-fallow. On the west side of the road, starting from the south, there were fields of summer-fallow, barley and durum wheat.

The road was a low grade with a ditch about four yards wide and two feet deep on the west side and a narrow bank along the edge of the summer-fallow. On the east side there was a shallow ditch about one and a half feet deep along the edge of the summer-fallow with a gradual slope up to the grade and a steep slope up to the edge of the field. On July 27 the east side of the roadallowance was mowed but never raked. The west side had been cut and raked before July 15 and there was a good growth of grass by the end of July.

(3) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXII). In all cases the plants are listed in order of abundance.

The vegetation I was about one foot high until cut on July 27 and consisted of Phleum pratense, Orchard grass (?), and Poa compressa with some Andropogon furcatus. Bushes of Rosa blanda, Aster laevis and Aster multiflorus, were also present in considerable numbers. There was an occasional plant of Artemisia ludoviciana, Polygonum convolvulus, Salix longifolia, and Salix babbiana.

On the east side II was similar to I but the plants were not so luxuriant or coarse and the following differences were noteworthy. There was more sod with some bare patches and a number of plants of Taraxacum officinale. The road was bordered by Rosa blanda. Aster multiflorus, A. laevis, and Orchard grass were fairly abundant with an occasional plant of Artemisia ludoviciana.

At III there was some Aster laevis and A. multiflorus with large patches of Artemisia ludoviciana and Andropogon furcatus.

At IV patches of Spartina michauxiana, Bromus inermis, and Andropogon furcatus occurred.

At V Poa compressa was predominent with some Spartina michauxiana two and a half feet high along the edge of the ditch.

At VI the vegetation consisted chiefly of Rosa blanda.

At VII the ditch contained chiefly Andropogon furcatus, with some Bromus inermis along the edge of the road. There was some Poa compressa, Aster laevis, A. salitiflorus, Rosa blanda, Solidago canadensis, Polygonum aviculare, and a few clumps of Salix longifolia.

At VIII there was more Rosa blanda and the grass was more luxuriant.

At IX Amaranthus graecizans, and A. retroflexus were predominant.

At X there was a ridge of recently deposited drift soil with clumps of Poa compressa, Phleum pratense, and Spartina michauxiana.

At XI there was an area of drift soil grown up to Chenopodium alba, Amaranthus retroflexus, Solidago rigida and Rosa blanda. (Plate XIII).

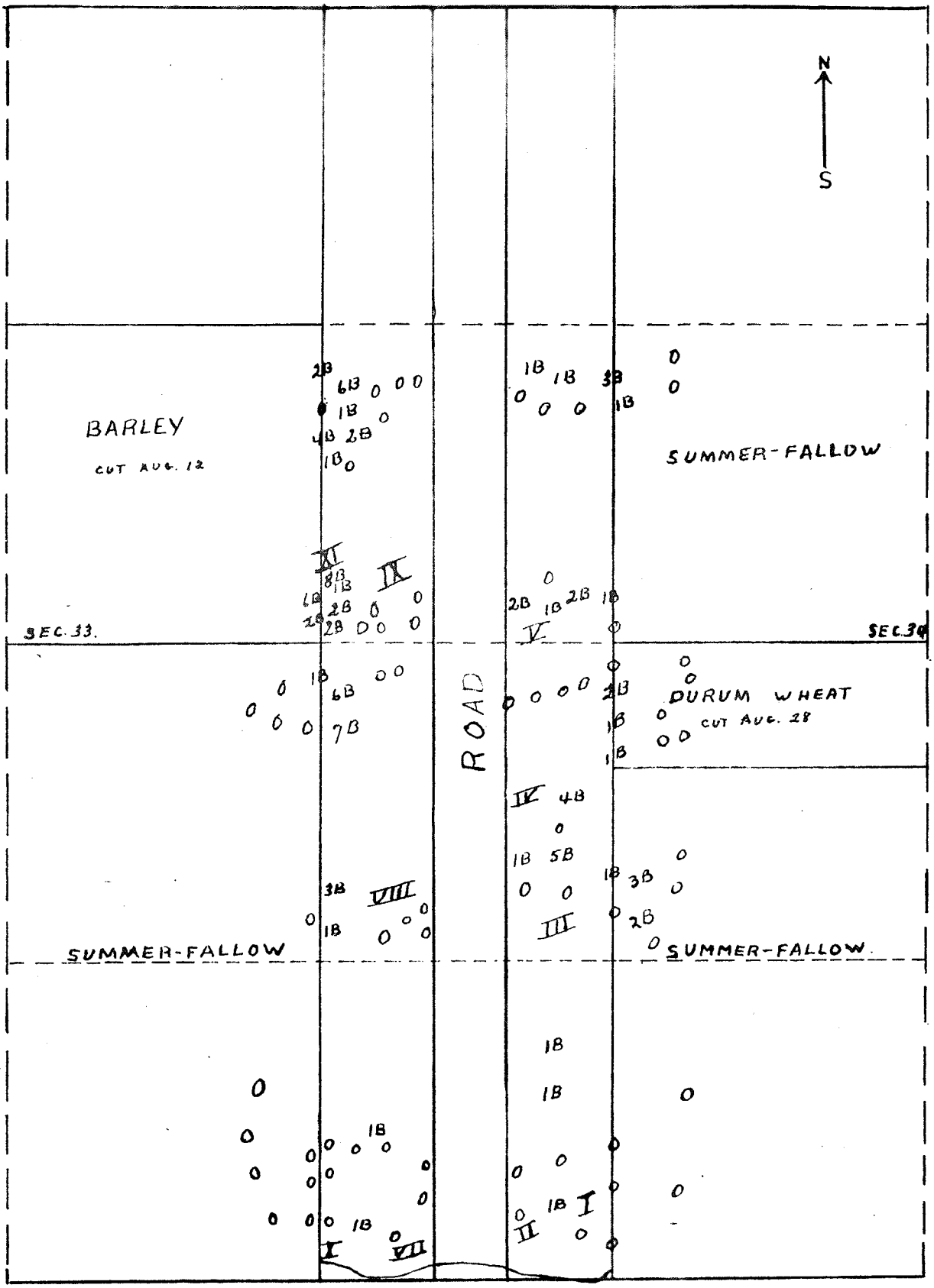
The west side of the roadallowance was cut for hay before July 15 and by the first of August had grown to a height of six inches. The east side of the road was cut for hay on July 27. The chief grasses present along this mile were Phleum pratense, Poa compressa, Spartina michauxiana, Orchard grass and Andropogon furcatus. Rosa blanda and Aster were numerous. North of the half mile line on the west side of the road the chief vegetation was Chenopodium alba and Amaranthus retroflexus.

(4) Grasshoppers.- The living population in July 23 was 25 per square yard and ran as high as 35 per square yard. It was 80 percent M. bivittatus. The chief species of grasshopper present along this mile was M. bivittatus, on the east side of the road with a few C. pellucida and M. Femur-rubrum at the south end of the mile. On the west side of the road M. bivittatus was the major species but there was about 10 percent of Chortophaga curtipennis present along the ditch. M. dawsoni and M. angustipennis were also present in small numbers.

Estimates of population were made every eighth of a mile from south to north along each side of the road. These are tabulated in the following tables (Table IV and V). The figures in the column headed "Averages" represent the average population per square yard. This value is derived by averaging the estimates taken at eighth mile intervals along each side of the

Plate XXII

A map of Plot I along the west roadallowance of Sec. 34, T. 3, R. 3E. The Roman numerals mark locations used in the description of the vegetation. The crops and use of the land in the season of 1935 are indicated with the dates of cutting of the crops. The results of the egg survey are also shown on the map; for example, 2B indicates 2 pods of M. bivittatus per square foot, 2C indicates 2 pods of C. pellucida per square foot, 2B + 2 C indicates 2 pods of C. pellucida and 2 pods of M. bivittatus in the same square foot, 0 indicates that there were no eggs present in the square foot sample examined. The transverse line at the bottom of the map shows the roadallowance in cross section.


N
S
BARLEY
CUT AUG. 12
SUMMER-FALLOW
SEC. 33.
SEC. 34
ROAD
DURUM WHEAT
CUT AUG. 28
SUMMER-FALLOW
SUMMER-FALLOW

road. (Graph 1 Plate XXX). The graph indicates the fluctuations in population during the study period. The average population for the season is given at the bottom of the table.

Table IV
Population Estimates
(For the east side of the road from south to north)

Date	Pop. per square yard for eighth mile divisions 0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	Av. pop. per Sq. Yd.
July 23	10	20	35	25	25	23.0
July 30	15	20	10	6	20	14.2
Aug. 6	10	12	15	12	15	12.8
Aug. 9	10	12	10	10	10	10.4
Aug. 14	10	15	10	10	10	11.0
Aug. 23	6	10	8	12	15	10.2
Aug. 29	3	2	3	5	3	3.2
Average population per square yard for the season						12.1

Table V
Population Estimates
(For the west side of the road[illegible] from south to north)

Date	Pop. per square yard for eighth mile divisions 0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	Av. pop. per Sq. Yd.
July 23	6	6	6	6	8	6.4
July 30	8	8	4	10	15	9.0
Aug. 6	10	15	12	10	20	13.4
Aug. 9	10	12	10	8	20	12.0
Aug. 14	10	8	10	10	18	11.2
Aug. 23	10	15	20	15	15	15.0
Aug. 29	2	4	4	3	6	3.8
Average population per square yard for the season						10.1

(5) Disease.- A large number of dead M. bivittatus were found up the stems of plants on the east side of the road on July 22. These grasshoppers died of the fungus Empusa grylli Fr. On July 23 the maximum dead was estimated at 25 per square yard indicating a high mortality. In one case 9 dead were found clinging to a single plant. M. bivittatus continued to die along here even after the grass was cut on July 27. No C. pellucida were found dead at any time. Although a large number of M. bivittatus died, the effect on the living population did not seem to be noticeable. (Graph I Plate XXX), however, indicates a decrease in the population due to this disease between July 23 and July 27. On August 9 the plot was extended to take in a piece of drift soil (X). Empusa grylli was present all along this drift soil to a small extent.

On August 14 a large number of M. bivittatus (P. 205) were found dead on the ground in this locality, apparently from another disease. Some of these specimens were quite fresh while others were old and brown. In the small ditch the average number of dead was about 6 per square yard while on the level part between the ditch and the road the average was less than one per square yard. In many places in the ditch there were 5 dead per square foot. Although conditions were not suitable for the study of Empusa grylli, an opportunity was presented to study a second disease. The cause of death in the second case is not known. Specimens sent to Ottawa for examination did not contain Empusa grylli (P. 205). Plots were established for the study of this second disease.

In an attempt to ascertain the rate of mortality from this disease four quadrats two feet square were marked out as follows:

Quadrat I in the bottom of the ditch. The ground was mostly bare but there was some Chenopodium album and Rosa blanda.

Quadrat II on the drift soil along the fence. The vegetation consisted of Rosa blanda, Solidago canadensis, Bromus inermis and Artemisia ludoviciana.

Quadrat III in the bottom of the ditch. It was bare of vegetation except for one plant of Amaranthus graecizans.

Quadrat IV on top of the drift soil. The vegetation consisted of Amaranthus graecizans.

Table VI

Results of Counts

Date	Quadrat I	Quadrat II	Quadrat III	Quadrat IV	Total
Aug. 14	16	22	20	20	78
Aug. 27	8[A]	3[AA]	0	5[AAA]	16
Aug. 29	1	0	0[AAAA]	0	1
Sept. 4	0	0	0	0	0
Total	25	25	20	25	95

Notes.

A All the grasshoppers were old and partly destroyed. They had probably been blown in. A cricket, Gryllus assimilis Fab., which had recently died apparently of the disease, was found.

AA All appeared to have died recently.

AAA In addition one was found dead clinging to a stem. It had apparently died of Empusa grylli.

AAAA One was found dead clinging to a stem.

Summary of table

There were 78 dead on the 4 quadrats when they were marked out on August 14.

On the 4 quadrats 17 died in 21 days.

Average dead per day for the 4 quadrats was 0.81.

" " " " per square yard was 0.45.

Average living population from August 14 to August 29 was 13 per square yard.

Daily mortality was 3.46% of the population.

The results are not very satisfactory. The quadrats were chosen because there was a large number of dead. Two weeks later there were some dead on the quadrats. The majority of them in

the ditch were on quadrats I and III. They looked as if they had been blown in. There were some fresh dead specimens on quadrats II and IV. After this date few dead were found. Many were still dying on the ground around the quadrats but very few on the quadrats.

The results were somewhat confused by the presence of Empusa grylli which became noticeable on August 23. 10 grasshoppers were observed dead up the stems of plants in six square yards adjoining the quadrats.

In studying mortality by the above method to get accurate results it would be necessary to have at least a dozen quadrats of a square yard each in area. They should also be visited every day for the following reasons; (a) Specimens may be blown off or into the quadrats, (b) Specimens might be lost due to the activities of birds, small mammals, ants, crickets, grasshoppers and other insects, (c) Specimens dying up the stems might fall off or be blown off and thus confuse the cause of death. All specimens should be examined by a competent mycologist and bacteriologist to determine the pathogenic organism. In 1935 it was impossible to visit the plots this often because of the size of the study area, lack of transportation and weather conditions. We did not have available the services of a specialist who could identify the disease organism in all specimens.

More grasshoppers died of Empusa grylli on this area, especially on the east side of the roadallowance, than on any other area studied in the Armand district. All the dead found were M. bivittatus. As many as 25 dead grasshoppers per square yard were found up the stems of plants on July 22 when the plot was established. The grasshoppers continued to die to some extent even after the grass was cut on July 27. There was no noticeable decrease in the living population due to the disease.

(6) Egg survey.- The map (Plate XXII) shows the results of the egg survey.

In this mile 106 square foot samples were examined and 90 pods of M. bivittatus eggs and 69 acres obtained.

The average adult population along this area was found to be 11.10 during the period from July 23 to August 29. The total number of egg pods deposited in 106 square feet was 90 (Table VII). The average number of egg pods per square foot was 0.39 in the fields and 0.99 per square foot along the roadallowance.

The results of the egg survey are summarized in the following table (Table VII) which shows the average number of egg pods deposited per square foot in each area. The rating of the infest-

ation for each area and for the mile, based on the eggs found, is given.

Table VII
Results of Egg Survey

Location	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating based on egg infestation
West side- S. $\frac{1}{8}$ mile	2	8	2B	0.20	normal
" " $\frac{1}{8}$-$\frac{1}{4}$ "	4	7	17B	1.54	light
" " $\frac{1}{4}$-$\frac{3}{8}$ "	10	11	29B	1.38	light
East " S. $\frac{1}{8}$ "	3	4	3B	0.43	normal
" " $\frac{1}{8}$-$\frac{1}{4}$ "	3	8	10B	0.90	normal
" " $\frac{1}{4}$-$\frac{3}{8}$ "	5	4	7B	0.77	normal
Summer-fallow Sec. 33	1	12	1B	0.077	normal
" " Sec. 34	3	7	6B	0.60	moderate
Durum wheat Sec. 34	1	3	2B	0.50	moderate
Summer-fallow Sec. 34	3	3	5B	0.83	heavy
Barley stubble Sec. 33	2	2	8B	2.00	heavy
	37	69	90B[A]	0.85	normal

A It will be noticed that this figure does not correspond with the figure on Table VIII for the total M. bivittatus egg pods. This is because of two series of records being kept, one on the map for infestation and one in notes for vegetation and slope. Omissions were sometimes made in recording the results of the samples

AA See page 198.

(7) Association and slope where eggs are found.- During the egg survey the association and slope where the eggs were found was recorded. These data are presented in the following table.

From the data in the table it can be readily seen that M. bivittatus much preferred the east slope to the west slope for laying eggs.

The table also indicates that M. bivittatus shows a preference for drift soil. In the table the order of preference seems to be Taraxacum officinale (dandelion), dandelion and rose bush (Rosa blanda) and rose bushes and bare ground.

Barley stubble was more heavily infested than durum wheat stubble or summer-fallow.

No C. pellucida egg pods were found on this plot.

Table VIII
Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq.ft. samples with eggs	Sq.ft. samples without eggs	Total no. of egg pods	Av. pods per sq. ft.
Dandelion		4	2	7B	1.17
Dandelion and Giant Blue Stem	E. slope	4	4	6B	1.00
Brome		4	9	6B	0.61
Rose bush and bare ground		2	1	3B	1.00
Couch grass	W. slope	0	3	0	0.00
Drift soil	E. slope	15	5	48B	2.40
Drift soil	level	3	5	4B	0.50
Drift soil	W. slope	3	3	7B	1.17
Summer-fallow border		3	14	6B	0.42
Summer-fallow		0	13	0	0.00
Barley stubble		2	2	8B	2.00
Durum stubble		6	19	14B	0.56
For the mile		48	80	115B	0.9

(8) Predators.- In 128 square foot samples examined during the egg survey 16 coarctate and 4 scarabaeoid blister beetle larvae, 5 carabid beetle larvae, 4 bee fly larvae and one wireworm were found associated with egg pods. Of these 3 carabids and 3 bee fly

larvae were found feeding in M. bivittatus egg pods. One egg pod of M. bivittatus was found partly destroyed by red mites.

80 percent of the blister beetle larvae were in the coarctate stage when this survey was made on September 9.

In the 128 square feet examined 32 predators and 135 M. bivittatus egg pods were found. The ratio of egg predators to egg pods was 1:4.22.

(9) Observations.- The graph 1 (Plate XXX) shows a fall in the population on the east side of the road between July 23 and July 30 and a rise on the west side of the road. The rise on the west side was not as great as the fall on the east. There was a large number dead of Empusa grylli on the east side on July 23 and the grasshoppers continued to die until the grass was cut on July 27. Therefore, this fall in population on the east side must have been due partly to a shifting of population over to the west side and partly to a decrease in population by Empusa grylli.

From July 30 to August 6 the population on the east side decreased and that on the west side increased almost in similar amounts. This seems to indicate that there was a further shift in population from the east to the west side after the grass on the east side of the road was cut on July 27.

After August 6 the population on both sides of the road began to decline but between August 14 and August 24 there was a sharp increase on the west side followed by a rapid decline while the east side continued in an unbroken decline. The high estimate on the west side of the road on August 24 does not correspond with the time of cutting of the crops and there was no apparent reason for the increase in population.

(10) Conclusions and summary.

(a) This plot was chosen because of the large population of M. bivittatus and the high mortality due to Empusa grylli Fr.

(b) The dominant plants, in order of importance, were Phleum pratense, Poa compressa, Orchard grass, Andropogon furcatus, Rosa blanda, Spartina michauxiana and Aster. In one place there was a predominance of Chenopodium alba, Amarantus retroflexus and A. graecizens.

(c) The predominant species of grasshopper was M. bivittatus. Other species present were C. pellucida, M. femur-rubrum Chorthippus curtipennis, M. dawsoni and M. mexicanus.

(d) Although Empusa grylli killed off more M. bivittatus

on this area than on any other area near Armaud, conditions were not suitable for a study of the rate of mortality. An opportunity was, however, presented to study a second disease the causative organism of which has not been identified. An attempt was made to determine the mortality due to this second disease by the quadrat method. The daily mortality was found to be 3.46 percent of the population.

(e) It was concluded that, to obtain satisfactory results in a study of the rate of mortality by the quadrat method, it would be necessary to have at least a dozen quadrats of a square yard in area and to visit them at least once a day.

(f) The average population per square yard on the west side of the road for the period from July 23 to August 29 was 10.1 and on the east side was 12.1.

(g) The average number of egg pods per square foot along the roadallowance was 0.99 and in the field 0.59. The infestation for this mile was rated as "normal."

(h) M. bivittatus preferred the east slope to the west slope for egg laying. The order of preference for vegetation was dandelion, dandelion and rose bushes, and rose bushes and bare ground. Barley stubble was more heavily infested than durum wheat stubble or summer-fallow.

(i) No C. pellucida egg pods were found in this plot.

(j) The ratio of egg predators to egg pods was 1:4.22.

(k) One wireworm was found associated with the egg pods but was not observed feeding.

(l) 80 percent of the blister beetle larvae were in the coarctate stage on September 9.

(m) The population shifted somewhat from the east to the west side of the road when the grass on the east side was mowed on July 27. The west side had been mowed before July 15 and by July 27 was quite luxuriant. This shift was probably due to disturbance by the mower and the lack of food and protection.

3. Detailed study plot II.
(The south roadallowance of Sec. 33, T. 3, R. 3E.)

(1) Reasons for selection.- This plot was selected because of the heavy infestation of M. bivittatus.

(2) General description.- This plot was established on July 22 and consisted, at first, of a road running north and south along the half mile line on Sec. 33 between a field of summer-fallow on the south-east quarter and a field of cereal wheat on the south-west quarter. The plot was later extended to take in the whole mile of the south roadallowance because the majority of the population shifted from the original plot to the east half mile on the south side. The west half of the mile was included because of the heavy population of M. bivittatus.

The roadallowance was bordered on the south, starting from the east, by a field of durum wheat, summer-fallow, a pasture and buildings west of the half mile, and fields of oats and durum wheat. The south-east quarter of Sec. 33 was summer-fallow and the south-west quarter was cropped to coree wheat.

The road was a high grade, part of the Arnaud grade west of town, with a ditch about three feet deep on the south side of the road and a ditch about two feet deep on the north side. There was a flat grassy strip six yards wide on the south side between the ditch and the field with a wagon road down the centre of it. On the north side there was a strip about one and a half yards wide, between the ditch and the field, on which the vegetation was undisturbed except for some fresh drift soil towards the end of the season.

(3) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXIII). In all cases the plants are listed in order of abundance.

The level area I had a wagon trail down the centre of it which cut up the vegetation. The centre of this trail and the edge of the road was grown up to Amarantnus retroflexus. On the rest of the area there was chiefly Phleum pratense and Poa compressa. There were many bare spots. Chenopodium alba, Rosa blanda, Aster laevis, A. multiflorus, Iva xanthifolia, Taraxacum officinale, and seedlings of Thlaspi arvense were also present. Between the trail and the crop the Chenopodium alba was about three feet in height while the rest of the vegetation ranged between two and six inches.

West of the corner II there was an increase in the amount of Chenopodium alba and Iva xanthifolia. There was also a large amount of Hordeum jubatum, Orchard grass, and Helianthus maximiliani. In one place a patch of durum wheat jutted out onto the grassy roadallowance.

The vegetation along the edge of the summer-fallow III was very patchy. Phleum pratense and Hordeum jubatum and Orchard grass were the chief plants but the plants listed under location I also occurred to some extent. Artemisia ludoviciana and Polygonum aviculare were also present.

At IV the vegetation was patchy with a large percentage of Taraxacum officinale, a little Poa compressa and bushes of Rosa blanda. Along the fence by the buildings the Chenopodium alba was one to three feet high with an occasional Iva xanthifolia. There was some Phleum pratense, Aster laevis and A. multiflorus present.

For the rest of the mile V the vegetation was almost

entirely Orchard grass and Amaranthus retroflexus, with some Andropogon furcatus and the other plants listed under I.

The ditch on the south side of the road VI was filled with a luxuriant growth of Spartina michauxiana, Andropogon furcatus and Salix longifolia. Bushes of Rosa blanda, Orchard grass, Aster laevis, A. multiflorus and Phleum pratense were also present. The edge of the road was bare except for bushes of Rosa blanda, Euphorbia serpyllifolia and a few Salix longifolia (two to three feet high).

One fifth of a mile west the road VII was bordered by Amaranthus retroflexus, A. graecizans, Euphorbia serpyllifolia, and Rosa blanda.

One eighth of a mile further west VIII the vegetation along the ditch became chiefly Andropogon furcatus, Salix longifolia, Aster laevis, A. multiflorus, seedlings of Apocynum cannabinum, bushes of Rosa blanda, with some Artemisia ludoviciana.

The west half mile IX continued almost the same but with Rosa blanda along the road and more Amaranthus graecizans, Euphorbia serpyllifolia, and Orchard grass.

The slope of the grade X was mostly bare but there were numerous plants of Rosa blanda, Salix longifolia, Euphorbia serpyllifolia, and Orchard grass.

One fifth of a mile farther west XI there was some Amaranthus retroflexus along the slope of the road.

At XII there was chiefly Salix longifolia and Rosa blanda with some Euphorbia serpyllifolia, Amaranthus graecizans and Andropogon furcatus.

At XIII there was Taraxacum officinale, Phleum pratense, and Poa compressa. Drift soil had almost covered the grass this fall. There was some Rosa blanda, Aster laevis, A. multiflorus, Solidago canadensis and Artemisia ludoviciana.

One eighth of a mile farther west XIV there were areas of Bromus inermis and at the quarter mile line XV the vegetation consisted chiefly of Agropyron repens, Poa compressa and Phleum pratense with some Andropogon furcatus and Bromus inermis. There was some Rosa blanda, Taraxacum officinale, Salix longifolia, Aster laevis and A. multiflorus.

Along the edge of the corse wheat (Plate XIV) XVI the

growth was much coarser but there were many bare spots. The vegetation was chiefly Phleum pratense, Andropogon furcatus, and Orchard grass. Rosa blanda, Artemisia ludoviciana, Helianthus maximiliani, Solidago canadensis, Aster laevis, A. multiflorus and Amaranthus retroflexus were also present.

Along the road by the cereo wheat XVII the vegetation was light and patchy and consisted of Rosa blanda, Amaranthus retroflexus, Orchard grass, Chenopodium alba, Polygonum convolvulus, and Aster laevis and A. multiflorus.

The predominant native plants along this mile were Taraxacum officinale, Amaranthus retroflexus, A. graecizans, Rosa blanda, Euphorbia serpyllifolia, Chenopodium alba, Iva xanthifolia and Aster. The grasses present were Phleum pratense, Hordeum jubatum, Andropogon furcatus and some Poa compressa.

(4) Grasshoppers.- The grasshopper along this mile were chiefly M. bivittatus with a few C. pellucida. On July 22 the average population on the south side of the road for the east half mile was 7 per square yard while on the west half mile it was 30 per square yard. At the half mile line along the edge of the cereo wheat on Sec. 33 the population was averaged on July 22 as 25 per square yard, 80 percent M. bivittatus, 13 percent C. pellucida and the rest were M. mexicanus and M. femur-rubrum. The population along this half mile line decreased before August 6 to an average of 12 per square yard.

Estimates were made every eighth of a mile from east to west along each side of the road and along the half mile road. These are tabulated on the following tables (Table IX, X and XI). The average for the mile is indicated in the column headed "average". The average per square yard for the entire season is also given. They are plotted on graph 2 (Plate XXX). The graph indicates the fluctuations in the population during the study period.

Plate XXIII

Map of the south roadallowance of Sec. 33, T. 3, R. 3E., and the half mile road on Sec. 33, studied under detailed study plot II. The cross section of the roadallowance is shown at each end. The symbols are the same as described for Plate XXII.

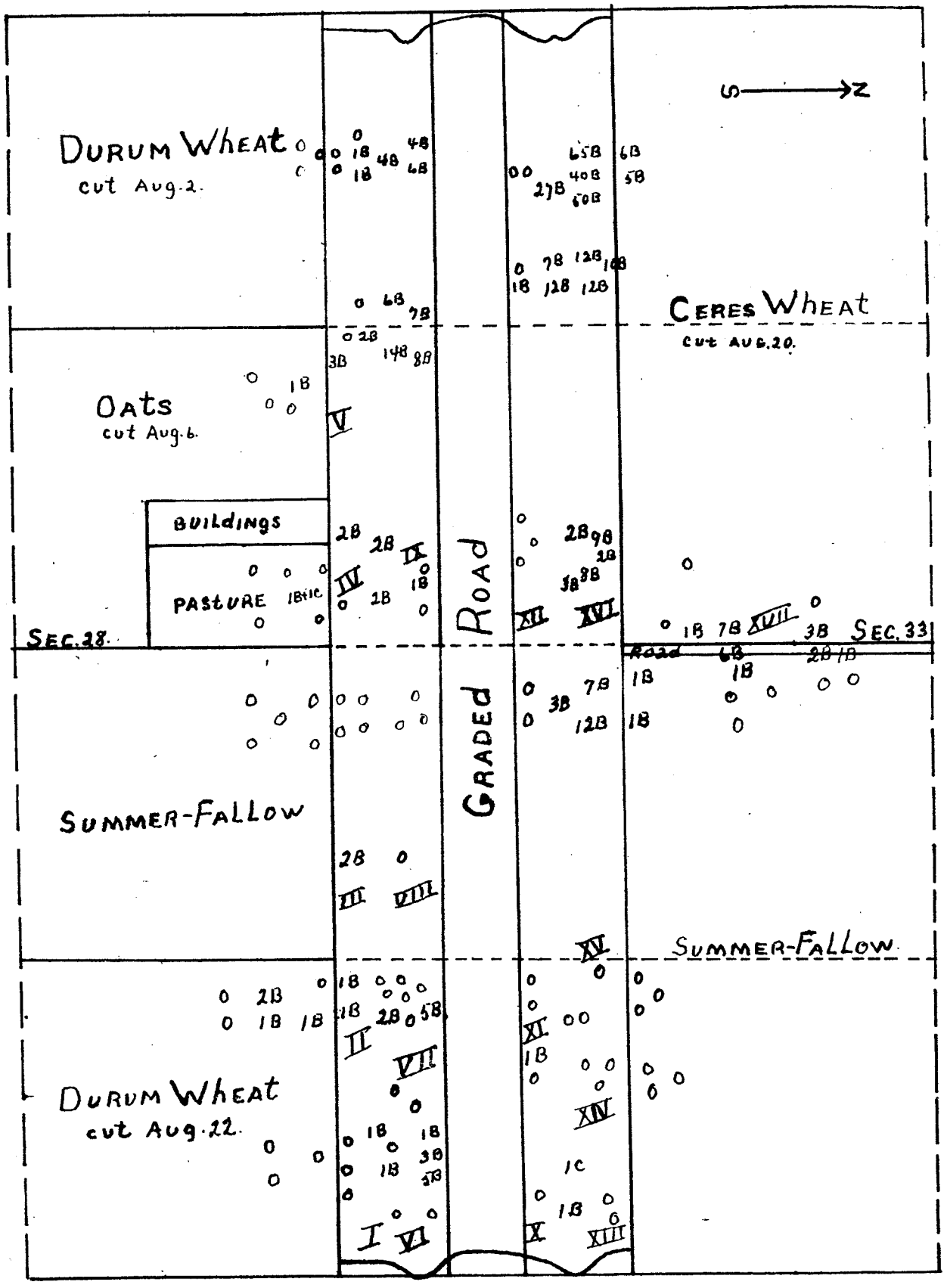

S → N
DURUM WHEAT
cut Aug. 2.
CERES WHEAT
cut AUG. 20.
OATS
cut Aug. 6.
BUILDINGS
PASTURE
SEC. 28.
SEC. 33
Road
GRADED ROAD
SUMMER-FALLOW
SUMMER-FALLOW
DURUM WHEAT
cut Aug. 22.
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIII
XIV
XV
XVI
XVII

Table IX
Population Estimates
(For the south side of the road from east to west)

Date	Population per square yard for eighth mile divisions								Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
July 22	16	10	12	12	15	15	30	30	17.5
July 30	25	20	10	15	15	15	15	20	16.9
Aug. 2	15	15	15	10	15	15	15	20	15.0
Aug. 6	15	15	10	10	15	15	10	18	13.5
Aug. 9	15	25	20	10	20	10	15	20	16.8
Aug. 23	20	25	25	14	15	10	15	15	17.4
Sept. 14	1	1	0	0	2	2	2	2	1.25
								Average population per square yard for the season	14.1

Table X
Population Estimates
(For the north side of the road from east to west)

Date	Population per square yard for eighth mile divisions								Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
July 22	15	15	15	15	7	7	5	5	10.5
July 30	18	18	20	10	7	7	5	5	11.25
Aug. 2				10	20	20	20	20	18.00
Aug. 6	6	6	8	8	15	18	20	18	12.4
Aug. 9	6	6	8	8	12	15	20	18	11.6
Aug. 23	10	6	6	8	2	12	12	15	8.8
Sept. 14	3	3	1	2	1	4	4	6	3.0
								Average population per square yard for the season	10.5

Table XI
Population Estimates
(For the half mile road on Sec. 33 from south to north)

Date	Pop. per square yard for eighth mile div. 0-1/8	1/8-1/4	1/4-3/8	Av. pop. per sq. yd.
July 22	35	25	20	26.6
July 30	20	15	15	16.6
Aug. 6	15	10	10	11.6
Aug. 9	8	10	12	10.0
Aug. 23	10	12	12	11.3
Sept. 14	1	1	1	1.0
Average population per square yard for the season				12.9

(5) Disease.- Some M. bivittatus dead of Empusa grylli were observed along the east half mile of this roadallowance and along the edge of the corse wheat field on Sec. 33 on July 22. On August 6 Empusa grylli was still active and on August 9 a large number of M. bivittatus dead of the disease were found up the grasses on the north side of the road for the west half mile. They averaged two to three per square yard. There was also a number of dead noticed on the ground in the ditch and on the edge of the grade on August 9. It was thought at first that they had probably been killed by passing cars. On August 12, however, a large number of dead were found on the ground south of Sec. 36, T. 3, R. 3E., too far away from the road to have been killed by cars. The cause of death has not been definitely determined but it was not due to Empusa grylli (P.205). On August 23 a C. pellucida was found dead up a blade of grass and on examination with a hand lens, the feathery growth of the conidiophores of Empusa grylli could be seen.

(6) Egg survey.- The map (Plate XXIII) shows the results of the egg survey.

In this mile 148 square foot samples were examined and 409 M. bivittatus egg pods, 2 C. pellucida egg pods and 86 acres were found.

The average adult population for the season along the half

mile road was found to be 13 while along the roadallowance the average population was found to be 12.39 per square yard. The total number of egg pods found in the 3 square foot samples examined along the half mile road was 9 M. bivittatus. Along the roadallowance 96 square foot samples were examined and 369 M. bivittatus egg pods and 1 C. pellucida egg pod were found. In the fields 49 square foot samples produced 31 M. bivittatus and 1 C. pellucida egg pod.

The average number of egg pods found along the roadallowance was 3.85 per square foot, in the fields 0.65 per square foot and along the half mile road 3.0 per square foot. The results of the egg survey are summarized in the following table (Table XII) which shows the average number of egg pods deposited per square foot for each area. The rating of the infestation for each area and for the mile, based on the eggs found, is given.

Table XII
Results of Egg Survey

Location	Sq.ft.samples with pods	Sq.ft.samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating based on egg infestation
S. side of road-E. ¼ mile	9	14	20B	0.95	normal
S. " " " ¼-½ "	1	8	2B	0.22	normal
S. " " " ½-¾ "	8	4	34B	2.83	light
S. " " " ¾-W. cor.	7	4	29B	2.63	light
N. " " " -E. ¼ mile	3	12	2B + 1C	0.20	normal
N. " " " ¼-½ "	3	2	22B	4.40	moderate
N. " " " ½-¾ "	5	3	24B	4.80	moderate
N. " " " ¾-W. cor.	10	3	236B	18.15	very heavy
½ mile road S.-N.	3	0	9B	3.00	heavy
Summer-fallow Sec. 33	3	11	3B	0.21	light
Cereo wheat Sec. 33	5	3	22B	2.75	very heavy
Durum wheat Sec. 28	3	6	4B	0.44	light
Summer-fallow Sec. 28	0	5	0	0.00	
Oats Sec. 28	1	3	1B	0.25	light
Durum wheat Sec. 28	0	3	0	0.00	
Pasture (sweet clover)	1	5	1B + 1C	0.33	moderate
	62	86	409 B + 2C	2.77	moderate

* These data vary from those for Table XI because of omissions in the records.

** See page 198.

(7) Association and slope where eggs are found.- The data recorded relating to this topic during the egg survey are presented in Table XIII.

The data show that M. bivittatus prefers the south slope to the north slope for egg laying but there is a shortage of data for the north slope.

The greatest infestation of eggs was found along a south slope in loose soil with a light vegetation of Rosa blanda, Amaranthus graecizans, Taraxacum officinale and Orchard grass.

The next greatest number of eggs was found on a south slope in bare, loose soil. The order of preference for vegetation was roses and weeds, Giant Blue Stem, Timothy, Poa, Orchard grass, and spurge. Eggs were found in cereal wheat, durum wheat and oat stubble and in summer-fallow. In the crops the greatest concentration of eggs was in the outside two feet along the edge of the field.

C. pellucida eggs were found in Timothy sod, sweet clover and in durum stubble.

Table XIII

Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Soil	Slope	Sq. ft. samples with eggs	Sq. ft. samples without eggs	Total no. of egg pods	Av. pods per sq. ft.
Timothy sod		level	8	4	36B + 1C	3.16
Poa sod		level	6	6	24B	2.00
Giant Blue Stem		South	3	0	21B	7.00
Orchard grass		South	6	7	23B	1.90
Dandelion			4	9	5B	0.38
Brome			0	1	0	0.00
Dandelion & Timothy			2	5	3B	0.43
Spurge		South	3	3	15B	2.5
Sweet clover & Stink weed			1	5	1B + 1C	0.16
Dandelion & Giant Blue Stem			2	0	4B	2.0
Wild barley			1	0	1B	1.0
Weeds, rose bushes, etc.		level	1	0	15B	15.0
Bare ground	loose	South	4	0	41B	10.25
Roses, weeds, etc.		South	6	0	211B	35.0
Bare ground	loose	North	3	7	20B	2.00

Table XIII (Con'd.)
Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Soil	Slope	Sq. ft. samples with eggs	Sq. ft. samples without eggs	Total No. of egg pods	Av. pods per sq.ft.
Drift soil			4	6	19B	1.90
Summer-fallow			0	10	0	0.00
Summer-fallow		edge	2	0	2B	1.00
Durum stubble			1	6	2B	0.28
Durum stubble		edge	4	4	12B & 1C	1.5
Ceres edge			1	0	6B	6.0
Oat stubble			1	3	1B	0.25
For the mile			63	76	466B	3.25

(8) Predators.- In the 139 square foot samples examined 21 carabid beetle larvae, 1 adult carabid beetle, 31 scarotate and 7 scarabaeoid blister beetle larvae, 2 bee fly larvae and 2 wireworms were found. Of these 12 carabid larvae and 2 wireworms were feeding on the M. bivittatus egg pods.

81.8 percent of the blister beetle larvae were in the scarotate stage when the survey was made on September 9.

In the 139 square feet examined 62 predators were found along with the 466 M. bivittatus and 3 C. pellucida egg pods. 2 wireworms were found feeding on the M. bivittatus eggs as well. The ratio of egg predators to egg pods was 1:7.56.

(9) General observations.- The graph 2 on Plate XXX shows the average population per square yard for the north and south sides of the road, and the half mile road along the edge of the ceres wheat field. The population along the half mile road, according to the graph, began to decrease between July 24 and 30 while the population on the north side of the road increased. It appears that the population shifted from the edge of the ceres wheat field to the roadallowance and although this was not recorded in the daily notes it was recorded on August 6 that the population along the half mile road had decreased and as the population on the south side of the roadallowance had increased, it was thought probable that the population had shifted from the half mile road to the south side of the roadallowance. The graph of population clarifies this movement. According to the graph the population shifted from the half mile road onto the north side of the roadallowance between July 23 and August 2, approximately, and then began to move over to the south side of the road from the north. The movement away from the half mile road

was probably because of the absence of sufficient suitable food. The later shift from the north side of the road to the south was probably due to the strong north winds that prevailed between August 4 and August 20. There was also some soil drifting from the summer-fallow on the south-east quarter of Sec. 33, which might account for the movement. After August 22 there did not seem to be any shifting of the population and this is indicated by the graph which shows the gradual decrease from this time until September 14 which is probably due to the gradual dying off of the grasshoppers during the fall.

(10) Conclusions and summary.

(a) This plot was chosen because of the heavy infestation of M. bivittatus.

(b) The dominant plants, in order of abundance, were Taraxacum officinale, Amaranthus retroflexus, A. graecizans, Rosa blanda, Chenopodium albe and Aster. The dominant grasses were Phleum pratense, Orchard grass, Andropogon furcatus and Poa compressa.

(c) The predominant species of grasshopper was M. bivittatus. Other species present were C. pellucida, M. mexicanus and M. femur-rubrum.

(d) Empusa grylli killed a few M. bivittatus on the plot and one C. pellucida was found dead of the fungus. On August 12 a large number of M. bivittatus were found dead of an unidentified disease on the north side of the west half mile.

(e) The average population per square yard for the period from July 22 to September 14 on the north side of the roadallowance was 10.8, on the south side 14.1, and along the half mile road was 12.9.

(f) The average number of egg pods per square foot along the roadallowance was 3.55, in the fields 0.65, and along the half mile road 3.0. The infestation for the mile was rated as "moderate."

(g) M. bivittatus showed a preference for the south slope for egg laying. The greatest concentration of eggs was found in the west half mile on the north side in an area of loose soil with a light vegetation of Rosa blanda, Amaranthus graecizans, Taraxacum officinale and Orchard grass. Bare loose soil was chosen for egg laying. The order of preference for vegetation was roses and weeds, Giant Blue Stem, Timothy, Poa, Orchard grass, and spurge. Eggs were found in the outside two feet of oats, durum and cut stubble and in summer-fallow.

(h) C. pellucida egg pods were found in Timothy Sod, sweet clover and in durum stubble.

(i) The ratio of egg predators to egg pods was 1:7.56.

(j) Two wireworms were found feeding on M. bivittatus eggs.

(k) 51.8 percent of the blister beetle larvae were in the coarctate stage by September 9.

(l) The population shifted from the half mile road to the north side of the east half mile of the roadallowance because

of a food shortage. They later moved from the north side to the south side because of the strong north wind and the drifting of the soil from the summer-fallow in the south-east quarter of Sec. 33.

4. Detailed study plot III.

(The north roadallowance of Sec. 21, T. 3, R. 3W)

(1) Reasons for selection.- The plot was chosen because of the heavy infestation of Empusa grylli and the presence of both M. bivittatus and C. pellucida.

(2) General description.- This plot was established on August 2. It was originally at the half mile line and included a portion of reverted land on the north-east quarter of Sec. 21, part of a durum wheat field on the north-west quarter and a portion of the roadallowance. The plot was later extended to include the whole mile.

The bordering crops on the north, from west to east, were an oat field, a field of summer-fallow, a pasture, with a group of farm buildings on the south-east quarter of Sec. 28. On the south there was a field of durum wheat on the north-west quarter of Sec. 21 and an area of waste reverted land on the north-east quarter.

The road was a low grade with ditches one foot deep and a yard wide on each side. On the south side there was a grassy area about six yards wide between the ditch and the crop. There was a strip about two yards wide covered with a heavy vegetation of Rosa blanda, Andropogon furcatus, Aster and Phleum pratense on the north side of the road.

(3) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXIV). In all cases the plants are listed in order of abundance.

Part of the oat field (I) was cut and stacked on August 1. The west side of the field (II) was cut and stooked on August 1 but had not been threshed by September 22. The field was planted to white sweet clover and the young plants could be seen in September. There was also a large amount of Orchard grass, Amaranthus retroflexus, Euphorbia serpyllifolia, small Chenopodium alba, Polygonum convolvulus, Ambrosia trifida and Amaranthus graecizans.

The area of reverted land (Plate XV) was cut with the mower for hay before August 1 except the west side where the study plot was established. The vegetation on the part of the area near the half mile line (III) which was the part studied was chiefly Artemisia ludoviciana. Solidago canadensis, Ambrosia trifida, Iva

xanthifolia, Aster laevis, A. multiflorus, Helianthus maximiliani, clumps of sod of Phleum pratense and Poa compressa, and Taraxacum officinale were present. The artemesia, golden-rod, ragweed and the maximilion sunflower ranged from one and a half to four feet high. Achillea millefolium, Amaranthus retroflexus, A. graecizans, Thlaspi arvense and Chenopodium alba were also present.

In the area of waste land cut for hay (IV) the chief plants were Phleum pratense, with some Poa compressa, Artemisia ludoviciana, Aster laevis, A. multiflorus, and Taraxacum officinale.

The west three quarters of a mile of the grassy strip (V) was cut for hay before the study plot was established. It was covered largely with Phleum pratense and Rosa blanda. There was some Poa compressa, Hordeum jubatum, Andropogon furcatus, Orchard grass, Melilotus alba, Aster laevis, A. multiflorus, Polygonum aviculare, Artemisia ludoviciana and an occasional plant of Amaranthus retroflexus and Achillea millefolium present.

At (VI) bushes of Rosa blanda became scarcer toward the east. There were more plants of Taraxacum officinale and many patches of bare soil.

The vegetation at (VII) was similar to that of the west half mile but was trampled down by horses and machinery. The surface of the ground was broken up and the sod was in clumps.

The east quarter of the mile (VIII) was entirely different from the west three quarters. The vegetation was one and a half to three feet in height and consisted chiefly of Iva xanthifolia with some Rosa blanda, Aster laevis, A. multiflorus, Polygonum aviculare, Poa compressa, Phleum pratense and Achillea millefolium.

In the ditch on the south side of the road (IX) the chief grasses were Andropogon furcatus and Phleum pratense. There was a large amount of Melilotus alba, Rosa blanda, Aster laevis, A. multiflorus, Artemisia ludoviciana and seedlings of Apocynum cannabinum. Along the edge of the road there was Amaranthus graecizans, Hordeum jubatum and some Chenopodium alba.

East of the quarter mile line (X) there was less Andropogon furcatus and more Phleum pratense.

The rest of the mile was similar to (X) in character except that the east quarter had the ditch filled with Iva xanthifolia, a few bushes of Rosa blanda, Aster laevis, A. multiflorus, and Polygonum aviculare.

The ditch on the north side of the road (XII) was similar in

character to that on the south side but the grass was taller and there was very little Melilotus alba. The grass was about a foot to a foot and a half tall.

A quarter of a mile further east (XIII) the grass in the ditch was shorter and more predominant. The chief grasses were Phleum pratense and Agropyron repens. There were some bushes of Rosa blanda, Aster laevis, Aster multiflorus and Artemisia ludoviciana.

The ditch for the east quarter of the mile (XIV) was filled with Iva xanthifolia, Polygonum aviculare, and some Phleum pratense, Hordeum jubatum and Andropogon furcatus. The east eighth of a mile (XV) had been cut with the mower.

The area on the north side of the road (XVI) was covered by Rosa blanda and Phleum pratense, with some Andropogon furcatus, Aster laevis, A. multiflorus, Agropyron repens, Artemisia ludoviciana, seedlings of Apocynum cannabinum, Solidago canadensis and Helianthus maximiliani. There was also some Iva xanthifolia present. The vegetation was one to one and a half feet tall.

East of the quarter mile line (XVII) the bank of the ditch was covered chiefly with some small Chenopodium alba, Aster laevis, A. multiflorus, Helianthus maximiliani, Solidago canadensis and a few bushes of Rosa blanda.

At(XVIII) the predominant plant was Iva xanthifolia about two feet high, with some Polygonum aviculare, Phleum pratense, Hordeum jubatum, and Andropogon furcatus.

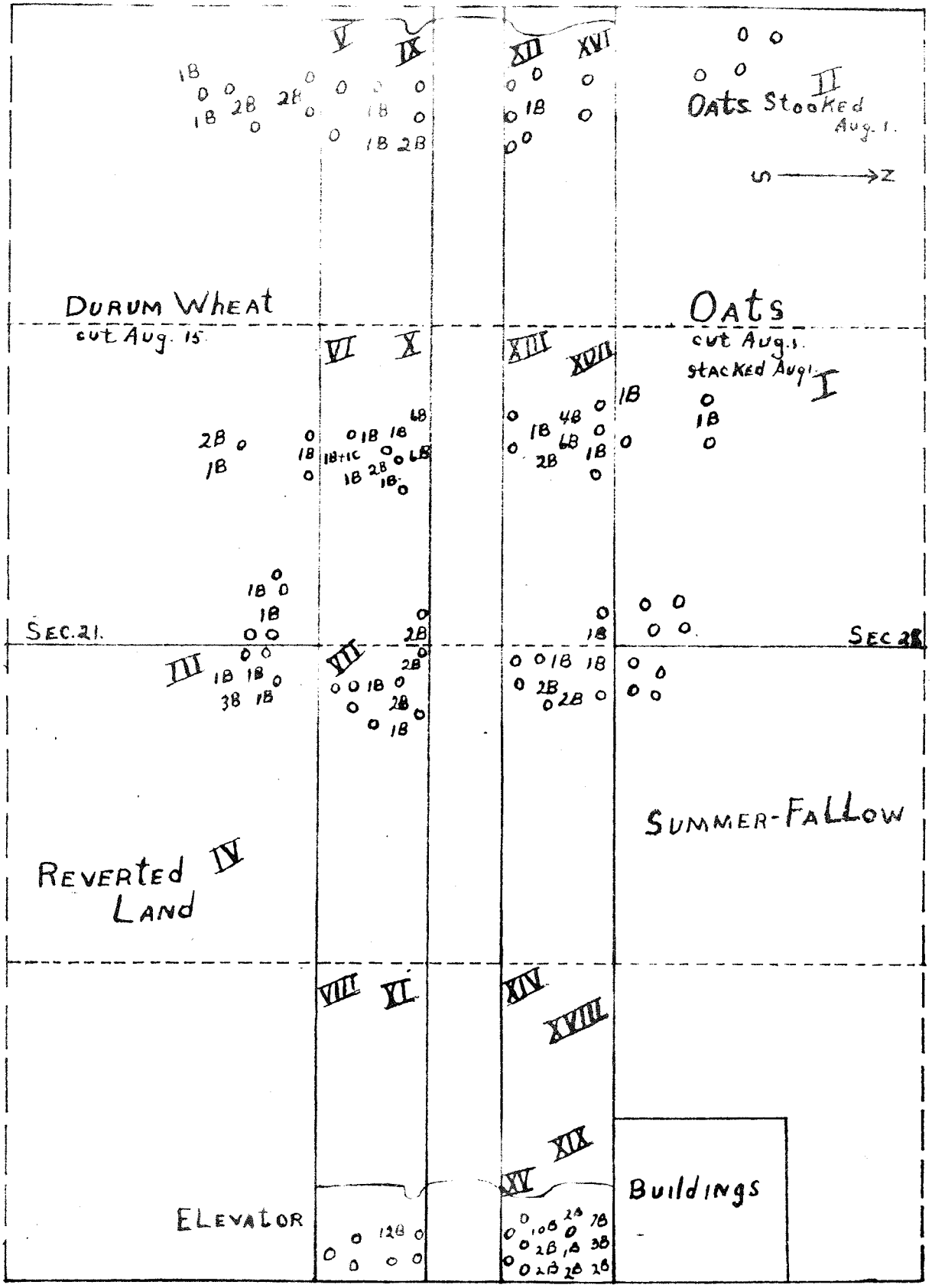
The vegetation on the east eighth of the mile had been cut with the mower before August 3. It consisted of Poa compressa and Taraxacum officinale, with Hordeum jubatum, Iva xanthifolia and Rosa blanda next to the ditch.

The chief plants found along this mile were Phleum pratense, Poa compressa, Rosa blanda, Artemisia ludoviciana, Andropogon furcatus, Taraxacum officinale, Amaranthus retroflexus, and Chenopodium alba. There was a large percentage of Iva xanthifolia, Chenopodium alba, Ambrosia trifida and Aster in the east half mile of this road-allowance.

(4) Grasshoppers.- The grasshoppers on plot III were M. bivittatus and C. pellucida, about 70 percent M. bivittatus. There were also a few M. femur-rubrum and M. mexicanus. Specimens of Arphia pseudonietana, M. dawsoni and Dissosteira carolina were collected along this mile. There were very few grasshoppers for the quarter of a mile east of the half mile line.

Plate XXIV

Map of the north roadalloweance of Sec. 21, T. 3, R. 3E, studied under Detailed Study Plot III. The cross section of the roadalloweance is shown at the top of the map. The symbols are the same as described for Plate XXII.


V
IX
XII
XVI
II
Oats Stooked
Aug. 1.
S → N
DURUM WHEAT
cut Aug. 15
OATS
cut Aug. 5.
stacked Aug. 1.
I
VI
X
XIII
XVII
SEC. 21.
SEC. 28
III
VII
SUMMER-FALLOW
REVERTED
LAND
IV
VIII
XI
XIV
XVIII
XIX
XV
ELEVATOR
BUILDINGS

The estimates made with the average population per square yard for each area are presented in the following tables (Table XIV, XV, and XVI). The estimates were made from the west end of the mile toward the east. The averages are plotted in graph 3 (Plate XXX). The graph indicates the fluctuations in population during the study period but is very incomplete. The average population for the season is given at the bottom of the tables.

Table XIV
Population Estimates
(For the south side of the road from west to east)

Date	Pop. per square yard for eighth mile div. 0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	Av. pop. per sq. yd.
Aug. 2	10	16	20	14	15.5
Aug. 6	12	12	15	12	12.7
Aug. 9	10	12	18	16	14.0
Sept. 5	2	2	3	3	2.5
Sept. 14	2	1	3	2	2.0
Average population per square yard for the season					9.34

Table XV
Population Estimates
(For the north side of the road from west to east)

Date	Pop. per square yard for eighth mile div. 0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	Av. pop. per sq. yd.
Aug. 2	2	12	12	12	9.5
Aug. 6	4	10	10	18	10.5
Aug. 9	2	10	18	18	12.0
Sept. 5	2	2	3	3	2.5
Sept. 14	2	1	3	2	2.0
Average population per square yard for the season					7.3

Table XVI
Population Estimates for Plot III.

Date	Estimates per sq. yd. in the following locations: Road Allowance	Durum Wheat	Durum Wheat	Waste Land	Waste Land	Road Allowance	Av. pop. per sq. yd.
Aug. 2	12	0	2	12	8	12	7.6
Aug. 6	10	2	0	12	15	8	7.8
Aug. 9	16	2	0	12	12	4	7.6
Sept. 8	3	0	1	2	3	3	2.0
Sept. 14	2	0	1	2	2	2	1.5
Average population per square yard for the season							5.32

(5) Disease.- There were a large number of dead noticed up the stems of plants on the plot on August 2. This was one of the reasons why the area was chosen for a study plot. On August 2 quadrats were marked out on the waste land adjacent to the durum wheat field in an attempt to follow the progress of the disease. The quadrats were a square yard in area and covered by the following plants:

Quadrat I, timothy, purple aster and white aster.

Quadrat II, Artemisia and some timothy.

Quadrat III, Lamb's quarter, purple aster and white aster.

Quadrat IV, French weed, purple aster and white aster.

Note.- The dead were left on quadrat IV in order to determine whether this would affect the rate of spread of the disease.

Table XVII
Results of Counts

Date	Quadrat I	Quadrat II	Quadrat III	Quadrat IV	Total
Aug. 2	6[A]	12	11	12	41
Aug. 6	1[A]	1[A]	0	2[AA]	4

Table XVII (Con'd.)
Results of Counts

Date	Quadrat I	Quadrat II	Quadrat III	Quadrat IV	Total
Aug. 9	0	0	1	0	1
Total	7	13	12	14	46

* All dead a long time.
** Dead in copulation.

Summary of Table.

There were 41 dead on the 4 quadrats when they were marked out on August 2.
On the quadrats 5 died in 7 days.
Average dead per day for the 4 quadrats was 0.71.
" " " " per square yard was 0.18.
Average living population from August 2 to August 9 was 7.7 per square yard.
The daily mortality was 2.33% of the population.

The results were not very satisfactory because the living population moved away from the quadrats. The stakes were removed by a farm hand on August 12 and this experiment was closed.

Two new quadrats of a different type were marked out on August 22. These were large quadrats (I) 4 yards by 6 yards and (II) 5 yards by 6 yards, and the plants with dead grasshoppers clinging to them were marked by tying a piece of gauze on them for each dead grasshopper. The stakes were removed on August 25 but the marks could be seen and some results were obtained. The vegetation on the quadrats was as follows:

Quadrat I, Artemisia, golden-rod and Lamb's quarter.

Quadrat II, Artemisia, Red root pig weed, Lamb's quarter, brome grass and tumble weed.

Table XVIII
Results of Counts

Date	Quadrat I	Quadrat II	Total
Aug. 22	15	6	21
Sept. 5	2*	0	2
Total	17	6	23

* By September 5 all the old dead had fallen off the stems but fresh dead were found.

On September 5 there were several dead observed on the plants outside the quadrats where there had been none dead formerly. Thus, although they were not dying on the quadrats the disease was still active.

Summary of Table.

There were 21 dead on the quadrats when they were marked out on August 22.

On the quadrats 2 died in 14 days.

Average dead per day was 0.14.

" " " " per square yard was 0.0026.

Average living population from August 22 to September 5 was 4.5 per square yard.

The daily mortality was 0.054% of the population.

The results were not satisfactory because the plot was not visited often enough and grasshoppers may have died and fallen off the stems between the visits.

Conclusion.

Small plots are not satisfactory for studying the rate of mortality in grasshoppers due to Empusa grylli, as the living population is apt to move away a small distance.

The best method of studying the rate of mortality due to this disease is to take a large area and mark the plants to which the dead grasshoppers are clinging with a piece of white cloth for each grasshopper clinging to them. In this way the length of time which the grasshoppers cling to the plants and the number of fresh dead on the area can be determined. There is also less chance of the grasshopper population moving to a larger area of this type. There is also a larger number of dead and, therefore, more representative results are obtained.

(6) Egg survey.- The map (Plate XXIV) shows the results of the egg survey.

In this mile 129 square foot samples examined resulted in 114 M. bivittatus pods, 1 C. pellucida pod and 78 zeros.

The average adult population per square yard during the period between August 2 to September 14 was 8.32 along the roadallowance and 5.32 per square yard on the original plot III. The total number of egg pods found on plot III in 26 square foot samples was 16 M. bivittatus pods. In 52 square foot samples along the roadallowance 94 pods of M. bivittatus eggs and 1 pod of C. pellucida were found. In 47 samples taken in the fields 20 M. bivittatus pods were found. The average number of egg pods per square foot along the roadallowance was 1.14, in the fields 0.43, and on plot III 0.62.

The results of the egg survey are summarized in the following table (Table XIX) which also shows the average number of egg pods deposited per square foot in each area. The rating of the infestation for each area and for the mile, based on the eggs found, is given.

Table XIX
Results of Egg Survey

Location	Sq. ft. samples with pods	Sq. ft. samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating based on egg infestation
North side-W. ¼ mile	1	7	1B	0.12	normal
" " - ¼-½ "	6	6	15B	1.25	light
" " ½-¾ "	4	5	6B	0.66	normal
" " E. ¼ "	9	6	31B	2.06	light
South side-W. ¼ "	3	5	4B	0.50	normal
" " ¼-½ "	8	4	19B + 1C	1.66	light
" " ½-¾ "	4	7	6B	0.54	normal
" " E. ¼ "	1	6	12B	1.71	light
Oats Sec. 25 (planted to sweet clover)	2	11	2B	0.15	normal
Summer-fallow Sec. 25	0	4	0	0.00	
Reverted land Sec. 21	4	5	6B	0.66	moderate
Durum wheat Sec. 21	9	12	12B	0.57	moderate
	51	78	114B[A] + 1C	0.89	light

A These data vary from those for Table XX because of omissions in the records.

AA See Page 156.

(7) Association and aloma where eggs are found.- The data recorded in regards to this subject during the egg survey is recorded in the following table. The predators found are also listed in the table.

The data show the M. bivittatus preferred the south slope to the north slope on level ground for egg laying. The order of preference for vegetation was timothy, Poa, Giant Blue Stem and couch grass. Some eggs were found in wild barley. More eggs were found in durum stubble than in the weedy oat field.

A C. pellucida egg pod was found in timothy sod.

Table XX
Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq.ft. samples with eggs	Sq.ft. samples without eggs	Total no. of egg pods	Av. pods per sq. ft.
Timothy sod	level	9	7	14B + 1C	0.87
Timothy sod	south	5	2	24B	3.50
Poa sod	level	5	4	21B	2.3
Timothy & Dandelion	north	1	8	1B	0.1
Timothy& Dandelion	south	1	4	1B	0.2
Giant Blue Stem		6	3	9B	1.0
Couch		2	4	5B	0.5
Orchard grass		1	4	1B	0.2
Dandelion		1	1	1B	0.5
Rose bushes (loose soil)		1	0	2B	2.0
Red root pig weeds		0	3	0	0.0
Bare ground	south	3	0	4B	1.3
Wild barley	north	0	2	0	0.0
Wild barley	level	2	1	12B	4.0
Weedy oats		2	7	2B	0.22
Durum stubble		9	12	12B	0.57
For the mile		48	62	107B	1.08

(6) Predators.- In the 110 square foot samples examined 12 carabid beetle larvae, 10 coarctate and 4 scarabaeoid blister beetle larvae and 1 bee fly larvae were found. Two wireworms were found associated with the egg pods but there was no sign of feeding. The bee fly larvae was the only one found feeding on the egg pods.

71.4 percent of the blister beetle larvae were in the coarctate stage when the survey was made on September 21.

In the 110 square feet examined 27 predators were found, not

including the wireworms, along with the 107 M. bivittatus and 1 C. pellucida egg pods. The ratio of egg predators to egg pods was 1: 4.

(9) General observations.- This study area was used chiefly for the study of disease. The graph shows a decrease in the population from August 9 to September 14. The data were very incomplete for the estimates. This gradual decrease in population was not due entirely to the disease but chiefly to the incompleteness of the data obtained.

(10) Conclusions and summary.

(a) This plot was elected because of the heavy infestation of Empusa grylli and the presence of both M. bivittatus and C. pellucida.

(b) The dominant plants, in order of abundance, were Phleum pratense, Poa compressa, Rosa blanda, Artemisia ludoviciana, Andropogon furcatus, Taraxacum officinale, Amaranthus retroflexus and Chenopodium alba.

(c) The predominant species of grasshoppers were M. bivittatus and C. pellucida. Other species present were M. femur-rubrum, M. mexicanus, Arphia pseudonietana, M. dawsoni and Dissosteira carolina.

(d) Empusa grylli killed a large number of M. bivittatus on this plot. An attempt was made to determine the mortality due to this fungus by the quadrat method and by the use of large plots and marking the plants, to which dead grasshoppers were clinging, with a piece of white gauze for each dead grasshopper. The daily mortality between August 2 and August 9 as determined by the first method was 2.83% of the population. Between August 22 and September 5 the daily mortality was found, by the second method, to be 0.054% of the population.

(e) The second method was found to be the most satisfactory for studying the mortality due to Empusa grylli. It would be necessary to visit the plots at least once a day.

(f) The average population per square yard for the period from August 2 to September 14 along the south side of the roadallowance was 9.34, for the north side 7.3, and for plot III 5.32.

(g) The average number of egg pods per square foot along the roadallowance was 1.14, in the fields 0.43, and on the original plot III 0.62. The egg infestation for this plot was rated as "normal."

(h) M. bivittatus preferred the south slope to the north slope or level ground for egg laying. The order of preference for vegetation was timothy, Poa, Giant Blue Stem and couch grass. Some eggs were found in wild barley. More eggs were found in the durum stubble than in the weedy oat field.

(i) One C. pellucida egg pod was found in timothy sod.

(j) The ratio of egg predators to egg pods was 1:4.
(k) Two wireworms were found associated with the egg pods but there was no sign of feeding.
(l) 71.4% of the blister beetle larvae were in the coarctate stage when the survey was made on September 21.

5. Detailed study plot IV.
(The west three-eighths of a mile of the south road allowance of Sec. 27, T. 3, R. 3E.)

(1) Reasons for selection.- The plot was selected because of the large number of C. pellucida present.

(2) General description.- This plot was established on August 6 and consisted of the north side of the roadallowance from the railroad track west to the corner of the section.

The roadallowance was bordered on the south by a barley field and on the north by a field of durum wheat.

The road was a low grade with a ditch about a foot deep and three yards wide on the north side and a level area about seven yards wide between the ditch and the fence. On the south side of the road there was a ditch about a foot and a half deep and four yards wide and a level strip about three yards wide between the ditch and the barley field.

(3) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXV). In all cases the plants are listed in order of abundance.

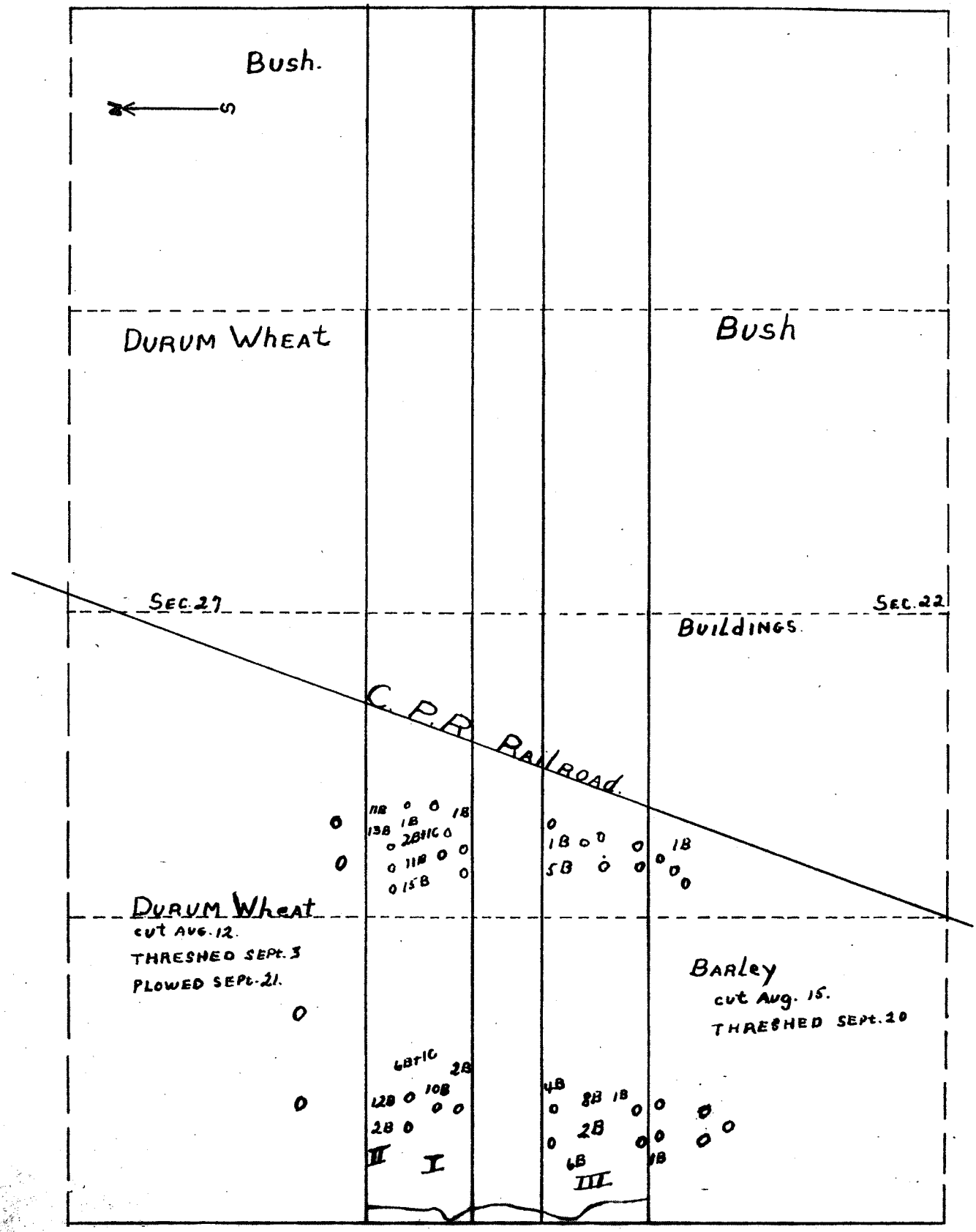
The ditch (I) was filled with Phleum pratense, Rosa blanda, Aster laevis and A. multiflorus with some Artemisia ludoviciana and Andropogon furcatus (Plate XVI). The edge of the ditch by the road had some Poa compressa sod.

The level area (II) was mowed for hay before July 15. The vegetation was chiefly Bromus inermis with some Phleum pratense and Poa compressa. There was some Rosa blanda and Aster laevis. There was a strip of Poa compressa and Phleum pratense sod along the fence by the durum wheat field.

The area on the south side of the road (III), including the ditch and the level area, was covered with Iva xanthifolia, Chenopodium alba, Ambrosia trifida, Aster laevis, Rosa blanda and Solidago canadensis. These plants ranged from one to three feet in height. There were patches of Phleum pratense and Poa compressa along the edge of the ditch next to the road.

Plate XXV

Map of the south roadallowance of Sec. 27, T. 3, R. 3E., studied under Detailed Study Plot IV. The cross section of the roadallowance is shown at the bottom of the map. The symbols are the same as described for Plate XXII.


Bush.
DURUM Wheat
Bush
SEC. 27
SEC. 22
BUILDINGS.
C. P. R. RAILROAD.
DURUM Wheat
cut AUG. 12.
THRESHED SEPt. 3
PLOWED SEPt. 21.
BARLEY
cut Aug. 15.
THRESHED SEPt. 20
I
II
III

The chief grasses on this plot were Bromus inermis, Phleum pratense and Poa compressa. In the ditches there was Rosa blanda, Aster, Artemisia ludoviciana, Iva xanthifolia, Chenopodium alba, Ambrosia trifida and Solidago canadensis.

(4) Grasshoppers.- The grasshoppers on this area were C. pellucida and M. bivittatus. On August 6 the average population was 15 C. pellucida per square yard but the majority of them moved off the plot about August 23 and were replaced by M. bivittatus. There were still some C. pellucida left along the fence in the strip of Poa and Timothy sod and some eggs were deposited along here and a few in the brome grass. M. bivittatus, however, became the major species and deposited a considerable number of eggs.

Estimates of population taken along this strip of roadallowance on the north side from east to west are shown in the following table (Table XXI) and the averages per square yard are plotted in Graph 4 (Plate XXX). The graph indicates the fluctuations in population during the study period. The average population per square yard for the plot is given at the bottom of the table.

Table XXI
Population Estimates
(For the north side of the road from west to east)

Date	Pop. per square yd. for eighth mile div. 0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	Av. pop. per sq. yd.
Aug. 6	8	15	15	15	13.25
Aug. 9	8	20	20	20	17.0
Aug. 23	25	25	20	18	22.0
Sept. 5	2	2	2	2	2.0
Sept. 8	2	1	1	2	1.5
Average population per square yard for the season 11.15					

(5) Diseases.- There were no dead observed on this plot until August 22 when 4 M. bivittatus, apparently dead of Empusa grylli, were found up stems of grasses and one M. bivittatus was found dead on the ground. One C. pellucida was also observed dead up a stem of grass. These were the only dead found on the plot during the season.

(6) Egg survey.- The map (Plate XXV) shows the results of the egg survey.

On this plot 56 samples were examined and 115 M. bivittatus egg pods, 2 C. pellucida egg pods and 35 zeros were obtained.

The average adult population on the north side of the road was 11.15 per square yard during the period from August 6 to September 8. The total number of egg pods deposited in 56 square foot samples was 117. The average number of egg pods per square foot was 2.74 along the roadallowance and 0.14 in the fields.

The results of the egg survey are summarised in the following table (Table XXII) which shows the average number of egg pods deposited per square foot in each area. The rating of the infestation for each area and for the mile, based on the number of eggs found, is given.

Table XXII
Results of Egg Survey

Location	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating†† based on egg infestation
N. side of road-W. ½ mile	5	4	32B + 1C	3.66	moderate
N. " " " ½-railroad	7	9	54B + 1C	3.44	moderate
S. " " " W. ½ mile	5	4	21B	2.33	light
S. " " " ½-railroad	2	6	6B	0.75	normal
Durum wheat	0	4	0	0.00	
Barley	2	8	3B	0.20	light
For the plot	21	35	115B + 2C*	2.09	light

* These data vary from those for Table XXIII because of omissions in the records.

†† See Page 98.

(7) Association and slope where eggs are found.- The data recorded in connection with this topic during the egg survey is recorded in the following table.

The data show that M. bivittatus seems to prefer the south slope to the north slope for egg laying.

The largest number of eggs was laid in Andropogon furcatus, Poa compressa and in Bromus inermis. Some eggs were found in an open stand of false rag weed. This was probably due to the presence of patches of bare soil which were exposed to the sun but protected from the wind. There were a few eggs in the barley stubble but none in the durum wheat.

C. pellucida egg pods were found in Giant Blue Stem and brome grass sod.

Table XXIII

Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq. ft. samples with eggs	Sq. ft. samples without eggs	Total No. of egg pods	Av. pods per sq. ft.
Brome		6	7	41B + 1C	3.83
Brome	north	0	2	0	0.00
Poa	north	3	3	4B	0.66
Poa	south	5	2	37B	5.3
Poa	level	0	3	0	0.00
Giant Blue Stem		2	0	16B + 1C	8.5
Rag weed		3	4	10B	1.43
Barley		2	6	2B	0.2
Dandelion			2	0	0.00
Durum			4	0	0.00
For the mile		21	35	110B	1.93

(8) Predators.- In the 56 square feet samples examined 5 carabid beetle larvae, 10 coarctate and 3 scarabaeoid blister beetle larvae, and 11 bee fly larvae were found. Of these, 2 of the scarabaeoid blister beetle larvae and 4 of the bee fly larvae were feeding on the M. bivittatus egg pods. In one of the samples a wireworm was found associated with the egg pods but was not observed feeding on the eggs.

77 percent of the blister beetle larvae were in the coarctate stage on September 21.

In the 56 square feet examined 29 predators were found associated with 110 M. bivittatus and 2 C. pellucida pods. A wireworm was found also. The ratio of egg predators to egg pods was 1:3.8.

(9) General observations.- This plot was established because of the large number of C. pellucida present but soon after the plot

was established the C. pellucida moved off. For this reason and because of the difficulty of visiting this plot during wet weather the data on population drifts are very incomplete. However, the graph 4 (Plate XIX) shows that there was an increase in the population between August 6 and August 23. This was an increase in M. bivittatus population due probably to the cutting of the crops and the fall in the population after August 23 was due to the C. pellucida moving out. C. pellucida probably moved out because of the luxuriant growth of brome grass that came up during the rains between August 11 and August 23. The curve of population, then, slopes off more gradually into the fall decline.

(10) Summary and conclusions.-

(a) This plot was selected because of the large number of C. pellucida present.

(b) The dominant plants were Bromus inermis, Phleum pratense, Poa compressa, Rosa blanda, Aster, Artemisia ludoviciana, Iva, xanthifolia, Chenopodium albe, Ambrosia trifida and Solidago canadensis.

(c) The predominant species of grasshoppers were C. pellucida and M. bivittatus.

(d) There was very little disease present among the grasshoppers on this plot.

(e) The average population per square yard, for the period from August 6 to September 8, on the north side of the road was 11.15.

(f) The average number of egg pods per square foot was 2.74 along the roadallowance and 0.14 in the fields. The egg infestation for this plot was rated as "light".

(g) The order of preference by M. bivittatus for egg laying was Giant Blue Stem, pea and brome. Some eggs were found in an open stand of false rag weed. This was probably due to the presence of patches of bare soil which were exposed to the sun but protected from the wind. There were a few eggs in the barley stubble but none in the durum wheat.

(h) C. pellucida egg pods were found in Giant Blue Stem and brome grass sods.

(i) The ratio of egg predators to egg pods was 1:3.6.

(j) A wireworm was found associated with the egg pods but was not observed feeding.

(k) 50 percent of the blister beetle larvae were in the coarctate stage on September 21.

(l) C. pellucida moved off the plot after August 23 probably because of the luxuriant growth of brome grass that came up during the rains of August 11 to August 23. M. bivittatus moved onto the plot between August 6 and August 23.

6. Detailed study plot V
(The south-west quarter of Sec. 36, T. 3, R.3E)

(1) Reasons for selection.- The plot was selected because of the large M. bivittatus and C. pellucida population and because it was hayland.

(2) General description.- This plot was established on July 24 and consisted of hayland around two old stables (Plate XVII).

The hayland was bordered on three sides by a crop of durum wheat. On the west side it was bordered by the west roadallowance of Sec. 36. The hayland was on the east side of the roadallowance about one-sixteenth of a mile from the south-west corner of the section. The area had about a sixteenth of a mile frontage on the roadallowance.

(3) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXVI). In all cases the plants are listed in order of abundance.

The south-west corner (Plate XVIII) of the area (I) was covered chiefly with young Thlaspi arvense and Taraxacum officinale with clumps of Phleum pratense and Poa compressa sod and many bare spots.

On the centre of the area (II) the chief vegetation was Poa compressa, Phleum pratense and young Thlaspi arvense with a clump of tall Phleum pratense, Iva xanthifolia and Chenopodium alba around some old machinery.

South of the buildings (III) the Iva xanthifolia and Chenopodium alba had been cut with the mower but around the building the weeds had not been cut.

East of the stable (IV) the ground was worked up by machinery and was loosely packed. There was very little vegetation.

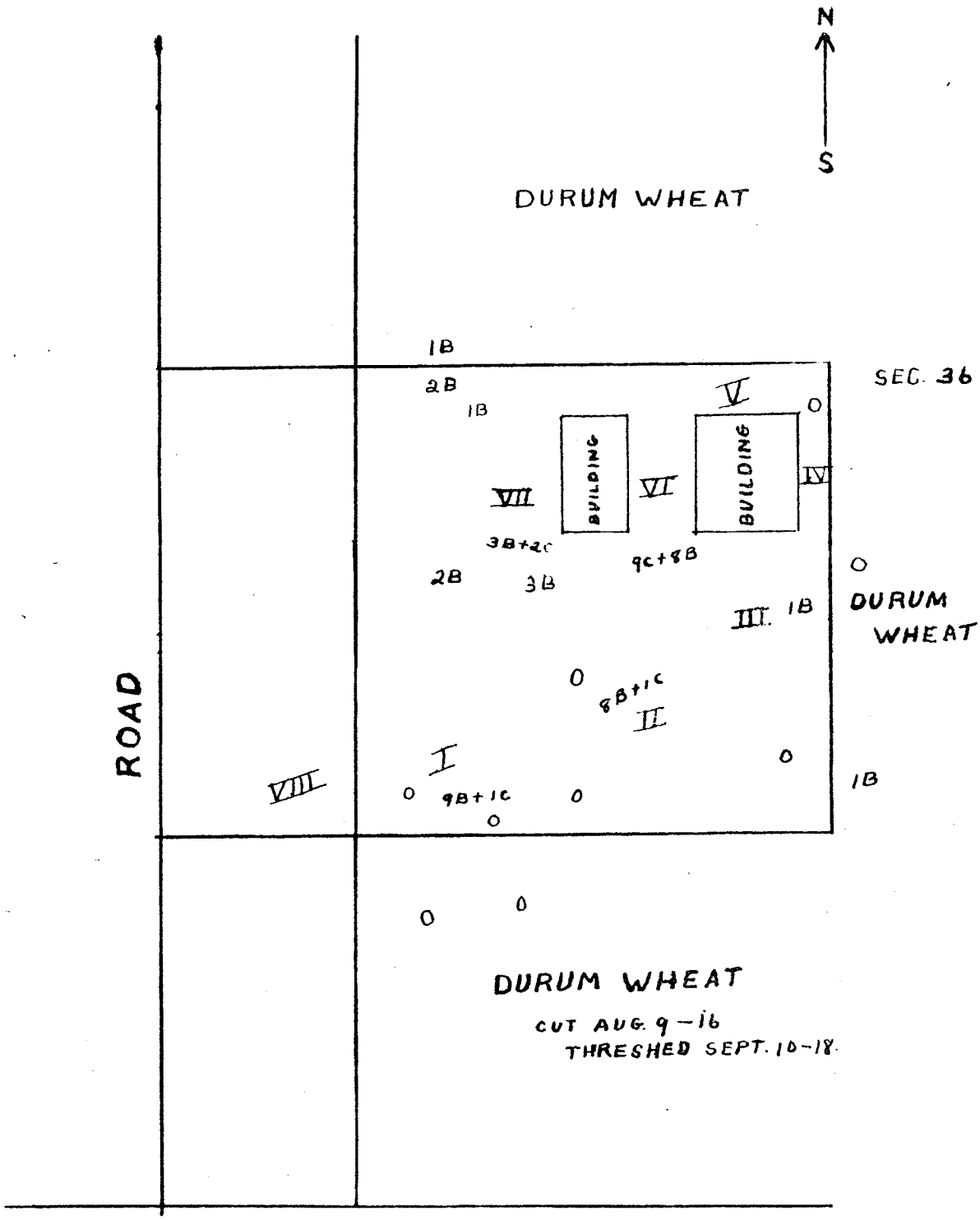
On the north side of the old buildings (V) there was an old straw stack bottom and close to the buildings there was some Bromus inermis and tall Iva xanthifolia.

Between the two buildings (VI) there was a very luxuriant growth of Bromus inermis with some Poa compressa.

The vegetation on the northwest corner of the area (VII) was chiefly Poa compressa with Taraxacum officinale in the bare spots. There was a heavier sod here with fewer bare spots than on the south west corner of the hayland (I).

Plate XXVI

A map of Plot V showing the location of the heyland in respect to the road and the section. The location of the buildings is indicated. The symbols are the same as described for Plate XXII.


N
S
DURUM WHEAT
1B
2B
1B
SEC. 36
V
O
BUILDING
BUILDING
IV
VII
VI
3B+2C
9C+8B
2B
3B
O
DURUM
WHEAT
III. 1B
O
8B+1C
II
ROAD
I
O
1B
VIII
O
9B+1C
O
O
O
O
DURUM WHEAT
CUT AUG. 9-16
THRESHED SEPT. 10-18

The chief grasses were Phleum pratense and Poa compressa with large patches of Bromus inermis. There were also large patches of Taraxacum officinale, Iva xanthifolia and Chenopodium alba and by September seedlings of Thlaspi arvense had appeared. The whole area had been cut with the mower and raked for hay before July 15.

(4) Grasshoppers.- The grasshoppers around these buildings were estimated on July 24 to be 25 per square yard, about 70 percent M. bivittatus and the rest C. pellucida. Camnula seemed to be congregated in front of the buildings (VII) and between them (VI).

Estimates of the population on this area are tabulated in the following table (Table XXIV) and the averages graphed on graph 5 (Plate XXX). The graph shows the fluctuation in population during the study period. The average population for the season is given at the bottom of the table.

Table XXIV
Population Estimates
For the following areas (Plate XXVI)

Date	Area I	Area II	Area III	Area VII	Av. pop. per sq. yd.
July 24					25
July 30					20
July 31	20	15	6	1	10.5
Aug. 3					20
Aug. 7	10	12	15	12	12.2
Aug. 10	15	15	12	16	14.5
Aug. 21	20	6	6	33	16.75
Aug. 28	8	10	12	15	11.25
Sept. 7	6	2	2	4	3.5
Sept. 8	4	6	6	4	5.0
Average population per square yard for the season					13.83

(5) Disease.- There were no dead M. bivittatus noticed on this plot until August 15 when a few M. bivittatus were found dead on the ground. On August 21 the M. bivittatus dead on the ground averaged one per square yard and two specimens were found clinging to the edge of a hole in the ground as if they had died of Empusa grylli. On September 5 a large number of M. bivittatus were found dead both on the ground and up the stems of grasses. The average dead was 3 per square yard with a maximum of 9 per square yard.

On September 6 there were still more dead of Eurygaster gryllii on this plot. In this case more died of Eurygaster gryllii under cool, moist conditions than under warm, moist conditions.

(6) Egg survey.- The map (Plate XXVI) shows the results of the egg survey.

In 15 square foot samples examined on this area 37 pods of M. bivittatus, 13 pods of C. pellucida eggs and 6 acres were found.

The average adult population for the period from July 24 to September 6 was 13.83 per square yard. The total number of egg pods deposited in 15 square feet was 37 M. bivittatus and 13 C. pellucida. The average number of egg pods found was 3.33 per square foot and in the durum wheat was 0.33.

The results of the egg survey are summarized in the following table (Table XXV) which shows the average number of egg pods per square foot in the hayland and the crop. The rating of infestation, based on the egg infestation, is given.

Table XXV
Results of Egg Survey

Location	Sq.ft.samples with pods	Sq.ft.samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating ** based on egg infestation
Hayland	9	6	378 + 130	3.33	moderate
Durum wheat	2	3	28	0.40	moderate
Total	11	19	358 + 130	1.73*	moderate

* It will be noticed that the total does not check with Table XXVI.

** See page 198.

(7) Association and slope where eggs are found.- During the egg survey the association where the eggs were found was recorded. These data are presented in the following table. The plot was level and hence no data were obtained for slope preferences.

The order of preference was French weed and timothy, brome, pea, and timothy. No eggs were found in French weed or in the straw stack bottom.

C. pellucida egg pods were found in brome, timothy and dandelion.

Table XXVI
Vegetation Preferences of M. bivittatus for Oviposition

Vegetation	Sq. ft. samples with eggs	Sq. ft. samples without eggs	Total No. of egg pods	Av. pods per sq. ft.
Timothy	2	1	9B + 1C	3.00
Poa	2	1	14B	4.66
Brome	2	0	12B + 9C	6.0
French weed	0	2	0	0.0
French weed & Timothy	1	0	9B + 1C	9.0
Dandelion	3	0	6B + 2C	2.0
Straw bottom		1	0	0.0
Durum wheat	2	3	2B	0.40
For the mile	12	8	39B	

(8) Predators.- In the 20 square feet examined 2 carabid beetle larvae, 2 coarctate and 3 scarabaeoid blister beetle larvae were found. The 2 carabid beetle larvae were feeding on M. bivittatus egg pods.

40 percent of the blister beetle larvae found were in the coarctate stage by September 16.

In 20 square feet examined 7 predators, 30 pods of M. bivittatus and 13 pods of C. pellucida eggs were found. The ratio of egg predators to egg pods was 1:9.

(9) General observations.- The C. pellucida seemed to be concentrated in front of the buildings (VII) and between them (VI). The durum wheat around this area was cut on August 15. On August 15 there were very few grasshoppers (less than one per square yard) in the stubble. On August 21 the population decreased in the south-west corner of the plot (I) but increased on the north-west corner (VII). The sod was heavier on the north-west corner and probably offered better food and shelter from the rain and cold during this period. The Cammula population in front of the buildings (VII) increased about August 21, Cammula being about 60 percent of the population. On August 28 the population in the durum stubble increased to an average of 2 per square yard with a maximum of ten per square yard around the stooks. When the durum stubble was burned on September 30 some of the M. bivittatus were burned to death.

The graph of trend of population (Graph 5, Plate XXX) shows

that there was a general decline in the population from July 24 to August 7. The average population as indicated on the graph for July 24 and July 30 was perhaps a little too high as an average was taken for the entire plot instead of estimates being made in six different parts of the plot and averaged as was done later. There does not seem to be any relation between the decline in population and the weather conditions and there was no disease present at this time. This decline was probably due to a shift in the populations away from the plot but was not recorded. From August 5 to August 21 there was an increase in the population. This may have been due to higher estimates due to greater activity among the grasshoppers because of the higher prevailing temperature between August 6 and 15. On August 5 and August 21 the weather was fine and warm when the estimates were made while on August 3 the temperature was not as high and there was a gusty wind of 5.5 miles per hour velocity blowing. On August 7 the temperature was high but it had rained during the night. The fluctuations as shown on the graph might, therefore, be due to the weather conditions at the time that the estimates were taken but most of the graphs show this decrease in the population and then the rise. There must, therefore, be some other factor involved. From August 21 to September 7 there was a general decrease in the population as on the other plots. This was not due to disease as disease was not prevalent on this plot until September 5. It may have been due to the cutting of the durum wheat around the plot on August 15 as M. bivittatus in the stubble averaged less than one per square yard on August 15 but on August 25 the average was 3 per square yard with a maximum of ten per square yard around the stooks. The slight rise in the population between September 7 and 8 can only be accounted for by the difference in estimation which should probably have been higher on September 8 as there was a north wind blowing and the grasshoppers were seeking the protection of the grass.

(10) Conclusions and summary.

(a) This plot was selected because of the large M. bivittatus and C. pellucida population and because it was hayland.

(b) The dominant plants were Phleum arvense, Bromus inermis, Poa compressa, Taraxacum officinale, Iva xanthifolia, Chenopodium album and seedlings of Thlaspi arvense.

(c) The predominant species of grasshoppers were M. bivittatus and C. pellucida.

(d) Disease was not prevalent on this plot until September 5 when a large number of M. bivittatus were found dead of Empusa grylli. In this case more died of this fungus under the cool, moist conditions between September 5 and September 8 than under the warm, moist conditions previous to September 5.

(e) The average population per square yard for the period from July 24 to September 8 was 13.83.

(f) The average number of egg pods per square foot was 3.33 on this plot and 0.33 in the durum stubble. The egg infestation was rated as "moderate".

(g) M. bivittatus showed preference, for egg laying, of the following associations in order of preference, French weed and timothy, brome, pea, and timothy. No eggs were found among French weed alone, or in the straw stack bottom.

(h) C. pellucida egg pods were found in brome, timothy and dandelion.

(i) The ratio of egg predators to egg pods was 1:9.

(j) 40 percent of the blister beetle larvae were in the coarctate stage by September 16.

(k) On August 21 the population moved from the south west corner of the plot to the north-west corner. The grass on the north-west corner offered better food and shelter during the cold wet period. The population in the durum stubble increased about a week after the crop was cut. Some M. bivittatus were burned to death when the durum stubble was burned on September 20.

7. Detailed study plot VI.
(The south roadallowance of Sec. 1, T. 3, R. 3E.)

(1) Reasons for selection.- The north side of this roadallowance was chosen as a study plot because of the heavy M. bivittatus population and because there was a north slope down from the road which offered protection to the grasshoppers from the south winds. At the bottom of the slope a level grassy area adjoining crops of rye and thatcher wheat, was protected on the south by the grade and on the north by the crops.

(2) General description.- This plot was established on July 24.

The roadallowance was bordered on the north by a crop of rye on the south-west quarter of Sec. 1 and a crop of thatcher wheat on the south-east quarter and farm buildings on the south-east corner. On the south side of the roadallowance there were two fields of durum wheat, one on the north-west quarter and one on the north-east quarter of Sec. 36.

The road was a very high grade with a steep slope, covered with heavy vegetation three to five feet tall, running down to a level grassy area about five yards wide on the north side of the road. Along the south side of the grade there was a ditch about six feet deep and about five yards wide with a narrow strip of level land between the ditch and the crop.

(3) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXVII). In all cases the plants are listed in order of abundance. The general characteristics of the plot may be seen in the photograph (Plate XIX).

The edge of the grade (I) on both sides of the road was covered with heavy vegetation three to five feet in height consisting of Agropyron repens, Aster laevis, A. multiflorus, Rosa blanda, Iva xanthifolia and Salix longifolia. The rest of the quarter mile (II) had more Agropyron repens and Rosa blanda with patches of Salix bebbiana. The edge of the ditch was bordered with Solidago canadensis, Iva xanthifolia, Chenopodium alba, Aster laevis and Aster multiflorus.

The vegetation for the next half mile (III) was chiefly Rosa blanda with Iva xanthifolia, Aster laevis, A. multiflorus and Bromus inermis. Amaranthus retroflexus was present along the edge of the road.

The east quarter of the mile (IV) had had the vegetation along the north slope of the grade cut with the mower in July. The vegetation was chiefly Agropyron repens, Phleum pratense and Poa compressa with a few bushes of Rosa blanda.

The level area (V) was cut with the mower before July 15 but the grass had grown to a height of six inches by September. There was a road along here which was used for trucking and was, therefore, cut up. There was Taraxacum officinale, Phleum pratense, Andropogon furcatus and Bromus inermis but there were also many bare patches. There were bushes of Rosa blanda and patches consisting entirely of Bromus inermis and others of Andropogon furcatus.

The vegetation remained the same for the west half mile but in the east half mile it became chiefly Orchard grass, Agropyron repens and there were patches of Andropogon furcatus.

The level area (VII) was covered with a large amount of Solidago canadensis and Rosa blanda. Aster laevis, A. multiflorus and Agropyron repens were also present. The plants were three to nine inches tall.

A fifth of a mile east (VIII) the vegetation became lighter with a large amount of Phleum pratense and Andropogon furcatus. Amaranthus retroflexus was also present.

The east half mile (IX) had been cut with the mower so that the vegetation was three inches tall but the same plants were present as in the west half mile. There were, however, several patches of Phleum pratense.

The chief plants along this mile were Chenopodium alba, Iva xanthifolia, Rosa blanda, Phleum pratense, Solidago canadensis and Aster. Along the level strips on each side of the roadallowance the chief plants were Andropogon furcatus, Bromus inermis, Phleum pratense, Taraxacum officinale and Rosa blanda.

(4) Grasshoppers.- On July 19 the population along this mile was recorded as M. bivittatus at an average of 20 per square yard with some C. pellucida at the west end. Specimens of Dissosteira carolina, M. femur-rubrum and Arphia pseudonietana were taken along here from August 15 to September 1. The grasshoppers were present all along the edge of the crops and extended nine to ten yards into the rye stubble. There was ten to fifteen percent damage to the rye. M. bivittatus would eat half of several kernels in a head both while the crop was standing and after cutting and stooking.

During the windy weather the grasshoppers congregated along the north slope of the road and in the ditch on the south side in the heavy vegetation. On sunny days when the wind was blowing the grasshoppers could be observed warming themselves on top of the grade along the road sheltered from the wind by the heavy vegetation along the edges of the road.

Estimates were made along this roadallowance. In an attempt to bring the areas estimated down to a more restricted area, plots 12 yards wide along the road and including from the road into the crop about 6 yards were marked out. Estimates were made at three points along the edge of the grade, three along the level grassy area and three in the crop on each plot. This was done with two plots for two weeks and then discarded. This method would be ideal if the plots could be observed every day and sufficient time could be taken to do this with three or four plots all in a row, side by side. Thus shifts to different types of vegetation, slopes, etc., could be observed. As for seasonal population changes where the area covered is large, and can be visited twice a week at most, the method of making observations every eighth of a mile along both sides of a roadallowance was found to be much more satisfactory.

The estimates made along this mile, from west to east every eighth of a mile, are tabulated in the following tables (Tables XXVII and XXVIII). The average for the mile for each trip is given in the right hand column. The average population for the mile for the period from July 24 to September 8 is given at the bottom of the table. The trip averages are graphed in graph 6 (Plate XXX). The graph indicates the fluctuations in the grasshopper population during the season and is discussed under general observations (P. 97).

Plate XXVII

Map of the south roadallowance of Sec. 1, T. 4, R. 3E., the north side of which constituted Detailed Study Plot VI. The cross section of the roadallowance is shown. The symbols are the same as described for Plate XXII.

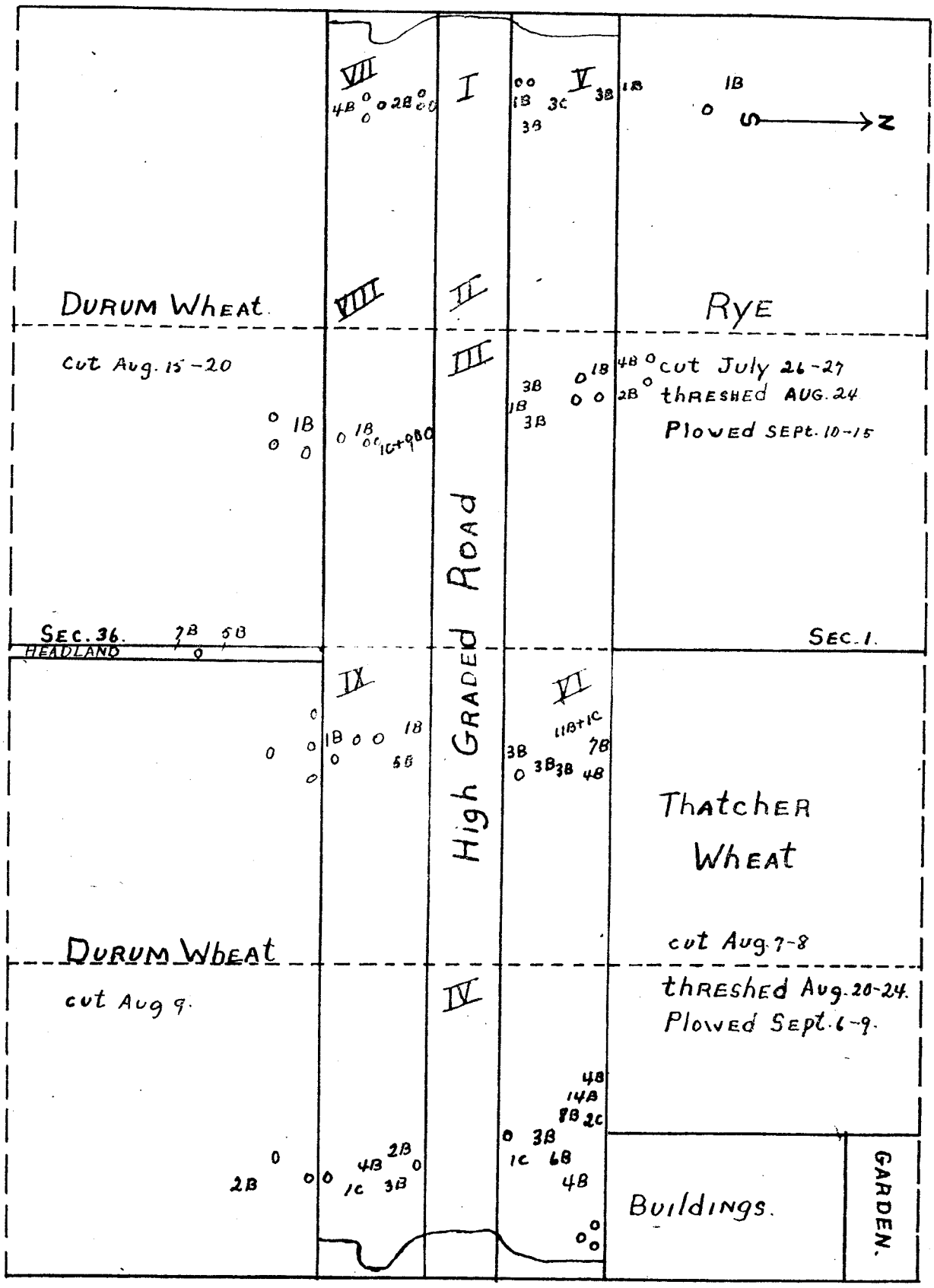

VII
I
V
VIII
II
III
IX
VI
IV
High Graded Road
Durum Wheat
Cut Aug. 15-20
Rye
cut July 24-27
threshed AUG. 24
Plowed SEPt. 10-15
SEC. 36.
HEADLAND
SEC. 1.
Thatcher Wheat
cut Aug. 7-8
threshed Aug. 20-24.
Plowed Sept. 6-9.
Durum Wheat
cut Aug 9.
Buildings.
GARDEN.
S
N

Table XXVII
Population Estimates
(For the north side of the road from west to east)

Date	Population per square yard for eighth mile divisions								Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
July 24	12	20	25	12	18	10	15	8	15.
July 26	16	15	18	12	18	10	12	10	14.
July 31	20	10	20	25	20	20	25	12	19
Aug. 3	6	10	20	20	15	10	18	12	14
Aug. 7	8	12	18	15	12	10	15	15	13
Aug. 10	6	12	15	12	10	8	10	10	10.35
Aug. 21	12	15	25	35	12	15	12	10	17
Sept. 8	5	8	6	6	2	2	4	0	4
								Average population per square yard for the season	13.29

Table XXVIII
Population Estimates
(For the south side of the road from west to east)

Date	Population per square yard for eighth mile divisions								Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
July 24	12				8				10
July 31	12	12	10	10	8				10.4
Aug. 3	8	10	12	20	10				12
Aug. 7	6	6	8	8	12				8
Aug. 10	8	6	8	10	8	10			8
Aug. 21	6	6	8	8	10				7.6
Sept. 8	3	1	4	5			6		3.25
								Average population per square yard for the season	8.46

p. 45

(5) Disease.- M. bivittatus were found dead up the stems of plants in the deep ditch on the south side of the road on July 19. On July 24 although there were a few dead up stems in the ditch there were not as many as previously. There were, however, dead up the stems of rye averaging 5 dead per square yard in places along the edge of the crop. After July 31 very few dead M. bivittatus were found along here. On August 15 for example, only an occasional grasshopper dead of Empusa grylli was observed. Empusa grylli was active in the ditch on the south side of the road all through the season but at no time were dead found on the ground as along the mile south of here, south of Sec. 36.

(6) Egg survey.- The map (Plate XXVII) shows the results of the egg survey.

In this mile 140 M. bivittatus and 9 C. pellucida egg pods and 34 sacs were found in 75 square foot samples.

The average adult population per square yard for the period from July 24 to September 5 was 10.87. The total number of egg pods deposited in the 75 square feet examined was 140 M. bivittatus and 9 C. pellucida. The average number of pods per square foot along the roadallowance was 2.17. In the fields the average was 1.35 pods per square foot.

The results of the egg survey are summarized in the following table (Table XXIX) which shows the average number of egg pods deposited per square foot in each area. The rating of the infestation for each area and for the mile, based on the egg infestation, is given.

Table XXIX
Results of Egg Survey

Location	Sq.ft.samples with pods	Sq.ft.samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating based on egg infestation
North side-W. ¼ mile	4	2	7B + 3C	1.66	light
North " ¼-½ "	4	3	8B	1.14	light
North " ½-¾ "	6	1	31B + 1C	4.57	moderate
North " E. ¼ "	8	4	39B + 3C	3.50	moderate
South " W. ¼ "	2	6	6B	0.75	normal
South " ¼-½ "	2	4	10B + 1C	1.83	light
South " ½-¾ "	3	3	7B	1.16	light
South " E. ¼ "	4	2	9B + 1C	1.66	light
Durum wheat N.W.¼Sec.36	1	3	1B	0.25	light
Headland Sec.36	2	1	12B	4.00	moderate

Table XXIX (Con'd.)
Results of Egg Survey

Location	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating* based on egg infestation
Durum wheat N.E.¼Sec.36	1	2	2B	0.66	moderate
Rye S.W. ¼ Sec.1	4	3	8B	1.14	heavy
Thatcher wheat	Plowed				
For the plot	41	34	140B + 9C	1.99	light

* See Page 198.

(7) Association and slope where eggs are found.- The data recorded under this heading were collected during the egg survey and are tabulated in the following table (Table XXX).

The data show a preference of M. bivittatus for the south slope over the north slope for egg laying. The south slope also seemed to be preferred to level ground.

As in other plots open ground sheltered by tall vegetation seemed very suitable for egg laying. Slight preference was shown for the following types of vegetation, couch, Giant Blue Stem, pea, and Orchard grass. Eggs were found in the durum and rye stubble especially just inside the edge of the fields.

C. pellucida egg pods were found in couch, pea, and in Giant Blue Stem sod.

Table XXX
Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq.ft. samples with eggs	Sq.ft. samples without eggs	Total No. of egg pods	Av. pods per sq. ft.
Couch grass	level	5	2	20B + 3C	2.85
Couch grass	south	5	1	21B + 1C	3.50
Couch grass	north	2	5	1B + 1C	0.16
Giant Blue Stem	south	4	1	19B	3.80
Giant Blue Stem	level	3	1	12B + 1C	3.00
Orchard grass	level	7	4	32B	2.90
Pea sod	level	3	0	6B + 3C	2.00
Open ground	south	1	0	6B	6.00
Open ground	level	2	2	5B	1.25

Table XXX (Con'd)
Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq.ft. samples with eggs	Sq.ft. samples without eggs	Total No. of egg pods	Av. pods per sq. ft.
Timothy sod	level	1	0	1B	1.00
Asters	level	1	3	2B	0.50
Dandelion	level	0	2	0	0.00
Durum stubble	level	1	4	2B	0.40
Durum edge	level	2	1	5B	1.66
Rye stubble	level	1	3	1B	0.25
Rye edge	level	3	0	7B	2.33
For the mile		41	29	140B + 9C	

(8) Predators.- In the 70 square foot samples examined along this roadallowance 6 carabid beetle larvae, 17 coarctate and 5 scarabaeoid blister beetle larvae and 5 bee fly larvae were found. 3 of the carabid beetle larvae, 2 of the scarabaeoid and 4 of the coarctate blister beetle larvae and 4 of the bee fly larvae were observed inside of M. bivittatus egg pods.

77.27 percent of the blister beetle larvae were in the coarctate stage by September 12.

In the 70 square feet examined 33 predators were found associated with 140 M. bivittatus and 9 C. pellucida egg pods. The ratio of predators to egg pods was 1:4.5.

(9) General observations.- On July 19 the population along the north side of this roadallowance was estimated at an average of 30 M. bivittatus per square yard. In the survey of the area before the study area was established, that is during the previous week, Mr. R. H. Handford recorded the population as 35 M. bivittatus per square yard. Apparently the population had started to fall before the study was begun. The result of this continued fall is shown in the graph and continued until July 26. It was also recorded on July 24 that the population had decreased, apparently having moved into the rye where the population of M. bivittatus averaged 10 per square yard. There was some damage to the rye. This fall continued until July 31 when the estimate was high. It was recorded that this estimate was higher than the previous one because there was a north west wind blowing and the population left the crop of rye which had been cut on July 26 to 27 for the protection of the grass and the heavy vegetation on the slope of the grade or became concentrated around the stooks. The same thing happened along the edge of the thatcher wheat although the crop had

not been cut. The graph shows a general decrease in the population from July 31 to August 10. There seemed to be no way of accounting for this fall in population although Mr. Lillijord reported that the population in his yard and in his garden increased. This may have been due to the shifting of the population from the rondallowance. The population moved into the rye stubble when the rye was cut but moved out again in a few days. On August 21 the graph shows an increase in the population on the rondallowance due to this movement out of the stubble. It was also recorded on August 21 that the population along the edge of the thatcher wheat had decreased because the grass which was chiefly Orchard grass, slough grass and Giant blue stem which had been cut with the mower before July 15, had grown coarse. Cannula at the west end of the mile was becoming more predominant and was now recorded as 30 percent of the population. On August 28 although estimates were not made because it was raining off and on, the population appeared to be decreasing probably because of the wet windy weather causing the grasshoppers to concentrate around the stooks and in the tall grass, or perhaps partly due to the trucking of the grain along the edge of the stubble. From this time on there was a general decrease in the population as on other plots.

Mr. Lillijord, the owner of Sec. 1, estimated the damage to the crop of rye as about 15 percent and to his wheat as 8 to 10 percent.

(10) Conclusions and summary.-

(a) This plot was chosen because of the large population of M. bivittatus and because of the protection offered to this population by the heavy vegetation on the slope down from the grade from the south and the crops of rye and thatcher wheat on the north.

(b) The dominant vegetation along this rondallowance was Chenopodium alba, Ive xanthifolia, Rosa blanda, Phleum pratense, Solidago serondenis and Aster.

(c) The predominant species of grasshopper was M. bivittatus with some C. pellucida at the west end. Other species collected were Dissosteira carolina, M. femur-rubrum and Arphia pseudonietana.

(d) Encoptus gryllii was present in the ditch on the north side of the road and along the edge of the rye field.

(e) The average population per square yard for the period from July 24 to September 8 was 10.87.

(f) The average number of egg pods per square foot along the rondallowance was 2.17 and in the fields was 1.35. The egg infestation for this mile was rated as "light".

(g) M. bivittatus showed a preferencefor the south slope over the north slope for egg laying. The south slope also seemed to be preferred to level ground. As in other plots, open ground sheltered by tall vegetation seemed very suitable for egg

laying. Slight preference was shown for the following types of vegetation, couch, giant blue stem, pea, and orchard grass. Eggs were found in the durum and rye stubble especially just inside the edge of the field.

(h) C. pellucida egg pods were found in couch, pea and giant blue stem.

(i) The ratio of egg predators to egg pods was 1:4.5.

(j) 77.27 percent of the blister beetle larvae were in the coarctate stage by September 12.

(k) The M. bivittatus population spread into the rye crop on July 24. The crop was cut on July 26 and on July 31 the population left the stubble to seek the protection of the grass or concentrated around the slopes because of the strong north-west wind. There was 15 percent damage done to the rye before and after cutting and stooking and 8 to 10 percent damage to the thatcher wheat. The M. bivittatus would eat part of a kernel and leave it.

8. Detailed study plot VII.

(The south side of the north roadallowance of Sec. 31, T. 3, R.4E.)

(1) Reasons for selection.- The plot was selected because of the heavy population of C. pellucida in the east half mile.

(2) General description.- This plot was established on July 24 and consisted, at first, of a grassy strip, about four yards wide, between the ditch and the field on the south side of the east half mile. The population here on July 24 was 90 percent C. pellucida and 10 percent M. bivittatus. The plot was later extended to take in the west half mile because there was a strip of waste land covered with vegetation about four feet high with four or five grassy open places next to a field of summer-fallow. C. pellucida gathered in these open places for protection during the windy wet weather in August.

The roadallowance was bordered on the north by summer-fallow on the south-west quarter of Sec. 6, T. 4, R.4E., and a barley field on the south-east quarter of this section with a group of farm buildings just west of the half mile line. On the south side of the road there was a strip of waste land about fifteen yards wide on the north-west quarter of Sec. 31, T.3, R.4E., and south of this a field of summer-fallow. On the north-east quarter there was another field of summer-fallow with a school yard on the north east corner of the section. At the half mile line on Sec. 31 there was a headland about four yards wide.

The road along here was a high grade with a ditch about seven feet deep on the south side of the road and on the north side the

edge of the grade sloped down to a level area between the edge of the grade and the field.

(3) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXVIII). In all cases the plants are listed in order of abundance.

The vegetation in the school yard (I) consisted of Agropyron repens with Bromus inermis and Taraxacum officinale in the south west corner.

The chief grass on the south side along the edge of the road (II) was Bromus inermis with some Agropyron repens and Phleum pratense. There was a predominance of Chenopodium alba and Rosa blanda. The vegetation was about a foot high.

One third of a mile farther west (III) Agropyron repens and Bromus inermis were again predominant with only a few plants of Chenopodium alba and Rosa blanda.

Along the edge of the road on the south side (IV) the vegetation had been cut with the mower but had grown to a height of about one foot by September. There was Chenopodium alba along the edge of the road with some Bromus inermis and Symphoricarpus sp. Along the north edge of the ditch there was Bromus inermis, couch and Rosa blanda.

The deep ditch on the south side of the road for the east half mile (V) was filled with Bromus inermis, Ambrosia trifida, Iva xanthifolia, Bidens frondosa, Phleum pratense, Rosa blanda, Solidago canadensis, Aster laevis, Aster multiflorus and Achillea millefolium. The plants were one and a half to four feet in height. The south bank of the ditch was bare except for occasional plants of Rosa blanda, Iva xanthifolia, Bromus inermis, Aster laevis, A. multiflorus and Andropogon furcatus.

The ditch (VI) was filled with Phleum pratense and Bromus inermis with some Iva xanthifolia, Aster laevis and A. multiflorus, but the plants were only about a foot high. The south bank of the ditch was covered with Solidago canadensis, Phleum pratense, Aster laevis, A. multiflorus, Taraxacum officinale and a few Fragoria virginiana plants.

The level (VII) was about four yards wide (Photograph Plate XX). The vegetation was chiefly Phleum pratense and Agropyron repens. There was some Poa compressa, Aster laevis and Polygonum aviculare. The grass was cut for hay before July 15 but had grown to a height of three to four inches by September.

A quarter of a mile west (VIII) the grass was chiefly Agropyron repens with some Bromus inermis along the edge of the summer-fallow.

One eighth of a mile further west (IX) the grass was chiefly Bromus inermis with Phleum pratense along the edge of the ditch.

The west half mile on the south side of the road was an area of reverted land on which Salix longifolia, Populus tremuloides, Aster laevis, A. multiflorus, Solidago canadensis and Helianthus Maximiliani grew up to a height of three to four feet.

There was a strip along the edge of this waste land next to the summer-fallow (XI) about two yards wide which was cut with the mower and raked. The vegetation along here was chiefly Bromus inermis and Taraxacum officinale with small bushes of Rosa blanda.

There were openings in the brush (XII) all along this strip next to the summer-fallow which were covered with Agropyron repens, Poa compressa and Bromus inermis.

The vegetation on the north slope of the grade (XIII) was chiefly Bromus inermis.

On the level area (XIV) there was a predominance of Agropyron repens, and Chenopodium alba with some Iva xanthifolia and Bromus inermis about two and a half feet high. There were many bare spots and patches of Chenopodium alba.

Along the edge of the road (XV) there was Chenopodium alba while along the next eighth of the mile west there was mainly Amaranthus graecizans along the edge of the grade.

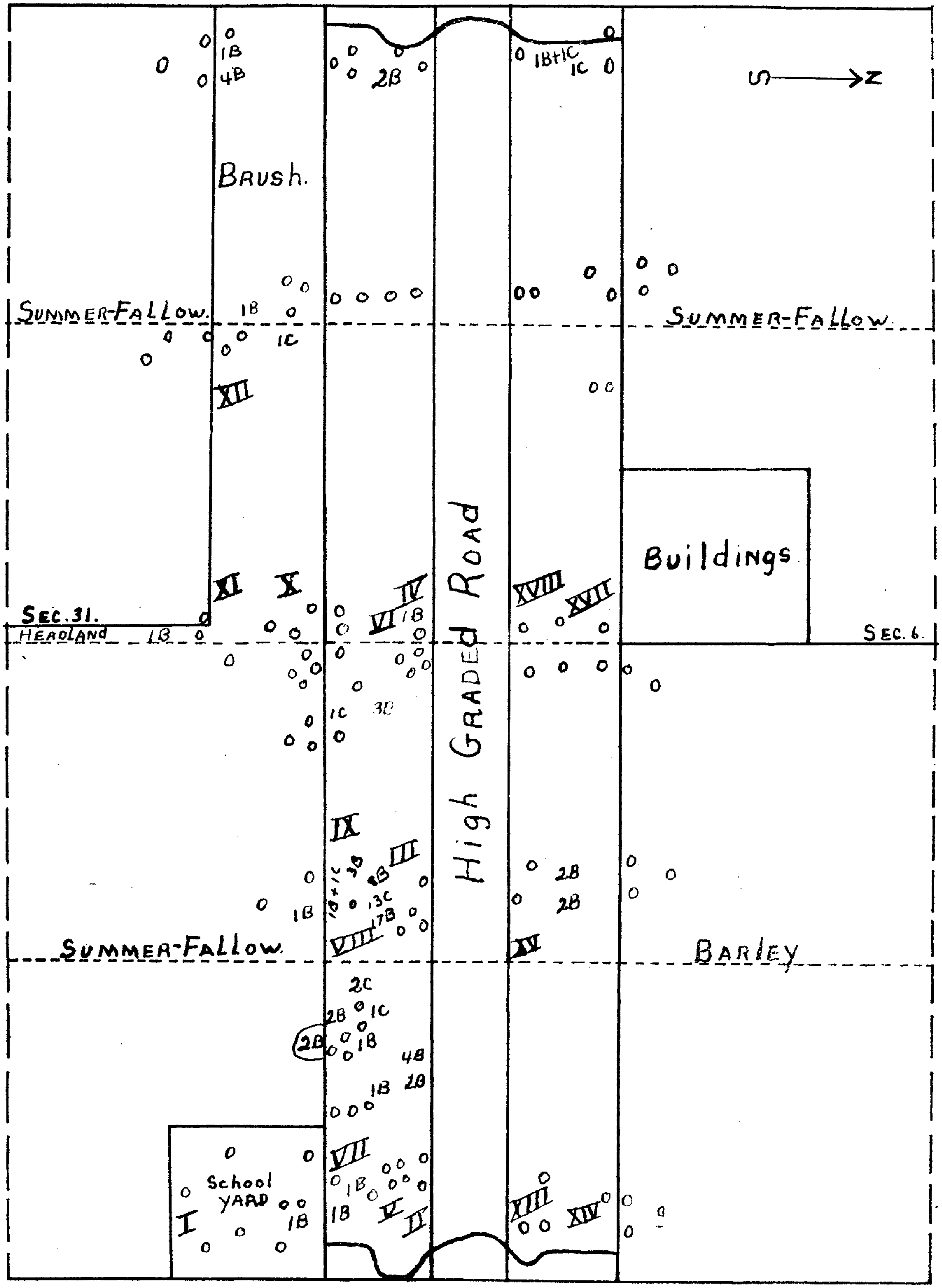
The level part of the west half mile (XVII) was grown up to Bromus inermis with some Aster laevis, A. multiflorus, Solidago canadensis and Iva xanthifolia.

The edge of the road (XVIII) was bordered by Symphoricarpus and Rosa blanda while the west quarter was bordered by Rosa blanda and small Salix longifolia.

The grasses in order of abundance along this mile were Bromus inermis, Phleum pratense, Agropyron repens and Poa compressa. Taraxacum officinale, Chenopodium alba, Rosa blanda and Aster were abundant. Iva xanthifolia, Ambrosia trifida, Solidago canadensis and Helianthus maximiliani were present in the ditch as well as the above mentioned plants. On the brush land there were also Salix longifolia, Populus tremuloides and some Symphoricarpus.

Plate XXVIII

Map of the north roadallowance of Sec. 31, T. 3, R. 4E., the east half mile of the south side of which constituted Plot VII. The cross section of the roadallowance is shown. The symbols are the same as described for Plate XXII.



S → N
Brush.
Summer-Fallow.
Summer-Fallow.
Buildings
High Graded Road
Sec. 31.
Headland
Sec. 6.
Summer-Fallow.
Barley
School Yard

(4) Grasshoppers. - Along the edge of the road on the south side at the west end there were not many grasshoppers at any time during the season. On August 24 the population was recorded as 3 C. pellucida and M. bivittatus per square yard and it remained about the same throughout the season. Along the south edge of the brush land by the summer-fallow in a grassy strip there were more grasshoppers. On July 31 they were recorded as an average population of 5 per square yard M. bivittatus and in the grassy areas extending into the brush as 6 C. pellucida per square yard. Along the south side of the east half mile of this roadallowance the population was recorded as 12 per square yard on July 24 with C. pellucida equal to 90 percent and the rest M. bivittatus. This area was placed under observation as a probable C. pellucida egg bed. On August 10 there were fewer C. pellucida and more M. bivittatus recorded and on August 21 the population was recorded as 25 per square yard with only 40 percent C. pellucida. In the school yard on July 31 there was an average of 10 per square yard, 60 percent M. bivittatus and 40 percent C. pellucida but these moved out and by August 21 the population was only 1 M. bivittatus per square yard.

Specimens of M. dawsoni and M. femur-rubrum were quite numerous along this mile from August 15 to September 8. Specimens of Dissosteira carolina and Arphia pseudonietana were collected along this mile in September.

The estimates of population from west to east on the north and south sides of the east half mile of the roadallowance and in the west half mile from west to east along the edge of the summer-fallow are tabulated in the following tables (Tables XXXI and XXXII). The average population for the mile for each trip is shown in the column headed "averages". The average per square yard for the study period is shown at the bottom of the table. The averages of the population for each trip are graphed in graph 1 (Plate XXXI). This graph shows the fluctuation in population during the season.

Table XXXI
Population Estimates
(For the north side of the road from west to east)

Date	Population per square yard for eighth mile divisions								Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
July 24	3	3	4	6	15	15	15	15	9.5
July 30	3	2	2	6	15	15	12	15	8.75
July 31	4	6	4	6	8	15	20	18	10
Aug. 3	3	4	6	8	10	12	18	18	10
Aug. 7	10	8	6	8	8	12	15	15	10.25
Aug. 10	8	8	6	6	6	12	10	15	8.9
Aug. 21	15	15	15	15	18	25	25	20	18.5
Aug. 26	4	6	4	4	2	4	3	6	4.1
Sept. 8	2	6	4	2	2	4	2	2	2.5
								Average population per square yard for the season	9.15

Table XXXII
Population Estimates
(East half of mile on south side of the road from west to east)

Date	Pop. per square yd. for eighth mile divisions				Av. pop. per sq. yd.
	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
July 24	15	15	15	15	15
July 30	15	15	12	15	14.75
July 31	8	15	20	18	15.25
Aug. 3	10	12	18	18	14.5
Aug. 7	8	12	15	15	12.5
Aug. 10	6	12	10	15	10.75
Aug. 21	18	25	25	20	22.0
Aug. 28	2	4	3	6	3.75
Sept. 8	2	4	2	2	1.75
Average population per square yard for the season					12.25

(5) Disease.- No grasshoppers were found dead of disease along this mile until August 24 when one C. pellucida and several M. bivittatus were found dead evidently of Empusa grylli. The C. pellucida was dead up a stem of grass on the level strip but the M. bivittatus were found dead up the stems of weeds in the ditch at the rate of about one over 50 yards. It is odd that Empusa grylli was not greater in evidence along this ditch as the humidity was high during almost the entire period due to the heavy rains. It must be because the population was not dense enough to facilitate the spread of the fungus.

(6) Egg survey.- The map (Plate XXVIII) shows the results of the egg survey.

In this mile 137 square foot samples were taken and resulted in 63 M. bivittatus egg pods and 21 C. pellucida egg pods and 107 zeros.

The average adult population per square yard during the period from July 24 to September 8 was 9.15. On the south side of the road in the east half mile the average population per square yard

was 12.25 for the study period.

The total number of egg pods deposited in 137 square foot samples examined was 63 M. bivittatus and 21 C. pellucida. The average number of egg pods per square foot for the roadallowance was 0.89. The average in the fields was 0.19 egg pods per square foot.

The results of the egg survey are summarized in the following table (Table XXXIII) which shows the average number of egg pods deposited per square foot in each area. The rating of the infestation for each area and for the mile, based on the egg infestation, is given.

Table XXXIII
Results of Egg Survey

Location	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating based on egg infestation[AA]
North side-W. ¼ mile	2	7	1B + 2C	0.33	normal
" " ¼-½ "	0	5	0	0.00	
" " ½-¾ "	2	5	4B	0.57	normal
" " E. ¼ "	0	4	0	0.00	
South " W. ¼ "	1	9	2B	0.20	normal
" " ¼-½ "	1	3	1B	0.25	normal
" " ½-¾ "	7	12	32B + 15C	2.47	light
" " E. ¼ "	10	16	14B + 3C	0.65	normal
Brush land	5	10	7B+ 1C	0.53	light
Sum.-fall. N.W. ¼ Sec. 31	0	7	0	0.00	
" " N.E. ¼ " 31	1	10	1B	0.09	normal
School yard	1	8	1B	0.11	normal
Sum.-fall. S.W. ¼ Sec. 6	0	3	0	0.00	
Barley S.E. ¼ Sec. 6	0	8	0	0.00	
For the plot	30	107	63B + 21C[A]	0.61	normal

[A] These data vary from those for Table XXXIV because of omissions in the records.

[AA] See page 98.

(J) Association and slope where eggs are found.- The data recorded under this heading are presented in the following table (Table XXXIV).

The number of eggs found was too small to make any comparisons of vegetation and slope preferences although couch grass (A. repens) and timothy contained the most eggs.

C. pellucida egg pods were found in couch, timothy and brome.

Table XXXIV
Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq.ft. samples with eggs	Sq.ft. samples without eggs	Total No. of egg pods	Av. pods per sq. ft.
Couch grass	level	11	15	35B + 9C	1.35
Couch & Dandelion	level	0	4	0	0.00
Brome	level	2	12	2B	0.14
Timothy	level	7	8	12B + 3C	1.80
Burned area	level	2	0	3B	1.50
Brome, Aster, etc.	north	0	10	0	0.00
Brome, Aster, etc.	south	2	9	1B + 1C	0.68
Bare ground	south	2	0	3B	1.50
Spurge	level	1	2	1B	0.33
S.F. border	level	1	10	1B	0.91
S.F.	level	0	10	0	0.00
Barley edge	level	0	7	0	0.00
For the mile		33	135	61B + 20C	0.47

(8) Predators.- In the 171 square foot samples examined 7 carabid beetle larvae, 9 coarctate blister beetle larvae and 3 bee fly larvae were found. Of these 2 of the carabid beetle larvae, 3 of the coarctate blister beetle larvae and the 3 bee fly larvae were found feeding on M. bivittatus egg pods.

All the blister beetle larvae found were in the coarctate stage on September 12.

In the 171 square feet examined 61 M. bivittatus and 20 C. pellucida egg pods and 19 predators were found. The ratio of predators to egg pods was 1:4.26.

(9) General observations.- On July 24 the strip of grassland on the south side of this roadallowance in the east half mile was regarded as a possible future C. pellucida egg bed. There was an average of 15 grasshoppers per square yard almost 100 percent C. pellucida. This continued the same until about August 3 as shown on the graph for plot VI (Graph 1, Plate XXXI). This portion of the graph between July 24 and August 3 shows the variation that is to be expected in estimates of population of this type. The graph shows a decrease of population from August 3 until August 10. The notes for August 10 point out that the estimates for that day are lower than on the preceding days because of the south-east wind which was apparently causing them to seek shelter in the ditch.

This decrease may, therefore, be said to be only a daily fluctuation but shows on the graph as a seasonal fluctuation because the estimates were not taken on the days on either side to show the probable true comparative population corresponding to the other readings on the graph. The graph shows a large increase in population between August 10 and August 21 but, although an increase in population was recorded in the notes the graph exaggerates the increase because the estimate on August 10 was low as pointed out above. It was recorded on August 21 that the population of C. pellucida had greatly decreased although M. bivittatus had moved in to increase the population as shown on the graph. C. pellucida was now only 40 percent of the population whereas formerly it was almost 100 percent. The reason given for this moving out of C. pellucida was that the grass, which had been cut for hay before July 15, had grown coarse and luxuriant because of the recent rains. M. bivittatus moved in and the growth of grass in plot VI was given as the reason for M. bivittatus moving out. This may still be true as on plot VI the grass was orchard grass, slough grass and giant blue stem while on plto VII the grass was chiefly timothy, poa and couch grass (A. smithii). The latter grasses are not nearly as coarse as those on plot VI. The graph then shows the gradual fall decline as on the other plots.

The graph for the population of the south side follows the above graph in a general way but does not show all the fluctuations. The dotted line indicates the figures first used for the points indicated but it was later decided that as these figures were for the ditch and did not correspond to the rest of the figures that it would be better to separate them from the others and indicate them as a dotted line. The new figures show more clearly the true trend of the population.

(10) Conclusions and summary.

(a) The plot was chosen because of the heavy population of C. pellucida in the east half mile.

(b) The grasses in order of abundance along this mile were Bromus inermis, Phleum pratense, Agropyron repens, and Poa compressa. Taraxacum officinale, Chenopodium alba, Rosa blanda and Aster were abundant. Iva xanthifolia, Ambrosia trifida, Solidago canadensis and Helianthus maximiliani were present in the ditch as well as the above mentioned plants. On the brush land there were also Salix longifolia, Populus tremuloides and some Symphoricarpus.

(c) The predominent species of grasshopper during the first part of the season was C. pellucida but was replaced to a large extent by M. bivittatus on August 21.

(d) Empusa grylli was not in very great evidence along this mile although specimens of M. bivittatus and C. pellucida dead of this fungus were found.

(e) The average population per square yard for the period from July 24 to September 5 was 9.15. On the south side of the road in the east half mile the average population per square yard was 12.25.

(f) The average number of egg pods was 0.59 for the roadallowance, in the fields 0.19, and in the east half of the south side 1.42. The egg infestation for this plot is rated as "light".

(g) The number of eggs found on this plot was too small to make any comparison of vegetation and slope preferences although couch grass (A. repens) and timothy contained the most M. bivittatus eggs.

(h) C. pellucida egg pods were found in couch, timothy and brome.

(i) The ratio of egg pods to egg predators was 1:4.26.

(j) All the blister beetle larvae found were in the coarctate stage on September 12.

(k) On August 10 the south-east wind caused the grasshoppers to seek protection in the deep ditch. C. pellucida sought protection in the open grassy areas in the brush during the latter part of the season.

9. Detailed Study plot VIII.
(The south roadallowance of Sec. 31, T. 3, R. 4W.)

(1) Reasons for selection.- The east half of this mile was chosen as a study area because there was a large population of M. bivittatus along the south side of the road and in the sweet clover field on the north-east quarter of Sec. 30.

(2) General description.- This plot was established on July 24 and consisted at first of the east half mile but was later extended to take in the whole mile.

The roadallowance was bordered on the south side of the road by a field of sweet clover on the north-east quarter of Sec. 30, part of which didnot come up and was very weedy, another part was cut and stacked on July 25 to 26 and the rest was not cut until August 20. The entire field was plowed on August 21. On the north west quarter of Sec. 30 there was a field of durum wheat which was never cut because it was so rusty. The north side of the road from east to west was bordered by a field of barley, a piece of summer-fallow, a garden, a pasture field, a field of oats, a crop of durum wheat and a half section of summer-fallow.

The road was a high new grade about five feet high and sloping down on each side. On the south side there was a ditch about two feet deep and on the north side a ditch about a foot deep. There was a level space on each side of the road between the ditch and

the fields. The level area on the north side in the east half mile was about four yards wide while in the west half mile it was about six yards. On the south side of the road the level area was six yards wide.

(3) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXIX). In all cases the plants are listed in order of preference.

The flat grassy strip on the south side of the road at the east end of the mile (I) was about six yards wide. The vegetation consisted chiefly of Phleum pratense. This was cut for hay but by September clumps of Iva xanthifolia, ranging from one to three feet in height, had grown up again. There were many scattered bushes of Rosa blanda and some Aster laevis, Aster multiflorus and Helianthus maximiliani.

West of the quarter mile line (II) the grass, consisting of Phleum pratense, Bromus inermis and Agropyron repens, was one to one and a half feet high. Aster laevis, Aster multiflorus, Rosa blanda, Solidago canadensis and large patches of Andropogon furcatus, Polygonum aviculare and Euphorbia serpyllifolia were also present.

Three-sixteenths of a mile west of the quarter mile line (III) the vegetation became heavier and consisted of Hordeum jubatum, Amaranthus retroflexus, Rosa blanda, Aster laevis, Aster multiflorus, Polygonum aviculare, Salix longifolia and Solidago canadensis. Along the edge of the ditch there was a strip of Phleum pratense, Rosa blanda and Solidago canadensis.

The vegetation on the west half mile (IV) consisted of Phleum pratense, Andropogon furcatus and Hordeum jubatum with the other plants as in the east half mile.

The ditch on the south side of the road had a gradual slope down from the grade for the east half mile (V) which was bare but had a few scattered plants of Taraxacum officinale, Rosa blanda and Euphorbia serpyllifolia along the west half mile (VI).

The south slope of the ditch for the east half mile (V) had Iva xanthifolia at the corner and small plants of Iva xanthifolia scattered all along the mile. Rosa blanda, Solidago canadensis, Aster laevis, Aster multiflorus and Polygonum aviculare were present in almost equal abundance. There was some Achillea millefolium and plants of Fragaria virginiana and Euphorbia serpyllifolia.

The vegetation continued the same to within one-sixteenth of a mile from the west corner of the mile (VII) where there were Salix longifolia, Ambrosia trifida, Iva xanthifolia and Chenopodium alba.

The ditch on the north side of the road (VIII) had a gradual slope down from the grade (Photograph Plate XXI) also but the ditch was shallower and had plants of Taraxacum officinale, Rosa blanda and Orchard grass along the slope for the whole mile. The north side of the ditch was covered with grasses and low weeds. The chief grass was Phleum pratense with some Andropogon furcatus and a large number of Taraxacum officinale.

There was a narrow grassy strip between the ditch and the field (Photograph Plate XXI) on which, for the east one-third of a mile (IX) there was very little growth except for a few plants of Amaranthus retroflexus, Thlaspi arvense and Iva xanthifolia. There were also occasional plants of Cirsium arvense, Aster laevis and Aster multiflorus present.

In the west two-thirds of a mile (X) the vegetation consisted of Phleum pratense, Agropyron repens and Hordeum jubatum with some Rosa blanda, Solidago canadensis, Amaranthus retroflexus, Aster laevis, Aster multiflorus, Taraxacum officinale and Orchard grass.

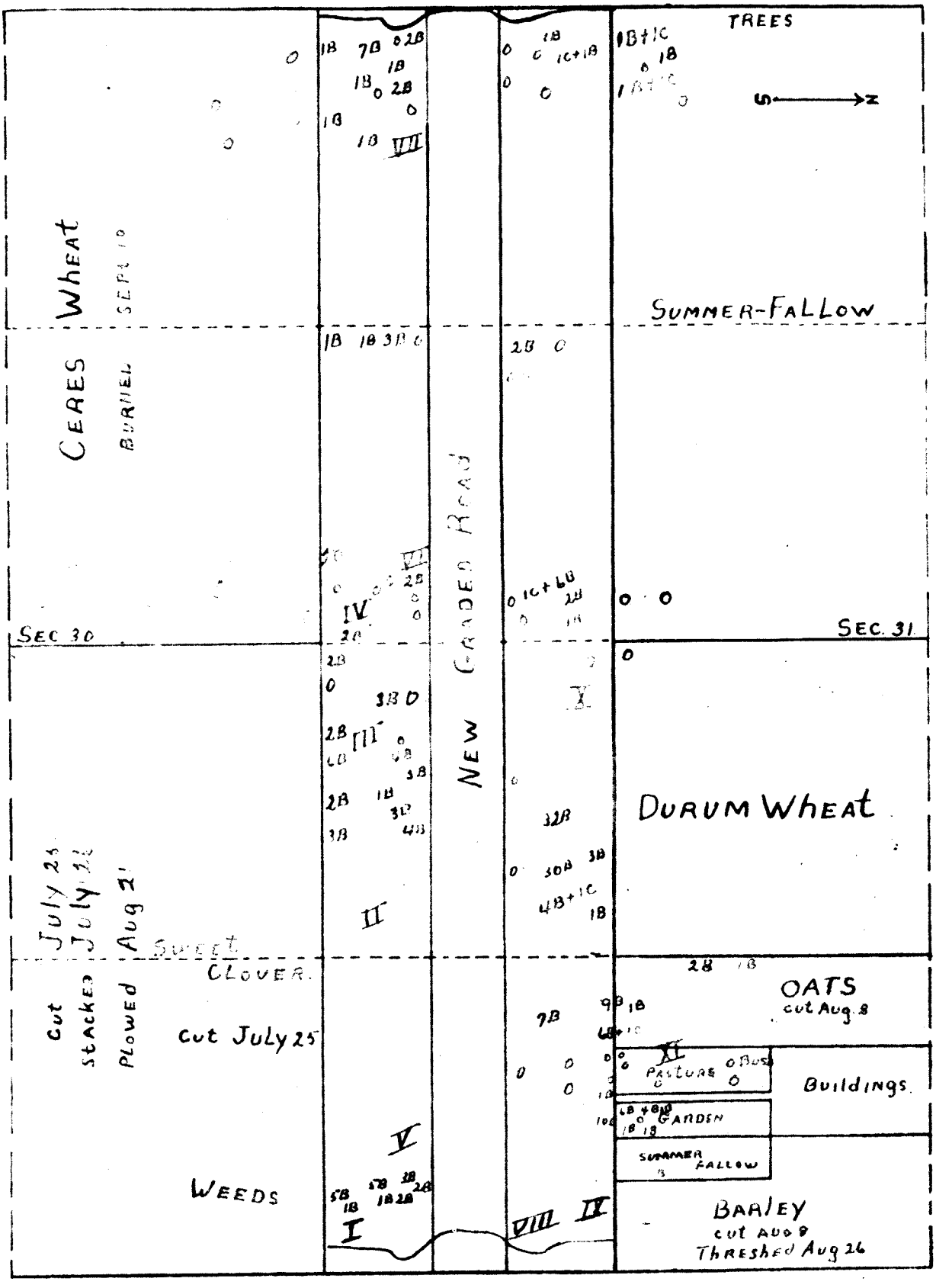
The pasture field (Photograph Plate XXI) on the north side of the road (XI) was covered with a short sparse growth of Polygonum aviculare, Euphorbia serpyllifolia, Thlaspi arvense and Orchard grass with some Aster laevis, Aster multiflorus, Amaranthus retroflexus and Achillea millefolium. There were many bare spots and the vegetation was overgrazed. North of this pasture there was a bluff of Populus tremuloides and Salix longifolia with openings in which Taraxacum officinale and Phleum pratense were present.

The grasses found along this mile in order of abundance were Phleum pratense, Bromus inermis, Andropogon furcatus, Orchard grass, Spartina michauxiana, Agropyron repens and Hordeum jubatum. Other plants found along this mile in order of their abundance were Taraxacum officinale, Rosa blanda, Chenopodium alba, Iva xanthifolia, Aster, Solidago canadensis, Helianthus maximiliani, Euphorbia serpyllifolia, and Polygonum aviculare. Specimens of the following plants were also collected along this mile, Grindelia squarrosa, Apocynum cannabinum and Ambrosia psylostachya.

(4) Grasshoppers.- On July 18 the population along this mile was recorded as 85 percent M. bivittatus and 15 percent C. mollipes on the south side of this road among the clover, rag weed

Plate XXIX

Map of the roadallowance south of Sec. 31, T. 3, R. 4E., the east half of which was shwiad as Plot VIII. The cross section of the roadallowance is shown. The symbols are the same as described for Plate XXII.


TREES
S
N
CERES Wheat
BURNEL
SEPT 10
SUMMER-FALLOW
NEW GRADED ROAD
SEC 30
SEC. 31
DURUM Wheat
July 25
July 22
Aug 2'
Sweet
CLOVER.
Cut
stacked
Plowed
Cut July 25
WEEDS
OATS
cut Aug 8
PASTURE
Buildings
GARDEN
SUMMER FALLOW
BARLEY
cut Aug 9
Threshed Aug 26
I
II
III
IV
V
VI
VII
VIII
IX
X
XI

and rose bushes, and almost 100 percent M. bivittatus and very abundant all over the north-east quarter of Sec. 30. On Sec. 31 along the oats M. bivittatus and C. pellucida were both present and along the sweet clover on Sec. 31 almost 100 percent M. bivittatus. On the north side of the road at the east end and through the barley field the average population of M. bivittatus was 8 per square yard. Along the edge of the pasture and extending into the pasture for seven yards the population averaged 15 M. bivittatus per square yard. Opposite the oat field the population again decreased to an average of 8 per square yard. In the west half mile along the summer-fallow the population averaged 5 per square yard almost 70 percent M. bivittatus and 30 percent C. pellucida. On the north side and along the cereo wheat on the south side of the road the population averaged 12 per square yard, 85 percent M. bivittatus and 15 percent C. pellucida. On July 26 the clover had been cut and some of the population shifted from the south to the north side of the road. On July 31 M. femur-rubrum was recorded as almost 1 per square yard along the west five-eighths of a mile, On the south side of the road. There was also some M. mexicanus present. On August 10 the population of 15 M. bivittatus in the pasture field shifted north, due to the south-east wind prevailing and were present in opening in the poplar and willow bush. On August 21 the clover ground was all plowed except a strip in the centre where the population averaged 30 M. bivittatus per square yard. The population in the pasture field and bush decreased but that in the oats and along the border of the oats and wheat increased, so probably there was a shift in population. When the clover ground was plowed on August 21 the grasshoppers became heavier along the stocked sweet clover and cereo wheat the average population being 30 per square yard with a maximum of 50. On August 28 the population was much smaller in the east half mile but still remained high along the edge of the stocked sweet clover. The population along the west half mile was somewhat lighter also.

Other species collected along this mile were M. femur-rubrum, M. mexicanum, Spharagemon collare, Dissosteira carolina and Arphia pseudonietana.

The estimates of the population for the east half mile of the north and south sides of the roadallowance are tabulated in the following tables (Table XXXV and XXXVI). The average for each trip and the average for the study period are shown as grasshoppers per square yard. The averages for the trips are graphed in graph 2 (Plate XXXI). The graph indicates the fluctuations in population during the study period.

Table XXXV
Population Estimates
(For the south side of the road from east to west)

Date	Pop. per square yd. for eighth mile divisions 0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	Av. pop. per sq.yd.
July 24	8	8	10	10	12	9.6
July 26	8	12	10	8	12	10.0
July 30	8	10	10	8	12	9.6
July 31	10	12	12	14	20	13.6
Aug. 3	6	6	10	10	12	8.8
Aug. 7	8	6	10	15	12	10.2
Aug. 10	10	4	12	18		11.0
Aug. 21	10	1	1	40	20	14.4
Aug. 28	2	6	10	15	16	9.8
Sept. 8	1	1	1	15	12	6.0
Sept.12	1	1	1	1	6	2.0
Sept.16	2	2	2	4	8	3.6

Average population per square yard for the season 9.05

Table XXXVI
Population Estimates
(For the north side of the road from east to west)

Date	Pop. per square yd. for eighth mile divisions 0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	Av. pop. per sq.yd.
July 24	20	10	8	8	6	10.4
July 26	15	25	30	15	6	18.2
July 30	15	20	30	8	8	14.2
July 31	3	15	30	10	12	12.0
Aug. 3	6	8	8	15	12	9.8
Aug. 7	8	10	6	12	10	9.2
Aug. 10	10	4	2	10	12	7.6
Aug. 21	8	1	1	10	15	7.0
Aug. 28	1	1	2	0	0	5.8
Sept. 8	0	0	0	6	6	2.4
Sept.12	1	0	0	1	6	1.6
Sept.16	0	0	0	1	2	0.6

Average population per square yard for the season 8.23

(5) Disease.- On July 15 specimens of M. bivittatus dead from Empusa grylli were abundant in the west half mile and a few were observed in the east half mile. There was no other record of disease until August 25 when a number of dead M. bivittatus were observed both up the stems and on the ground especially in the ditch at the east end in the Iva xanthifolia and Phleum pratense. There were also a few noticed dead up stems on September 5. Disease was not prevalent along this mile.

(6) Egg survey.- The map (Plate XXIx) shows the results of the egg survey.

In this mile 106 square foot samples were examined and 217 M. bivittatus and 12 C. pellucida egg pods and 47 acres were found.

The average adult population during the period from July 24 to September 16 was 8.64 per square yard in the east five-eighths of the mile of this roadallowance. The total number of eggs deposited in the 94 square foot samples along the roadallowance was 211 M. bivittatus and 4 C. pellucida egg pods. In the fields 29 square foot samples gave 20 M. bivittatus and 2 C. pellucida egg pods and 15 acres. The average number of eggs deposited along the roadallowance was 2.69 per square foot and in the fields was 0.76.

The results of the egg survey are summarized in the following table (Table XXXVII) which shows the average number of egg pods per square foot for each area. The rating of the infestation for each area and for the mile, based on the egg infestation, is given.

The lack of eggs in this mile especially in the west half mile was attributed to the soil rather than to the vegetation. The soil in this mile is hard and unfriable and, although not surveyed by Prof. Ellis, it is probably Osborne Clay as it is very similar to that on Sec. 35. This roadallowance was disturbed by the building of the grade in the spring of 1935. It may be that much of the sub-soil has been brought to the surface and is unsuitable for egg laying.

Table XXXVII
Results of Egg Survey

Location	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. Pods per sq.ft.	Rating based on egg infestation
North side-W. ½ mile	2	4	2B + 1C	0.5	normal
" " ½-½ "	4	5	11B + 1C	1.73	light
" " ½-¾ "	5	3	70B + 1C	8.87	moderate

Table XXXVII (CON'D.)
Results of Egg Survey

Location	Sq.ft.samples with pods	Sq.ft.samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating based on egg infestation. **
N. side- E. ½ mile	5	5	33B	3.30	moderate
S. " W. ½ "	8	3	16B	1.45	light
S. " ½-¼ "	6	6	11B	0.92	normal
S. " ¾-½ "	11	3	35B + 7C	3.00	light
S. " E. ¼ "	7	0	19B	2.71	light
Sum.-fal. S.W.¼Sec.31	3	4	3B + 2C	0.71	heavy
Durum wheat Sec. 31	0	1	0	0.00	
Oats Sec. 31	2	1	3B	1.00	heavy
Pasture Sec. 31	0	5	0	0.00	
Garden Sec. 31	5	1	13B	2.16	heavy
Sum.-fal. Sec. 31	1	0	1B	1.00	heavy
Ceres wheat Sec. 30	0	6	0	0.00	
For the plot	59	47	217B + 12C*	2.16	light

* These data vary from those in Table XXXVIII because of omissions in the records.

** See page 196.

(7) Association and slope where eggs are found.- The data recorded relating to this topic during the egg survey are recorded in the following table (Table XXXVIII).

The data show in the case of timothy that M. bivittatus preferred a south slope to a north slope and level to a north slope. The greatest number of eggs was found in timothy sod, couch grass (A. repens), and brome grass. There were eggs found around the edges of plowing, barley stubble and summer-fallow. No eggs were found in burned ceres wheat or durum wheat stubble.

C. pellucida eggs were found in timothysod, couch and summer fallow.

Table XXXVIII
Vegetation and Slope preferences of M. bivittatus for Ovipesition

Vegetation	Slope	Sq.ft.samples with eggs	Sq.ft.samples without eggs	Total No. of egg pods	Av. pods per sq. ft.
Couch		6	0	26B + 1C	4.34
Brome		4	2	10B	1.66
Timothy		10	5	35B + 2C	2.33

Table XXXVIII (Con'd)
Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq.ft. samples with eggs	Sq.ft. samples without eggs	Total No. of egg pods	Av. pods per sq. ft.
Timothy	south	10	10	83B + 1C	4.15
Timothy	north	7	8	15B	1.00
Giant blue stem		2	1	2B	0.66
Orchard grass		5	4	5B	0.55
Wild barley		1	0	1B	1.00
Redroot pig weed		2	2	16B	4.00
Dandelion		4	9	13B	1.00
Loose soil around potatoes		1	1	1B	0.50
Border of plowing		2	0	7B	3.5
Edge of barley		1	1	1B	0.5
Corex burned		0	6	0	0.0
Durum stubble		0	1	0	0.0
Summer-fallow		3	4	3B + 2C	0.43
Ditch--bare soil		2	0	5B	2.5
		60	54	223B + 3C	

(8) Predators.- In the 114 square foot samples examined 7 carabid larvae, 12 acorotato, 2 scarabaeoid blister beetle larvae and 4 bee fly larvae were found. 4 wireworms were also found associated with the egg pods. None of the predators were reported as feeding on egg pods.

85.7 percent of the blister beetle larvae were in the acrotate stage by September 20.

In the 114 square foot samples examined 25 predators were found associated with 223 M. bivittatus and 6 C. pellucida egg pods. 4 wireworms were found also. The ratio of predators to egg pods was 1:9.16.

(9) General observations.- The major species along this five-eighths of a mile, the population of which is graphed on graph 2 on Plate XXXI, was M. bivittatus. The graph shows an increase in the population on the north side of the road about July 26 when the clover on the south side of the road was cut. In the notes it was recorded that there was a shift in population from the south to the north side of the road but the graph indicates that the shift must have been from the clover to the roadallowance and then across the road. The rise in the graph on August 21 was probably due to the plowing of the clover ground

August 19 to 21 and the shifting of the population from the stubble where it averaged about 8 per square yard onto the roadallowance as well as into the centre of the field as recorded. After this time the graph indicates that the population gradually decreased as on the other plots studied.

The number of eggs recorded in this mile is a little lower than was expected especially along the south side of the west half mile where the population averaged about 20 M. bivittatus per square yard August 15 until about September 5. All during the season M. bivittatus were observed with their abdomens in the ground along the south slope on the south side of the grade in the loose, bare earth as if depositing eggs. Very few eggs were found along this slope of the grade. There must be some reason for this failure to oviposit although they went through the motions. There must have been some physiological stimulus lacking, perhaps some constituent of the soil.

(10) Conclusions and summary.

(a) The east half of this mile was chosen as a study area because there was a large population of M. bivittatus along the south side of the road and in the sweet clover field on the north-east quarter of Sec. 30. It was later extended to take in the whole mile.

(b) The grasses along this mile in order of abundance were Phleum pratense, Bromus inermis, Andropogon furcatus, Orchard grass, Spartina michauxiana, Agropyron repens, and Hordeum jubatum. Other plants found along this mile in order of abundance were Taraxacum officinale, Rosa blanda, Chenopodium album, Iva xanthifolia, Aster, Solidago canadensis, Helianthus maximiliani, Euphorbia serpyllifolia and Polygonum aviculare. Specimens of the following plants were also collected along this mile, Grindelia squarrosa, Apocynum cannabinum and Ambrosia psylostachya.

(c) The dominant species of grasshopper was M. bivittatus with some C. pellucida. Other species present were M. mexicanus, M. femur-rubrum, Schistocerca collare, Dissosteira carolina and Arphia pseudonietana.

(d) On July 15 Empusa grylli was active in the west half mile. There was no further record of disease until August 28 when a number of dead M. bivittatus were observed both up stems and on the ground. Disease was not prevalent along this mile.

(e) The average population in the east five-eighths of a mile for the period from July 24 to September 16 was 8.04 per square yard.

(f) The average number of eggs deposited along the roadallowance was 32.69 per square foot and in the fields was 0.76. The egg infestation was rated as "light".

(g) M. bivittatus preferred the south slope to level ground and level ground to a north slope according to the data

for timothy sod for this plot. The greatest number of eggs were found in timothy sod, couch grass (A. repens) and brome grass. Eggs were found around the edges of the plowing, barley stubble and summer-fallow. No eggs were found in burned corse wheat or durum stubble.

(h) C. pellucida eggs were found in timothy sod, couch and summer-fallow.

(i) The ratio of egg predators to egg pods was 1:9.16.

(j) Four wireworms were found associated with the egg pods but were not observed feeding.

(k) 65.7 percent of the blister beetle larvae were in the coarctate stage by September 20.

(l) When the clover was cut on July 26 the population moved out of the clover over to the north side of the road. The clover ground was plowed on August 19 and the grasshoppers moved to the centre, unplowed strip and to the roadallowance.

(m) The lack of any great number of eggs in this mile was attributed to the soil rather than to the vegetation. This area has not been surveyed by Prof. Ellis and so the soil classification is not known.

Plate XXX

Graph 1. Graph of the average population of the east and west side of the west roadallowance of Sec. 34, T. 3, R. 3E. This is the graph for Plot I.

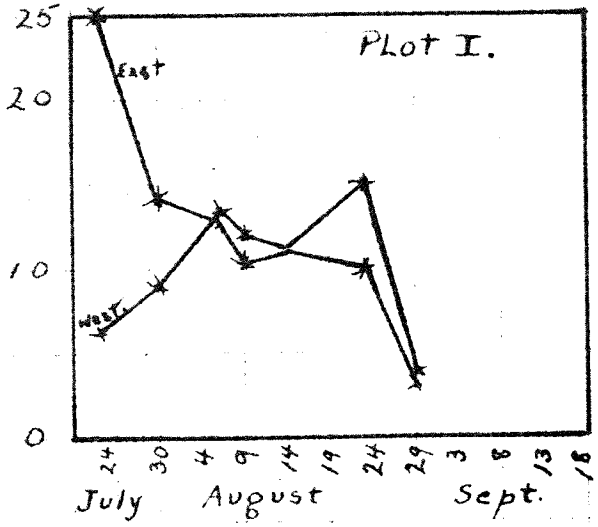
Graph 2. Graph for Plot II showing the graph of the average population of the north and south side of the south roadallowance of Sec. 33, T. 3, R. 3E., and the half mile road of Sec. 33.

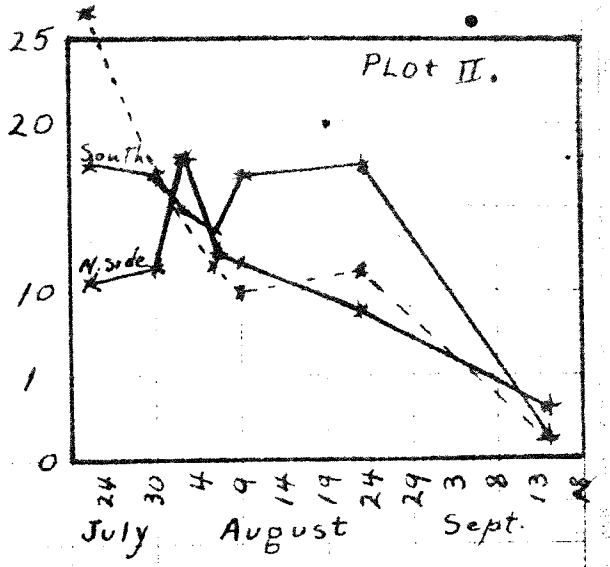
Graph 3. Graph for Plot III showing the graph of the average population of the north and south side of the west half of the north roadallowance of Sec. 21, T. 3, R. 3E., and the area described as Plot III.

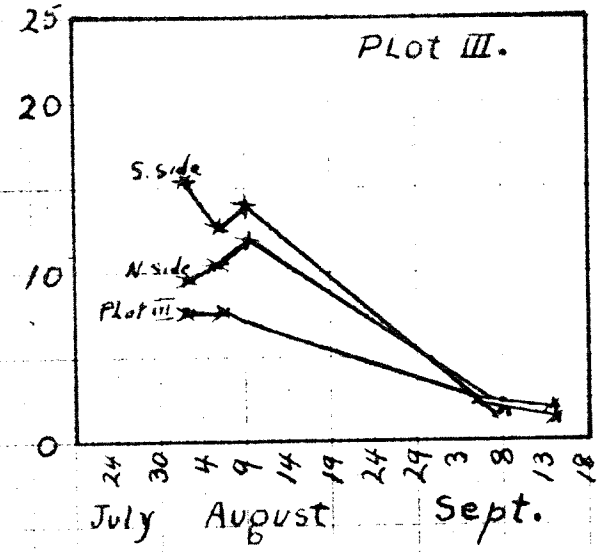
Graph 4. Graph for Plot IV showing the graph of the average population of the north side of the west three eighths of a mile of the south roadallowance of Sec. 27, T. 3, R. 3E.

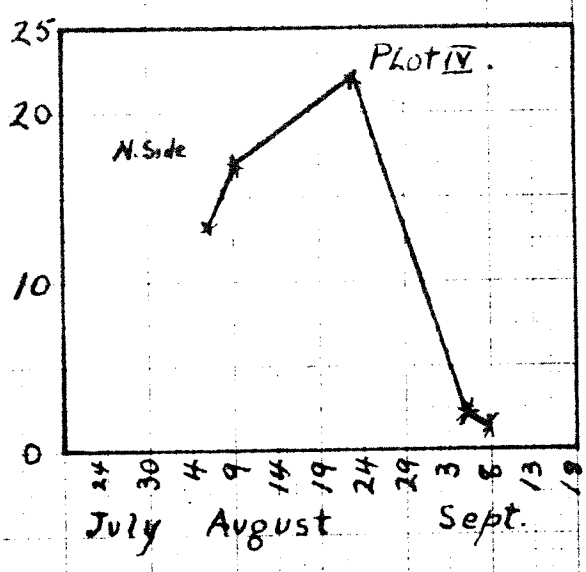
Graph 5. Graph of the average population of Plot V.

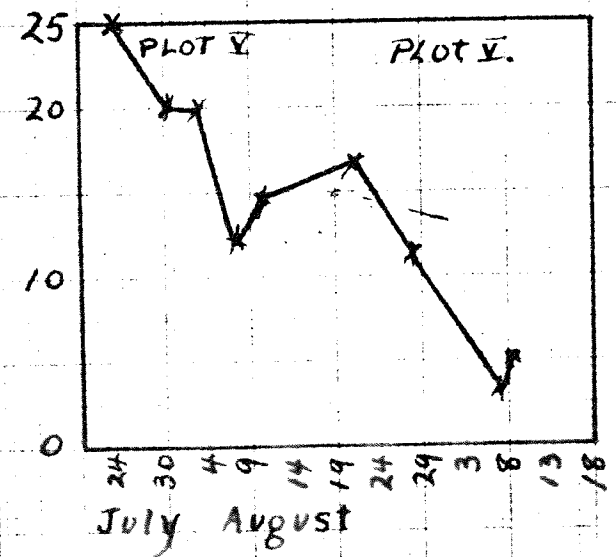
Graph 6. Graph for plot VI showing the graph of the average population of the north and south side of the south roadallowance of Sec. 1. T. 4, R. 3E.


PLot I.
East
West
25
20
10
0
24 30 4 9 14 19 24 29 3 8 13 18
July August Sept.


PLot II.
South
N. Side
25
20
10
1
0
24 30 4 9 14 19 24 29 3 8 13 18
July August Sept.


PLot III.
S. Side
N. Side
Plot III
25
20
10
0
24 30 4 9 14 19 24 29 3 8 13 18
July August Sept.


PLot IV.
N. Side
25
20
10
0
24 30 4 9 14 19 24 29 3 8 13 18
July August Sept.


PLOT V
PLot V.
25
20
10
0
24 30 4 9 14 19 24 29 3 8 13 18
July August

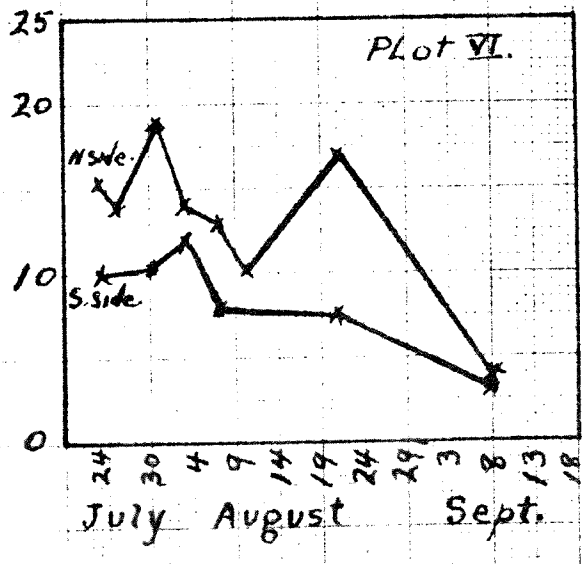

PLot VI.
N Side
S. Side
25
20
10
0
24 30 4 9 14 19 24 29 3 8 13 18
July August Sept.

Plate XXXI

Graph 1.
Graph of the average population of Plot VII and the south side of the north roadallowance of Sec. 31, T. 3, R. 4E.

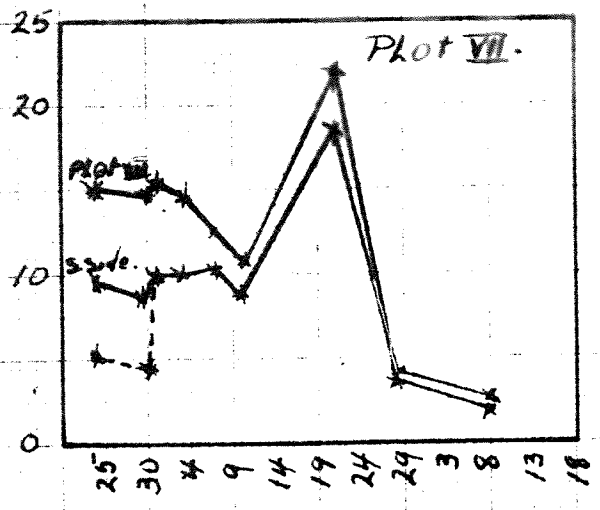
Graph 2.
Graph of the average population of Plot VIII showing the graph for the average population in the east five-eighths of a mile on the north and south sides of the south roadallowance of Sec. 31, T. 3, R. 3E.

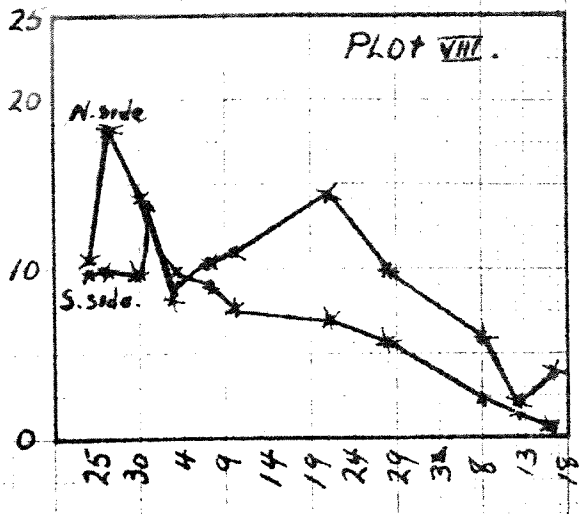
Graph 3.
Graph for observational study area I. The average populations of the east and west sides of the west roadallowance of Sec. 28, T. 3, R. 3E., are graphed.

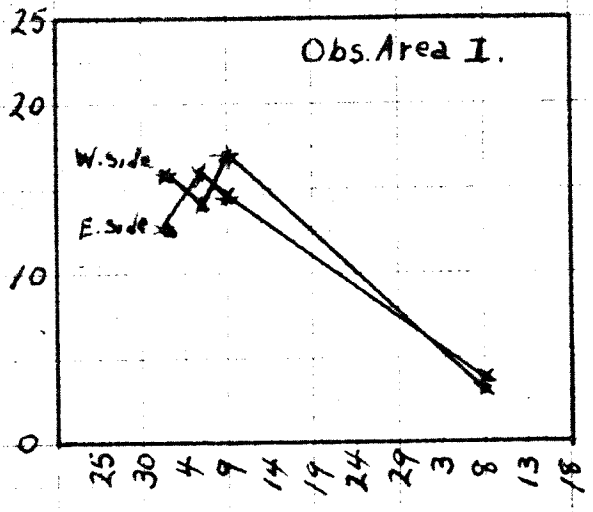
Graph 4.
Graph for observational study plot II. The average populations of the east and west sides of the east roadallowance of Sec. 31, T. 3, R. 4E., are graphed.

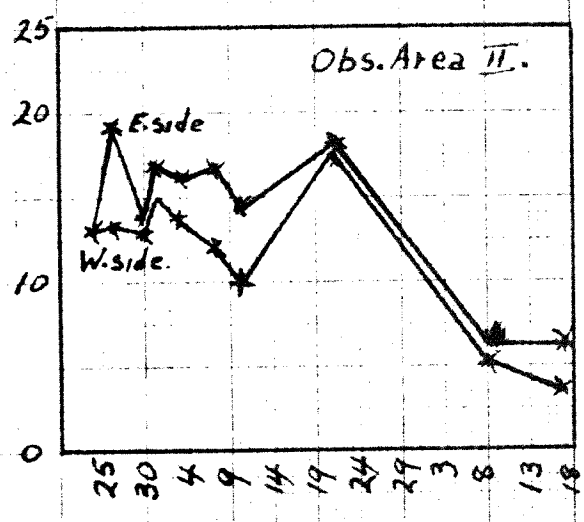
Graph 5.
Graph for observational study plot III. The average populations of the north and south sides of the west half mile of the south roadallowance of Sec. 34, T. 3, R. 3E., are graphed.

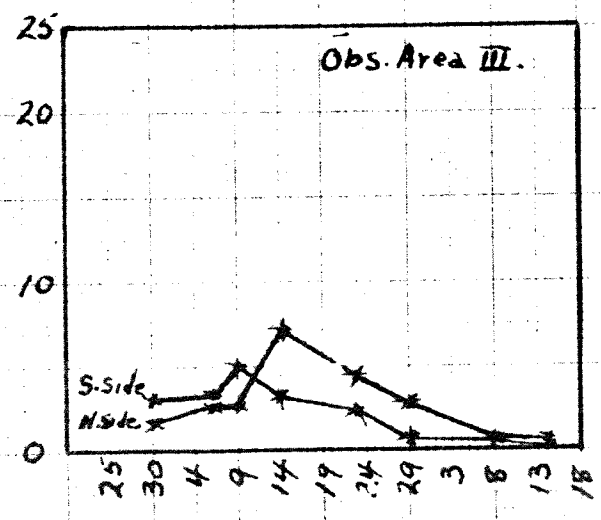
Graph 6.
Graph for observational study area IV. The average population of the south side of the south roadallowance of Sec. 35, T. 3, R. 3E., is graphed.


Plot VII.
Plot VII
S. side.
25
20
10
0
25 30 4 9 14 19 24 29 3 8 13 18


Plot VIII.
N. side
S. side.
25
20
10
0
25 30 4 9 14 19 24 29 3 8 13 18


Obs. Area I.
W. side
E. side
25
20
10
0
25 30 4 9 14 19 24 29 3 8 13 18


Obs. Area II.
E. side
W. side.
25
20
10
0
25 30 4 9 14 19 24 29 3 8 13 18


Obs. Area III.
S. side
N side
25
20
10
0
25 30 4 9 14 19 24 29 3 8 13 18

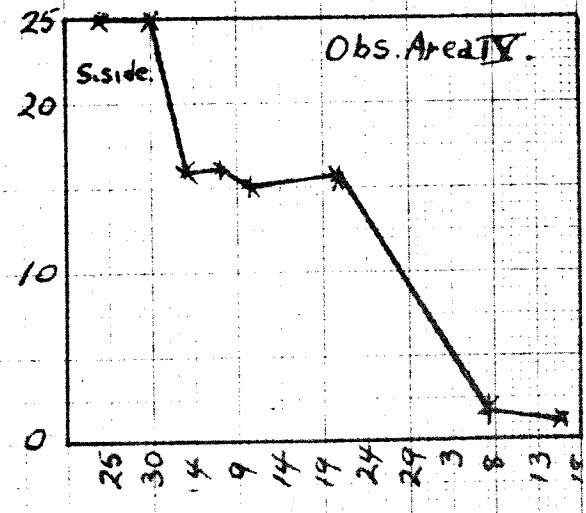

Obs. Area IV.
S. side.
25
20
10
0
25 30 4 9 14 19 24 29 3 8 13 18

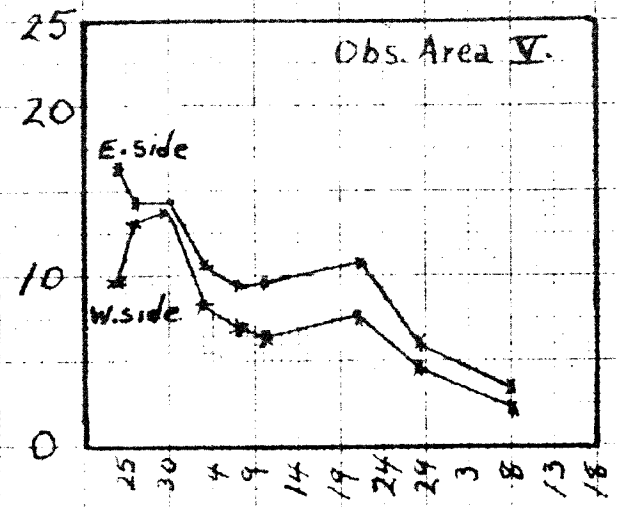
Plate XXXII

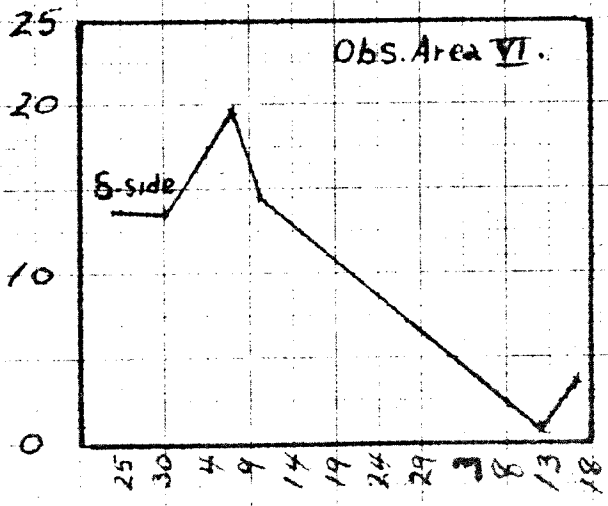
Graph 1.

Graph for observational study plot V. The graphs for the east and west sides of the west road-allowance of Sec. 36, T. 3, R. 3E., are shown.

Graph 2.

Graph for observational study plot VI. The graph for the south side of the road allowance south of Sec. 36, T. 3, R. 3E., is shown.


Obs. Area V.
E. side
W. side
25
20
10
0
25
30
4
9
14
19
24
24
3
8
13
18


Obs. Area VI.
S-side
25
20
10
0
25
30
4
9
14
19
24
29
7
8
13
18

VI. OBSERVATIONAL AREAS.

The observational areas differ from the detailed study plots in that they were chosen because of their proximity to the daily route of travel whereas the latter were chosen for definite characteristics. The former were not treated in as great detail. Population estimates were made while walking between study plots and general notes and observations made. In writing up the results of the study of these areas they are treated in a similar manner to the detailed plots. In most cases the data are not as complete as that for the plots but in some cases the results were just as satisfactory.

2. Observational area I.
(The west roadallowance of Sec. 28, T. 3, R. 3E.)

(1) General description.- Observations were made along this mile while walking between plots II and III. This area was established on August 2.

This roadallowance was bordered on the west by an oat field on the north-east quarter of Sec. 29 and by a durum wheat field on the south-east quarter. On the east it was bordered by a crop of durum wheat on the north-west quarter of Sec. 28 and a weedy oat field planted to sweet clover on the south-west quarter. There was a weedy headland at the half mile line of both sections. The one on Sec. 29 was two yards wide and the one on Sec. 28 was three yards wide.

There was only a trail along the west side of the roadallowance but otherwise there was no road. The remainder of the roadallowance was a slight grade covered with grass with a narrow ditch a foot wide and a foot deep on the east side.

(2) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXXIII). In all cases the plants are listed in order of abundance.

The trail along the west side of the roadallowance (I) was bordered in the north quarter mile by Poa compressa and Orchard grass with some Polygonum aviculare, Aster laevis, A. multiflorus, Solidago canadensis and an occasional plant of Chenopodium album next to the crop.

A quarter of a mile south (II) there was some Amaranthus graecizans and A. retroflexus.

Farther south (III) the edge of the road was bordered mainly by Hordeum jubatum, Orchard grass, Aster laevis and A. multiflorus.

South of the half mile line (IV) the durum wheat crop grew out to the edge of the road.

Along the edge of the road (V) there was Rosa blanda and Phleum pratense.

The vegetation on the grassy roadallowance (VI) was a mixture of Bromus inermis, Poa compressa, Agropyron repens, Phleum pratense, Andropogon furcatus and Hordeum jubatum. There was some Aster laevis, A. multiflorus, Artemisia ludoviciana, Helianthus maximiliani, Achillea millefolium and Rosa blanda along here also. This area had been cut for hay but the Andropogon furcatus had grown to a height of one and a half feet by September.

South of the half mile line (VII) the vegetation was chiefly Andropogon furcatus and Rosa blanda. There were a lot of bare places in the sod which in September were grown up to Thlaspi arvense seedlings.

The south quarter of the mile (VIII) was more grassy again with less Rosa blanda.

At the south corner (IX) there was a patch of tall Chenopodium alba, Aster laevis, and A. multiflorus about four feet high. There were also plants of Bidens frondosa, Amaranthus retroflexus, Orchard grass and Melilotus alba.

At the half mile line on Sec. 29 there was a headland (X) about two yards wide running east and west. This headland was covered with Orchard grass, Amaranthus retroflexus, Aster laevis, A. multiflorus and a few plants of Ambrosia trifida.

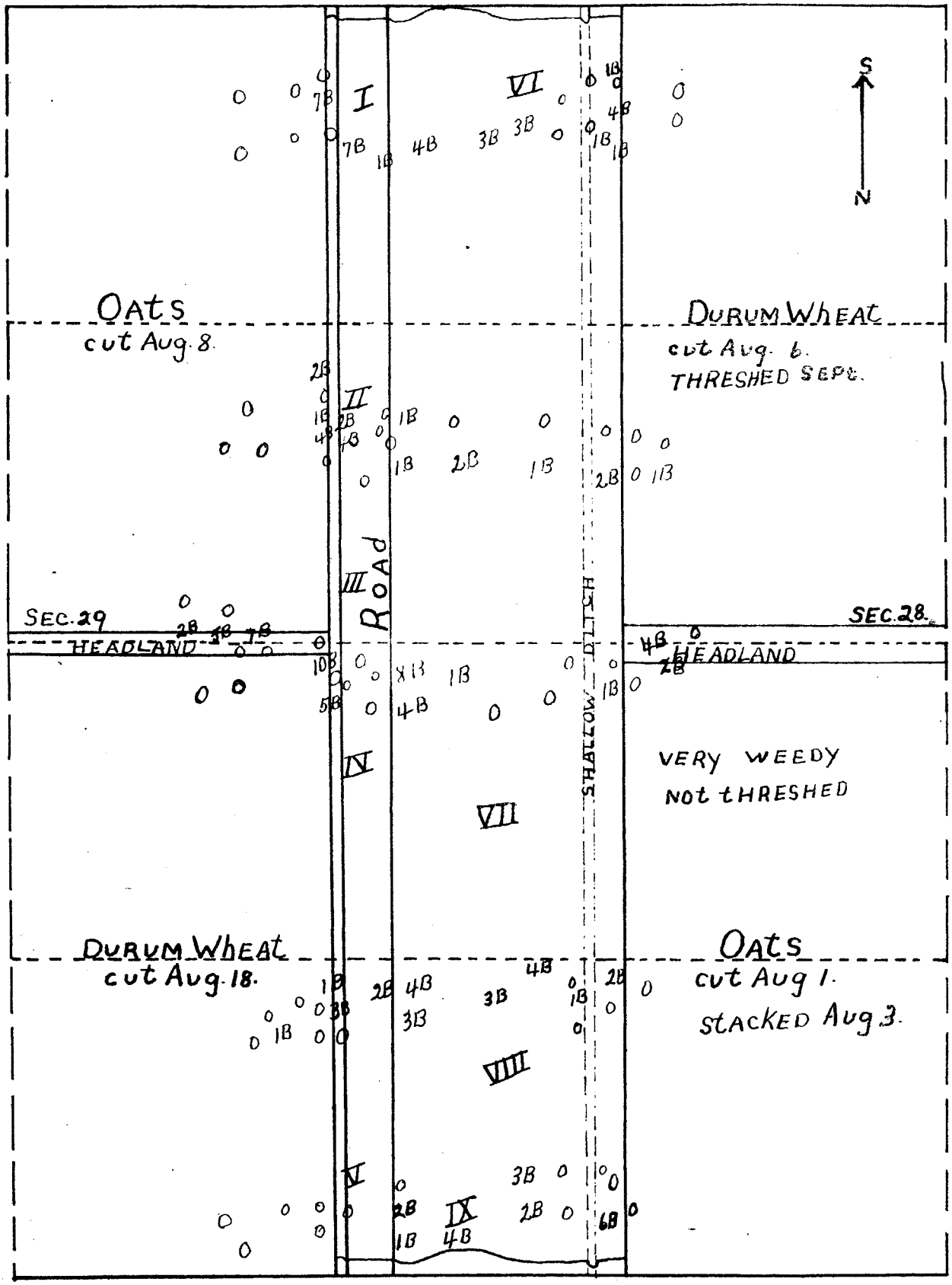
At the half mile line on Sec. 28 there was a headland (XI) about three yards wide covered with Chenopodium alba about four to six feet high, and Orchard grass, Amaranthus retroflexus and Melilotus alba.

The vegetation along this roadallowance consisted chiefly of the following grasses in order of abundance, Andropogon furcatus, Poa compressa, Orchard grass, Bromus inermis, Phleum pratense, and Hordeum jubatum. The following plants were numerous, Rosa blanda, Chenopodium alba, Amaranthus retroflexus, A. graecizans, Aster, Artemisia ludoviciana and Solidago canadensis.

(3) Grasshoppers.- There was a heavy population of C. pellucida and M. bivittatus averaging 30 per square yard along the edge of the crop on the west side and along the road and averaging 6 in the ditch. The population on August 2 was 85 percent M. bivittatus and was estimated at an average of 18 per square yard for

Plate XXXIII

Map of the [illegible] east of Sec. 18, T. 3, R. 32., which was observational study plot I. The cross section of the [illegible] is shown at the bottom of the map. The symbols are the same as described for Plate XXXI.


N
Oats
cut Aug. 8.
Durum Wheat
cut Aug. 6.
THRESHED SEPt.
ROAD
SHALLOW DITCH
SEC. 29
SEC. 28.
HEADLAND
HEADLAND
VERY WEEDY
NOT THRESHED
Durum Wheat
cut Aug. 18.
Oats
cut Aug 1.
STACKED Aug 3.
I
II
III
IV
V
VI
VII
VIII
IX

the whole roadallowance on August 6, the grasshoppers being spread out over the entire roadallowance instead of congregated along the edge of the crop. The population remained heavy until the first week in September. On September 8 the average population was recorded as between 3 and 4 per square yard. No other species were observed along this mile during the season.

Estimates of population were made along this roadallowance while walking between plot II and plot III, from north to south every eighth of a mile. The average population for each trip and for the period from August 3 to September 8 is given. The averages for the trips are plotted in graph 3 (Plate XXXI) which indicates the fluctuation in the grasshopper population during the study period. Unfortunately the data are rather incomplete as this area was not established until August 2 and due to unfavorable weather was not visited very often.

Table XXXIX

Population Estimates

(West side of roadallowance from north to south.)

Date	Population per square yard for eighth mile divisions								Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
Aug. 2	18	18	18	25	12	12	12	12	16
Aug. 6	20	15	18	15	15	12	10	10	14.35
Aug. 9	15	15	18	12	18	18	20	20	17.0
Sept. 8	8	2	1	3	1	4	3	4	3.25
Average population per square yard for the season									12.65

Table XL

Population Estimates

(East side of roadallowance from north to south)

Date	Population per square yard for eighth mile divisions								Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
Aug. 2	12	12	15	12	15	15	12	10	12.87
Aug. 6	12	20	18	12	18	18	15	15	16.0
Aug. 9	20	8	15	10	12	18	12	20	14.75
Sept. 8	2	3	4	2	2	8	8	1	3.75
Average population per square yard for the season									11.84

(4) Disease.- Empusa grylli was recorded as abundant along this mile on August 2 and specimens of M. bivittatus could be found up the straws of oats for 20 yards into the field. The living population was not heavy in the oats at this time. On August 6 additional dead M. bivittatus were present up the stems of oats. The grasshoppers continued to die of this fungus after August 9 but not to such a great extent.

(5) Egg survey.- The map (Plate XXXIII) shows the results of the egg survey.

In this mile 116 sample square feet were examined resulting in 144 M. bivittatus egg pods and 68 zeros.

The average population from August 2 to September 6 along this roadallowance was 12.24 per square yard. In the 73 square foot samples taken along the roadallowance there were 118 pods of M. bivittatus eggs. In the fields 34 square foot samples were examined and 26 pods of M. bivittatus egg pods obtained. The average number of egg pods per square foot along the roadallowance was 1.62 and in the fields was 0.60.

The results of the egg survey are summarized in the following table (Table XLI) which shows the number of egg pods deposited per square foot for each area. The rating of the infestation for each area and for the mile, based on the eggs found, is given.

Table XLI
Results of Egg Survey

Location	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating based on egg survey
North ½ mile	10	7	52B	1.88	light
½ - ⅓ mile	10	9	20B	1.05	light
⅓ - ⅙ "	6	9	29B	1.93	light
South ½ mile	13	9	37B	1.68	light
Durum wheat Sec. 29	3	13	5B	0.31	light
Oats Sec. 29	0	9	0	0.00	
Durum wheat Sec. 29	1	5	1B	0.16	light
Weedy oats Sec. 29	0	3	0	0.00	
Headland Sec. 29	3	3	14B	2.33	light
Headland Sec. 29	2	1	6B	2.00	light
	48	68	144B [A]	1.26	light

[A] These data vary from those for Table XLII because of omissions in the records.

AA See page 198.

(6) Association and slope where eggs are found.- The data recorded relating to this topic during the egg survey are recorded in the following table (Table XLII).

The data show that M. bivittatus showed a preference for the east slope over the west slope for egg laying. The west slope seemed to be preferred to the level.

The vegetation in order of preference seemed to be Orchard grass, Giant blue stem, young French weed, timothy and roses, and timothy.

Table XLII

Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq. ft. samples with pods	Sq. ft. samples without pods	Total No. of pods	Av. pods per sq. ft.
Giant blue stem	west	13	7	35B	1.75
Giant blue stem	level	3	4	9B	1.28
Giant blue stem & Aster		3	0	5B	1.66
Timothy		1	4	7B	1.40
Timothy & roses	east	3	2	8B	1.60
Orchard grass		7	4	21B	1.91
Orchard grass	west	0	4	0	0.00
Orchard grass	east	2	2	15B	3.75
Roses & aster		2	0	5B	2.50
Roses & blue stem		1	3	6B	1.50
White aster		2	0	9B	4.50
French weed		1	1	5B	2.50
Sweet clover & Lamb's quarter		1	3	4B	1.00
Lamb's quarter & false rag weed etc.		3	1	7B	1.75
Bare ground		1	0	4B	2.00
Durum stubble		2	12	2B	0.14
Edge of durum		2	6	4B	0.50
Oat stubble		0	8	0	0.00
		47	61	144B	

(7) Predators.- In the 108 square foot samples examined 10 carabid larvae, 14 scarabaeoid blister beetle larvae, and 1 bee fly larva were found. 6 of the carabid larvae and 1 of the bee fly larvae were found feeding on M. bivittatus egg pods. Two wireworms were found associated with the egg pods and one of

these was apparently feeding on a M. bivittatus egg pod.

93.33 percent of the blister beetle larvae were in the coarctate stage when the egg survey was made on September 19.

In the 76 square feet examined 26 predators were found associated with 138 M. bivittatus egg pods. The ratio of egg predators to egg pods was 1:5.4.

(8) General observations.- The population along here was chiefly M. bivittatus with 10 percent C. pellucida at the north end of the mile. M. bivittatus could be seen clinging to the oat plants as far as 20 yards into the crop on the north-east quarter of section 29. This was the only case where the dead were found clinging to plants of a cultivated crop to any extent. In the case of the rye on plot VI the dead only occurred along the few outside rows of grain.

When the oats on section 29 were cut on August 9 M. bivittatus moved into the stubble. No further data was obtained on this plot until September 6 because the weather made it impossible to visit all the plots and this one was one of those neglected.

From the egg survey results it may be seen that no C. pellucida eggs were found but that M. bivittatus eggs were quite wide-spread. The majority of the eggs were found along the east edge of the durum wheat and the oats. No eggs were found in the oat stubble but some were found in the durum wheat stubble both on section 29 and on section 28. Very few egg predators were found.

The graph of the average population for this area (Graph 3, Plate XXXI) is incomplete for the reasons mentioned above. The graph for the period from August 2 to August 9 seems to show a shifting of the population from one side of the road to the other but as the deviation on the graph is very slight it may be due to variation in estimates. The figures are incomplete so that the decline in population shown on the graph starts too early in the season.

(9) Conclusions and summary.

(a) The vegetation along this roadallowance consisted chiefly of the following grasses in order of abundance, Andropogon furcatus, Poa compressa, Orchard grass, Bromus inermis, Phleum pratense and Hordeum jubatum. The following plants were numerous, Rosa blanda, Chenopodium alba, Amaranthus retroflexus, A. graecizans, Aster, Artemisia ludoviciana and Solidago canadensis.

(b) The dominant species of grasshopper was M. bivittatus with some C. pellucida.

(c) M. bivittatus were found dead up the straws of oats

for 20 yards into the field. After August 9 there were fewer dead observed.

(d) The average population from August 2 to September 8 was 12.24 per square yard.

(e) The average number of egg pods per square foot along the roadallowance was 1.62 and in the fields was 0.60. The egg infestation is rated as "light."

(f) M. bivittatus showed a preference for the east slope over the west slope for egg laying. The west slope seemed to be preferred to the level. The vegetation chosen for egg laying in order of preference seemed to be Orchard grass, Giant blue stem, young French weed, timothy and roses, and timothy.

(g) The ratio of egg predators to egg pods was 1:5.4.

(h) 93.33 percent of the blister beetle larvae were in the coarctate stage by September 19.

(i) Two wireworms were found associated with the egg pods and one was apparently feeding on a M. bivittatus egg pod.

(j) When the oats were cut on section 35 on August 9 the M. bivittatus moved into the stubble.

3. Observational area II.
(East roadallowance of Sec. 31, T. 3, R. 4E.)

(1) General description.- Estimates of population were made along this mile while walking between plots VII and VIII. This area was established on July 24.

The roadallowance was bordered on the east, from south to north by two fields of barley and a field of cereal wheat. On the west side it was bordered by fields of barley, summer-fallow, rye, summer-fallow and a school yard on the north-east corner of section 31. The school was moved to the barley field on the south-east corner of the section.

There was a graded road along this roadallowance with a ditch two feet deep and three feet wide on the east side of the road and a ditch two feet deep and four feet wide with sloping sides on the west. There was a level area five yards wide between the ditch and the fields on the east side of the road. On the west side there was a flat strip three yards wide which sloped gradually down into the ditch.

(2) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXXIV). In all cases the plants are listed in order of abundance.

The vegetation on the west side of the road was the same in the ditch as on the level area. At the south end of the mile (I) it consisted of Agropyron repens and Phleum pratense with large

patches of Iva xanthifolia. There were some bare spots and Taraxacum officinale in the ditch. Along the edge of the road there was Amaranthus retroflexus, Polygonum aviculare, Aster laevis, A. multiflorus, Solidago canadensis, Rosa blanda and Artemisia ludoviciana were present generally over this entire area.

The same plants occurred throughout the south three quarters of the mile and were of a similar character except that about a quarter of a mile north of the south corner (II) the Amaranthus retroflexus was shorter and there was some Symphoricarpus seedlings.

North of the half mile line(III) the chief grasses were Bromus inermis and Agropyron repens.

In the north quarter of the mile (IV) the chief plants found were Agropyron repens, Bromus inermis, Andropogon furcatus and Thlaspi arvense seedlings.

The vegetation on the west side of the road had all been cut with the mower before July 15 but had grown up again by the beginning of August. The school was moved from the north corner of section 31 to the south corner and was dragged over this area tearing up the plants.

The ditch (V) was filled with Agropyron repens, Phleum pratense and short Iva xanthifolia with some Aster laevis, A. multiflorus, Solidago canadensis and Chenopodium alba. Artemisia ludoviciana, Polygonum aviculare, Achillea millefolium and Rosa blanda were also present. The vegetation was about a foot high

Along the ditch (VI) there were clumps of Salix bebbiana in the ditch.

For a quarter of a mile south of the half mile line there was less Iva xanthifolia but more Chenopodium alba and Symphoricarpus. Just south of the half mile line the vegetation became more dense and was about two to two and a half feet tall. There was a larger percentage of Solidago canadensis, Chenopodium alba and Amaranthus retroflexus. The chief grasses were Bromus inermis, Andropogon furcatus, Phleum pratense and Agropyron repens. Helianthus maximilieni, Aster laevis, A. multiflorus and Melilotus alba were also present. The vegetation remained the same for the next half mile.

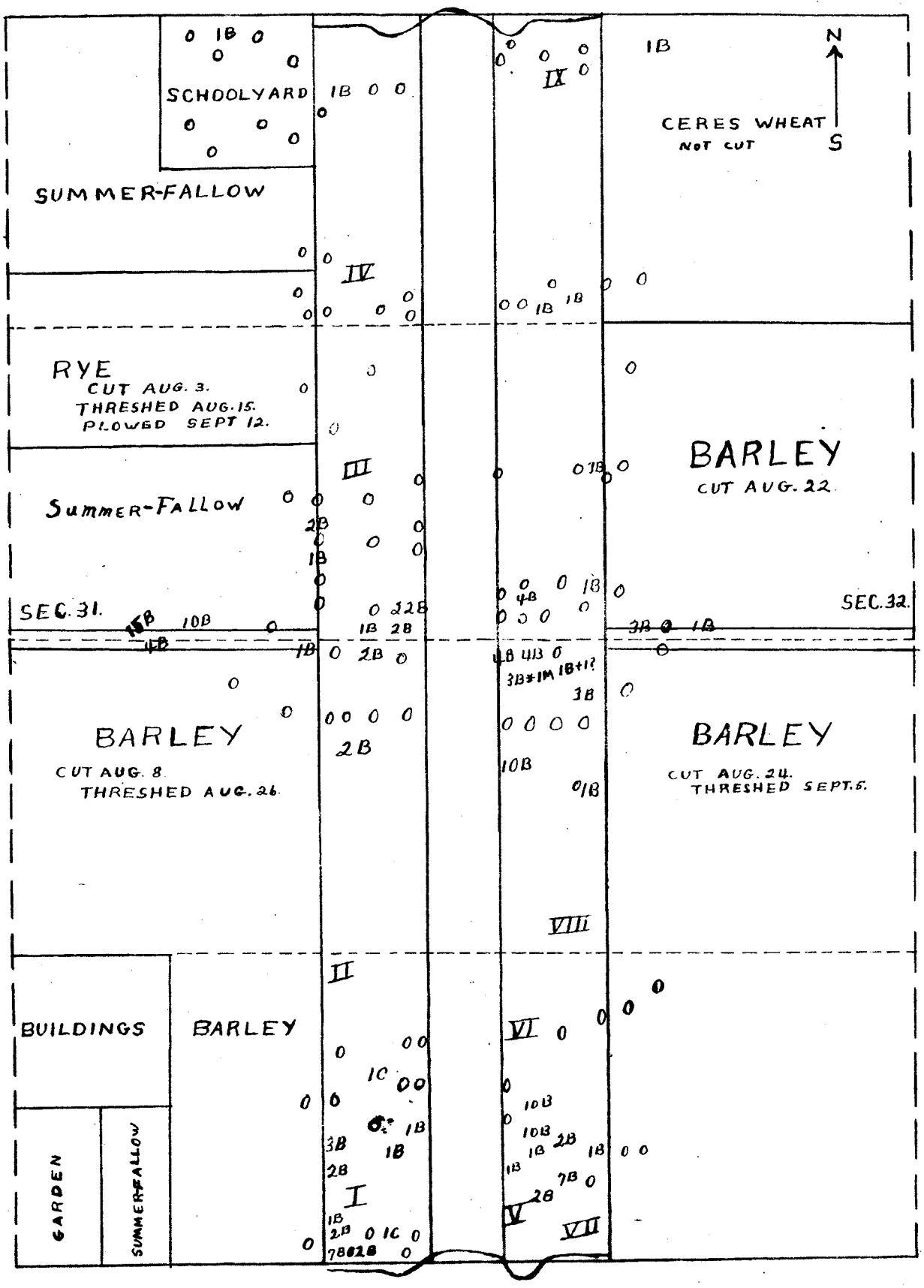
The area between the ditch and the crop on the east side of the road had been cut with the mower but the north half mile had only a narrow strip cut next to the crop. The vegetation at (VII) was chiefly Phleum pratense and Agropyron repens. The sod was loose with a few bare spots and Taraxacum officinale.

Just south of the quarter mile line there was a clump of Populus tremuloides and Salix bebbiana with Symphoricarpus in the ditch.

At (VIII) the vegetation became less grassy with more

Plate XXXIV

Map of the roadallowance east of Sec. 31, T. 3, R. 4E., which was studied under observational area II. The cross section of the roadallowance is shown at the bottom of the map. The symbols are the same as described for Plate XXII.


SCHOOLYARD
SUMMER-FALLOW
RYE
CUT AUG. 3.
THRESHED AUG. 15.
PLOWED SEPT 12.
Summer-Fallow
SEC. 31.
BARLEY
CUT AUG. 8
THRESHED AUG. 26.
BUILDINGS
BARLEY
GARDEN
SUMMER-FALLOW
CERES WHEAT
NOT CUT
N
S
BARLEY
CUT AUG. 22.
SEC. 32.
BARLEY
CUT AUG. 24.
THRESHED SEPT. 6.
I
II
III
IV
V
VI
VII
VIII
IX

Rosa blanda and Taraxacum officinale.

North of the half mile line there was an uncut strip between the ditch and a cut strip along the edge of the crop. The growth was one to one and a half feet tall along this uncut strip and consisted of Andropogon furcatus, Phleum pratense and Rosa blanda with quite a bit of Chenopodium alba.

At the north corner (IX) the vegetation consisted of Chenopodium alba, Agropyron repens and Solidago canadensis with some Hordeum jubatum.

The predominant grasses along this mile were Phleum pratense, Bromus inermis, Andropogon furcatus and Agropyron repens. The following plants, listed in order of their abundance, were also present: Iva xanthifolia, Taraxacum officinale, Chenopodium alba, Amaranthus retroflexus, A. graecizans, Polygonum aviculare, Aster, Solidago canadensis, Rosa blanda, Symphoricarpus and Artemisia ludoviciana. There were clumps of Populus tremuloides and Salix babbiana.

(3) Grasshoppers.- On July 15 the population for the north three-quarters of a mile was estimated as 90 percent C. pellucida and 10 percent M. bivittatus. Around the school the C. pellucida was equal to 85 percent of the population and for the south three quarters of a mile decreased but the south half mile remained the same until between August 21 and September 8 when the population began to decrease. C. pellucida and M. bivittatus and a few M. femur-rubrum and M. mexicanus were the only species present along the mile.

Estimates of population were made every eighth of a mile from south to north on both sides of the road. The estimates of the population from July 24 to September 17 are tabulated in the following tables (Tables XLIII and XLIV). The average population per square yard for each trip and for the study period is given. The trip averages are plotted in graph 4 (Plate XXXI). The graph shows the seasonal fluctuation in the grasshopper population during the study period.

Table XLIII

Population Estimates

(East side of roadallowance from north to south)

Date	Population per square yard for eighth mile divisions								Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
July 24	12	12	12	12	12	15	15	15	13.1
July 26	20	20	15	15	20	20	20	20	19.1
July 30	12	12	12	12	12	15	15	15	13.1
July 31	10	15	15	10	15	20	25	25	16.9
Aug. 3	10	10	12	12	15	20	25	25	16.1
Aug. 7	8	15	15	12	20	20	25	18	16.6
Aug. 10	8	10	12	12	15	20	20	15	14.37
Aug. 21	4	10	15	17	25	30	20	25	18.2
Sept. 5	2	2	1	10	10	10	6	10	6.3
Sept.17	1	2	4	4	10	10	10	10	6.35
Average population per square yard for the season									14.01

Table XLIV

Population Estimates

(West side of roadallowance from north to south)

Date	Population per square yard for eighth mile divisions								Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
July 24	12	12	12	12	12	15	15	15	13.1
July 26	10	10	8	8	15	15	25	15	13.25
July 30	12	12	8	8	12	12	25	15	13
July 31	4	15	16	12	15	18	25	25	15
Aug. 3	5	8	8	12	14	18	25	20	13.75
Aug. 7	12	16	6	10	10	15	15	15	12.35
Aug. 10	8	8	10	10	8	8	10	18	10
Aug. 21	8	10	12	20	25	25	20	25	18.1
Sept. 8	4	1	2	6	8	6	6	10	5.37
Sept.17	1	2	0	0	4	8	8	8	5.87
				Average population per square yard for the season					11.77

(4) Disease.- Empusa grylli was abundant along this mile on July 18. No more dead were observed until August 21 when the unidentified disease (P. 205) became evident by the number of M. bivittatus found dead on the ground. All of these died between August 10 and August 21 but only a few fresh specimens were present. No C. pellucida were found dead until September 18 when a large number of M. bivittatus were found dead on the ground and 1 C. pellucida and 2 M. bivittatus were observed clinging to stems of grasses, apparently dead of Empusa grylli.

(5) Egg survey.- The map (Plate XXXIV) shows the results of the egg survey.

Very few eggs were found along this mile in comparison to what would be expected from the population present during the study period. This was probably because the soil along here was very hard and packed. Where the soil was loose a large number of pods could be found especially around ant hills and in ridges of soil loosened by moving the school along here.

In this mile 115 square foot samples examined resulted in 156 M. bivittatus, 2 C. pellucida, 1 M. mexicanus and 1 unidentegg pod and 72 zeros.

The average adult population along this roadallowance for the period from July 24 to September 17 was 12.59 per square yard. The total number of egg pods found in 97 square foot samples taken along the roadallowance was 117 M. bivittatus, 2 C. pellucida, 2 M. mexicanus and 1 unidentified egg pod. There were very few eggs found in the fields.

The average number of eggs found along the roadallowance was 1.2 per square foot, in the fields 0.415, and on the headland 3.78.

The results of the egg survey are summarized in the following table (Table XLV) which shows the average number of eggs deposited per square foot in each area. The rating of each area, based on the number of eggs found, is also given.

Table XLV
Results of Egg Survey

Location	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating based on egg survey
W. side-N. ¼ mile	1	8	1B	0.11	normal
W. " ¼-½	3	8	25B	2.27	light
W. " ½-¾	2	6	4B	0.50	normal
W. " S. ¼ mile	10	11	19B + 2C	1.00	normal
E. " N. ¼ "	2	8	2B	0.2	normal
E. " ¼-½	3	9	6B	0.5	normal
E. " ½-¾	7	6	26B + 1 lmax. + 1?	2.15	light
E. " S. ½ mile	8	5	34B	2.61	light
Edge of S.F. Sec.31 near ½ mile	2	4	3B	0.50	moderate
Summer-fallow	0	0	0	0.00	
Rye stubble	0	0	0	0.00	
Barley	0	0	0	0.00	
Headland Sec. 31	4	1	30B	6.00	moderate
Headland Sec. 32	2	2	4B	1.00	normal
Coron stubble Sec.32	2	4	2B	0.33	moderate
	46	72	156B[A] + 2C + 1 max. + 1?	1.35	light

[A] These data vary from those for Table XLVI because of omissions in the records.

AA See page 198.

(6) Association and slope where eggs are found.- The data recorded relating to this topic during the egg survey are presented in the following table (Table XLVI).

The data seem to indicate that the west slope was preferred to the east for egg laying but the vegetation in the different slopes was not comparable.

There was a concentration of eggs in the burned area. M. bivittatus showed a preference for loose soil especially on the headlands. The order of preference for grasses was brome, couch, and timothy.

Table XLVI

Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.
Timothy (hard soil)	level	3	10	5B	0.38
Timothy	west	2	4	11B	1.83
Timothy	east	0	5	0	0.00
Loose soil	east	4	5	9B	2.11
Couch	west	5	2	42B	6.00
Brome	east	2	0	11B	5.50
Brome	level	6	7	11B	8.5
Couch & Dandelion		0	1	0	0.00
Poa		2	3	2C	0.00
Dandelion		1	2	1B	0.33
Orchard grass		2	4	2B	0.33
Burned area		1	0	22B	22.00
Headlands (loose)		5	2	30B	4.3
Corse		2	4	2B	0.33
Edge of barley		0	14	0	0.00
Rye		0	5	0	0.00
Summer-fallow		0	5	0	0.00
Unrecorded		12	27	19B	0.45
		50	98	176B + 2C	

(7) Predators.- In the 148 square foot samples examined 2 carabid beetle larvae and 6 coarctate blister beetle larvae were found. One pod of M. bivittatus eggs was found infested with red ants.

All the blister beetle larvae were in the coarctate stage on September 15.

In the 148 square feet examined 176 pods of M. bivittatus eggs, 2 C. pellucida, 1 M. mexicanus and 1 unidentified pod were found and 8 predators. The ratio of egg predators to egg pods was 1:2.6.

(8) General observations.- This roadallowance on July 24 had an infestation of 12 C. pellucida per square yard in the north half of the mile and in the south half of the mile there were very few grasshoppers on the west side but a heavy infestation of about 15 M. bivittatus per square yard on the east side. There were also about 15 M. bivittatus per square yard on the east side in the south quarter mile. The C. pellucida at the north and gradually became mixed with M. bivittatus toward the

south until at the half mile line the population was almost 100 percent M. bivittatus. The population remained almost the same until August 21 when it began to decrease in the fall decline. The fall in the population shown between July 31 and August 11 by the graph for the west side of the road was probably due to the disturbance caused by the dragging of the school buildings from the north end of this mile to the south-east corner of section 31. It seems odd that if this is the reason that the graph for the other side of the road did not remain straight or, if anything, rise.

The rise in population on the west side of the road between August 10 and August 21 was probably due to the cutting of the barley on August 8 and of the rye on August 15. The cutting of the crops seemed to be followed by a rise in population on the roadallowance within a few days. About August 21 the population began the fall decline. The exact time of the beginning of this decline is not shown because of the lack of observations between August 21 and September 6.

The graph (Graph 4, Plate XXXI) indicates that there was very little shifting of the population from one side of the road to the other. The crops on the west side of the road were cut between August 3 and August 15 and those on the east side between August 22 and August 24 but there is no difference in the date at which the graph begins to fall for the two different sides of the road. This may be because the points of the graph are not close enough together to illustrate this. The roadallowance offered shelter to the grasshoppers and the population on September 17 still remained high in comparison with the other plots.

(9) Conclusions and summary.

(a) The predominant grasses along this mile were Phleum pratense, Bromus inermis, Andropogon furcatus and Agropyron repens. The following plants listed in order of abundance, were also present: Iva xanthifolia, Taraxacum officinale, Chenopodium alba, Amaranthus retroflexus, A. graecizans, Polygonum aviculare, Aster, Solidago canadensis, Rosa blanda, Symphoricarpus and Artemisia ludoviciana. There were clumps of Populus tremuloides and Salix bebbiana.

(b) The predominant species of grasshoppers was C. pellucida at the north end of the mile on July 18. Later M. bivittatus became predominant throughout the mile. M. femur-rubrum and M. mexicanus were also present.

(c) Empusa grylli was present on July 18. The unidentified disease killed off a large number of M. bivittatus between August 10 and August 21. On September 18 M. bivittatus

and 1 C. pellucida were found apparently dead of Empusa grylli.

(d) The average population for the period from July 24 to September 17 was 12.89 per square yard.

(e) The average number of egg pods per square foot was 1.2 along the roadallowance, 0.415 in the fields and 3.78 on the headlands. The egg infestation was rated as "light".

(f) It is indicated that the west slope was preferred to the east slope for egg laying but the vegetation on the two slopes was not comparable. There was a concentration of eggs in the burned areas. M. bivittatus showed a preference for loose soil especially on the headlands. The order of preference for grasses was brome, couch, and timothy.

(g) The ratio of egg predators to egg pods was 1:2.6.

(h) All the blister beetle larvae found were in the coarctate stage by September 15.

(i) One pod of M. bivittatus eggs was found infested with red ants.

(j) The cutting of the rye and barley on section 31 was followed within a few days by an increase in the population on the roadallowance. The roadallowance offered shelter for the grasshoppers and the population remained high on September 17 in comparison with the other plots.

(k) C. pellucida eggs were found in pea sod.

(l) Although the population on this plot was high throughout the season there were not many eggs deposited. The soil was hard and unfriable and seemed unsuitable for egg laying. In any location where the soil was loose and friable there seemed to be a concentration of eggs as, for example, around ant hills and on the ridges of soil loosened by dragging the school over the area.

4. Observational area III.

(West half mile of the south roadallowance of Sec. 34, T. 3, R.3W.)

(1) General description.- Estimates were made on the west half mile while walking from the town to plot I. The area was established on July 19.

The south side of this roadallowance was bordered by a rye field except for the first sixteenth of a mile west of the half mile line where there was a garden. The rye crop was cut, stooked and plowed between August 2 to 6. On the north side of the roadallowance there was a garden for a sixteenth of a mile west of the half mile line and the next tenth of the mile was bordered by an oat field which was cut August 9 and threshed September . The rest of the half mile was bordered by summer-fallow which drifted somewhat causing loose drift soil to be present along the narrow strip of heavy vegetation.

There was a high grade along this mile with a ditch two feet deep on each side. The south side of the roadallowance had a grassy strip about five yards wide between the ditch and the field. The north side had a ditch with a narrow bank about a yard wide between it and the fields. The vegetation along this narrow strip was very coarse and heavy and although cut with the mower was not raked. The ditches were bare except for plants of Taraxacum officinale and clumps of Orchard grass. The road was bordered by Amaranthus graecizans and A. retroflexus.

(2) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXXV). In all cases the plants are listed in order of abundance.

The ditch on the south side of the road (I) was bare except for plants of Taraxacum officinale, clumps of Orchard grass, some Helianthus maximiliani, Amaranthus retroflexus, A. graecizans and Rosa blanda. Along the edge of the road Amaranthus graecizans was predominant. The south bank of the ditch was covered with uncut Phleum pratense, Poa compressa and some Hordeum jubatum. The above plants were present throughout the rest of the half mile but other species crept in to the west and became dominant.

Along the ditch (II) there were scattered Salix longifolia and the Amaranthus retroflexus became taller ranging from two to three feet in height. The Salix longifolia were two feet tall. Aster laevis and A. multiflorus were also present.

Along the ditch (III) Spartina michauxiana became predominant.

At the west end of this mile the ditch (IV) was filled with Spartina michauxiana, Amaranthus graecizans and A. retroflexus.

The grassy strip (V) was cut with themmower and raked before July 15. The chief grasses were Poa compressa and Phleum pratense. The sod was not continuous, there being many bare patches on which there were a few scattered Taraxacum officinale and Polygonum aviculare. There was some Chenopodium alba and Iva xanthifolia along the edge of the summer-fallow. There were also occasional plants of Artemisia ludoviciana, Aster laevis and A. multiflorus.

At (VI) there was more Chenopodium alba which had been cut but there was a second growth which was one to one and half feet high. Close to the telephone poles the Chenopodium alba was not cut and was two to three feet high.

At (VII) there was some Aster laevis, A. multiflorus and Taraxacum officinale with occasional clumps of Bromus inermis and some Polygonum convolvulus.

Near the corner (VIII) there were heavy patches of Aster laevis, A. multiflorus, Amaranthus retroflexus, Chenopodium alba, Artemisia ludoviciana, Helianthus maximiliani, Solidago canadensis and Phleum pratense.

The ditch on the north side of the road (IX) was almost bare of vegetation except for some young Melilotus alba, Amaranthus retroflexus, and Taraxacum officinale. Rosa blanda and Cirsium arvense were also present with an occasional plant of Ambrosia trifida, Thlaspi arvense and a few small Salix longifolia. This continued to the west corner. Taraxacum officinale became scarcer to the west.

The narrow strip of heavy vegetation (X) was about a yard wide and the vegetation was very heavy. This was cut with the mower before July 15 but not raked. Strips varying from a few inches to a foot in width along the ditch and along the fence were missed by the mower. The vegetation was a mixture of Phleum pratense, Poa compressa and Rosa blanda. There was Melilotus alba along the fence by the garden. There was some Iva xanthifolia inside the fence. Aster laevis, A. multiflorus, Artemisia ludoviciana, Cirsium arvense, Taraxacum officinale and some Polygonum convolvulus were also present.

Opposite the oat field (XI) the vegetation was almost the same but there was more Orchard grass, Iva xanthifolia and Salix longifolia along the edge of the ditch.

Along the edge of the summer-fallow the vegetation continued the same except that there was more Artemisia ludoviciana, an occasional patch of Bromus inermis and some drift soil.

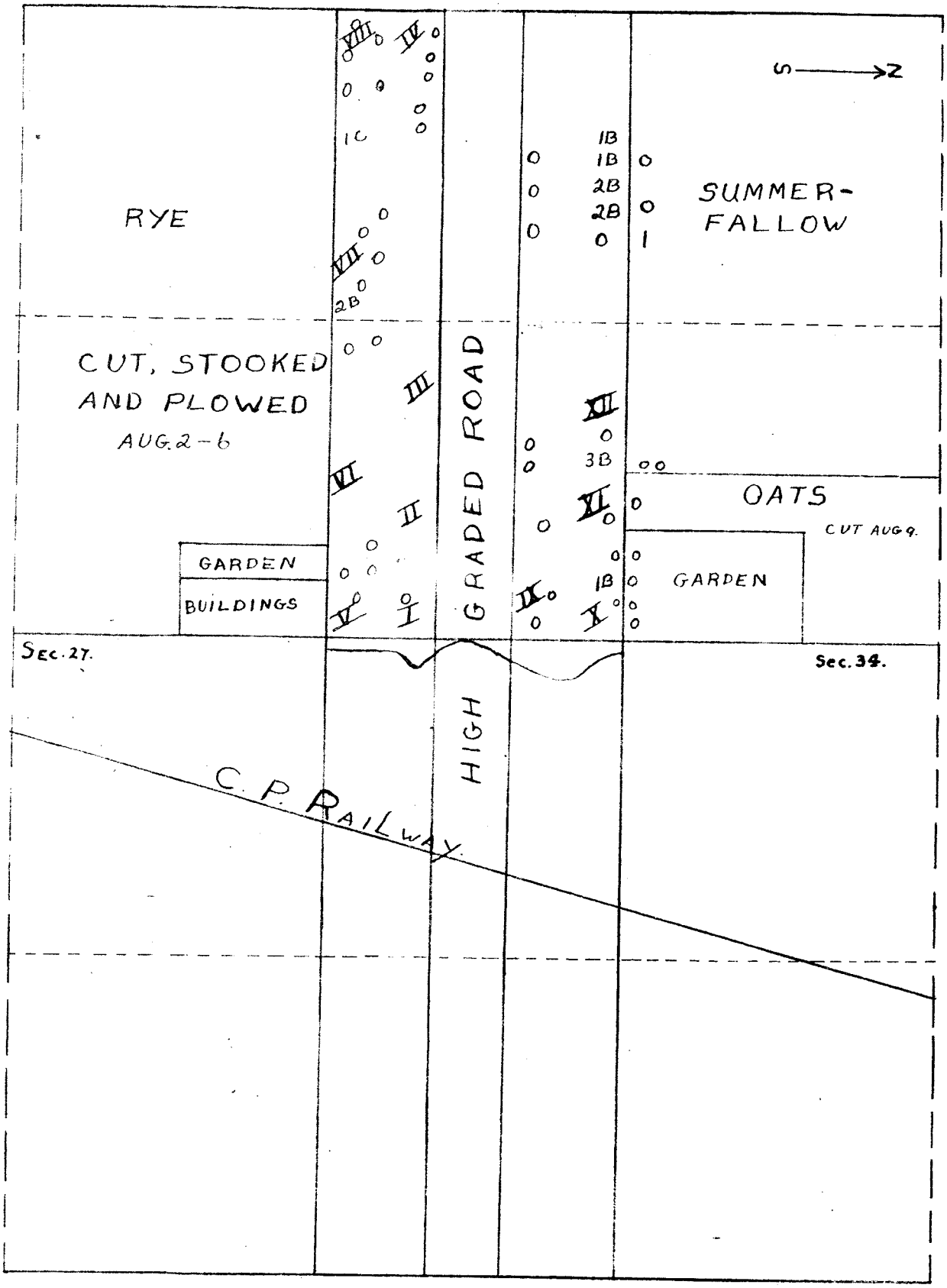
The dominant grasses along this mile were Phleum pratense, Poa compressa, Hordeum jubatum, Bromus inermis, Spartina michauxiana and Orchard grass. Other plants present, in order of their abundance were Taraxacum officinale, Rosa blanda, Chenopodium alba, Polygonum aviculare, Aster, Amaranthus graecizans, A. retroflexus, Iva xanthifolia and Helianthus maximiliani. There were patches of Salix longifolia and Artemisia ludoviciana.

(3) Grasshoppers.- There was a small population along here throughout the season. On July 19 the population was averaged at four grasshoppers per square yard, almost 100 percent M. bivittatus with a few C. pellucida. The percentage maturity at that time was very low for M. bivittatus. C. pellucida was 100 percent adult. About July 25 the M. bivittatus population decreased and C. pellucida population increased. On August 29 specimens of M. dawsoni, M. femur-rubrum and M. mexicanus were collected on this area. During the period from September 1 to 21, specimens of Spharagemon collare and Arphia pseudonietana were collected.

There must have been a large population along here in the spring of 1935 for during the egg survey in the fall a large number of last year's hatched eggs were found. The inhabitants of the area reported this mile to have always been heavily infested.

Plate XXXV

Map of the west half of the south roadallowance of Sec. 34, T. 3, R. 3E., studied under observational area III. The town of Armand is situated on the east half of this mile. The cross section of the road-allowance is shown at the half mile line. The symbols used are the same as described for Plate XXII.


S → N
RYE
SUMMER-FALLOW
CUT, STOOKED AND PLOWED AUG. 2-6
GRADED ROAD
OATS
CUT AUG 9.
GARDEN
BUILDINGS
GARDEN
SEC. 27.
SEC. 34.
C. P. RAILWAY
HIGH

Estimates were made every eighth of a mile from the half mile line west to the corner. These are shown in the following tables (Table XLVII and XLVIII). The tables also show the average population per square yard for the mile at the time that the estimates were made and for the period from July 30 to September 14. The average population for the trips is plotted in graph 5 (Plate XXXI). This graph indicates the fluctuation in the population during the study period.

Table XLVII
Population Estimates
(South side of roadallowance from east to west)

Date	Pop. per sq. yd. for eighth mile div.				Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	
July 30	3	3	4	2	3.0
Aug. 6	3	4	2	4	3.25
Aug. 9	4	4	6	6	5.0
Aug. 14	2	3	4	4	3.25
Aug. 23	1	3	3	3	2.5
Aug. 29	0	1	1	1	.75
Sept. 8	0	0	0	3	.75
Sept.14	1	0	0	1	.5
Average population per square yard for the season					2.28

Table XLVIII
Population Estimates
(North side of roadallowance from east to west)

Date	Pop. per sq. yd. for eighth mile div.				Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	
July 30	1	2	3	1	1.75
Aug. 6	3	2	3	3	2.75
Aug. 9	3	2	3	3	2.75
Aug. 14	6	8	6	8	7.0
Aug. 23	3	3	6	6	4.5
Aug. 29	0	3	4	4	2.75
Sept. 8	1	1	1	1	1
Sept.14	0	1	1	1	1
Average population per square yard for the season					2.93

(4) Disease.- On July 19 no dead were observed and on August 14 although there was water standing in the ditches and the vegetation was quite dense, no dead were recorded. On August 15 a few dead were found on the ground along the north side of the road. On the south side for a quarter of a mile west of the half mile line very few dead were found but in the west quarter of a mile the dead on the ground averaged one per square yard. No dead could be found in the stubble and none were found dead of Encoss gryllii. On August 29 only 2 M. bivittatus were found dead in the half mile. For the rest of the season the population was very low and no dead were observed.

(5) Egg survey.- The map (Plate XXXV) shows the results of the egg survey.

In this area 52 square foot samples were examined and 13 pods of M. bivittatus and 1 pod of C. pellucida eggs found.

The average adult population for this half mile was 2.6 per square yard for the period from July 30 to September 14. The average number of egg pods found along this half mile was 0.59 per square foot along the roadallowance. Very few eggs were found in the fields.

The results of the egg survey are summarised in the following table (Table XLIX) which shows the number of eggs deposited per square foot for each area. The rating of the infestation, based on the eggs found, is given.

Table XLIX
Results of Egg Survey

Location	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating based on egg survey
E.¼ mile of W.½ mile on N. side	2	9	4B	0.36	normal
W.½ mile of W.½ " on N. side	4	4	6B	0.75	normal
E.½ mile of W. ½ " on S. side	0	8	0	0.00	
W.½ mile of W.½ " on S. side	2	15	2B + 1C	0.11	normal
Rye on Sec. 27	0	0	0	0.00	
Summer-fallow Sec.34	1	5	1B	0.16	normal
Oats	0	4	0	0.00	
Garden	0	4	0	0.00	
	9	49	13B + 1C[A]	0.24	normal

A
These data vary from those for Table L because of omissions in the records.

See page 198.

(6) Association and slope where eggs are found.- The data recorded in relation to this topic during the egg survey are presented in the following table (Table L).

The data do not show very much as the number of eggs found was small. Orchard grass, Knot weed on a south slope had the highest number of eggs per square foot.

Table L

Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq. ft. samples with pods	Sq. ft. samples without pods	Total No. of pods	Av. pods per sq. ft.
Timothy		1	3	1B	0.25
Pea & Dandelion		1	6	2B	0.28
Knot weed	south	4	1	6R	1.20
Orchard grass		1	2	3B	1.00
Sum. Fallow edge		1	2	1B	0.33
Pea		1	5	1C	0.16
Knot weed & Tumble weed		0	7	0	0.00
Dandelion		0	8	0	0.00
Sweet clover		0	4	0	0.00
		10	38	13B + 1C	

(7) Predators.- In the 48 square foot samples examined 1 carabid beetle larva and 2 coarctate and 5 cerambycoid blister beetle larvae were found. None of these was observed feeding on egg pods.

28.6 percent of the blister beetle larvae were in the coarctate stage on September 11.

Associated with 13 M. bivittatus and 1 C. pellucida egg pods there were 8 predators. The ratio of egg predators to egg pods was 1:1.75.

(8) General observations.- The population was so low that very little can be gained by a discussion of the graph (Graph 5, Plate XXXI) as the percentage error in the estimates will be very high.

The low population may have been due to the effects of Empusa grylli but this is doubtful for no disease was recorded on this plot from July 19 until August 15, although the conditions were such that they seemed ideal for the disease except that the population was low. In other plots where the disease was heavy no great decrease in population took place after July 15 although such a decrease may have taken place before this time. The presence of the rye field on section 27 and the summer-fallow may have had something to do with the decrease or moving out of the grasshoppers but on other plots summer-fallow and rye fields did not seem to have this effect. The rye field was plowed August 2 to 6 but the population had decreased before July 26.

(9) Conclusions and summary.

(a) The predominant grasses along this mile were Phleum pratense, Poa compressa, Hordeum jubatum, Bromus inermis, Spartina michauxiana and Orchard grass. Other plants present in order of their abundance were Taraxacum officinale, Rosa blanda, Chenopodium alba, Polygonum aviculare, Aster, Amaranthus graecizans, A. retroflexus, Iva xanthifolia and Helianthus maximiliani. There were patches of Salix longifolia and Artemisia ludoviciana.

(b) The dominant species of grasshoppers were M. bivittatus and C. Pellucida. Other species collected along the mile were M. dawsoni, M. femur-rubrum, M. mexicanus, Spharagemon collare and Arphia pseudonietana.

(c) Very few grasshoppers died of disease on this area although the humidity was high. This may have been due to the small population. There was apparently a heavy population here in the spring of 1935 from the number of hatched eggs found during the fall egg survey. The decrease in this population may have been due to disease before July 17 but no traces could be found.

(d) The average population per square yard for this plot for the period from July 30 to September 14 was 2.6.

(e) The average number of egg pods per square foot along the roadallowance was 0.29 and in the fields 0.07. The egg infestation was rated as "normal".

(f) Orchard grass and Knot weed on the south slope had the highest number of eggs per square foot.

(g) A C. pellucida egg pod was found in pea sod.

(h) The ratio of egg pods to predators was 1:1.75.

(i) 28.6 percent of the blister beetle larvae were in the coarctate stage on September 11.

(j) The population was low on this plot throughout the study period.

5. Observational area IV.
(South roadallowance of Sec. 35, T. 3, R. 3E.)

(1) General description.- Estimates of population were made along this mile while walking from Armand to plot V. This area was established on July 24.

The roadallowance was bordered on the north and on the south side of the road by fields of cereal wheat.

The road was graded with a ditch two feet deep and three yards wide with a strip about a yard wide between the ditch and the field on the north side. On the south side, the ditch was about two feet deep and four yards wide with a level area six yards wide between the ditch and the field.

(2) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXXVI). In all cases the plants are listed in order of abundance.

There was a heavy growth of vegetation on the north side of the road along the strip between the ditch and the field (I). The dominant grasses were Agropyron repens, Poa compressa, Spartina michauxiana, Andropogon furcatus and Phleum pratense. Aster laevis, A. multiflorus, Solidago canadensis, Helianthus maximiliani, Artemisia ludoviciana, Rosa blanda, Salix longifolia and Salix bebbiana were also present and there was an occasional plant of Elaeagnus argentea. The asters were from one to three feet high. Grasses, asters and rose bushes were of almost equal abundance. The two species of Salix were very short and not very abundant. Helianthus maximiliani was more abundant than Artemisia ludoviciana. The ditch was filled mainly with Spartina michauxiana with Aster laevis, A. multiflorus and Rosa blanda on the banks. There was an occasional seedling of Populus deltoides and a few plants of Fragaria virginiana. A swath had been cut with the mower on the two banks of the ditch leaving an uncut strip about two feet wide on each side.

The same plants were present all along this mile but a quarter of a mile east (II) the vegetation thinned out with patches of Taraxacum officinale on the slope of the grade.

At (III) Taraxacum officinale became much more abundant and there were occasional plants of Iva xanthifolia along the edge of the road.

The whole roadside (IV) had been cut with the mower except in the ditch. The vegetation was almost entirely grass with a few roots of Rosa blanda, Solidago canadensis, Aster laevis and A. multiflorus. The dominant grasses were Andropogon furcatus and Poa compressa.

The vegetation in the ditch, which had not been cut with the mower, consisted of Spartina michauxiana, Phleum pratense and some Poa compressa and a few Aster laevis, A. multiflorus, Artemisia ludoviciana and plants of Fragaria virginiana. The vegetation was more open along here with some bare patches. Taraxacum officinale was quite abundant around the edges of the bare patches. Polygonum aviculare, Iva xanthifolia, Solidago canadensis and Achillea millefolium were also present.

A third of a mile east (V) there were frequent patches of Spartina michauxiana which had been mown but had grown to a height of one foot by September.

In the east half mile (VI) Spartina michauxiana and Andropogon furcatus became dominant.

The dominant grasses along this mile were Andropogon furcatus, Spartina michauxiana, Bromus inermis, Agropyron repens, Poa compressa and Phleum pratense. Aster, Solidago canadensis, Helianthus maximiliani, Artemisia ludoviciana and Rosa blanda were present. There were also a few plants of Populus deltoides, Fragaria virginiana and Elaeagnus argentea.

(3) Grasshoppers.- M. bivittatus, C. pellucida and a few M. femur-rubrum were present along this mile. On July 23 the population on the south side was estimated as 25 to 30 C. pellucida and M. bivittatus per square yard along the edge of the crop where the roadallowance had been cut for hay. M. bivittatus was 80 percent of the population. On the north side the population was much lighter averaging about 5 M. bivittatus per square yard with a few C. pellucida at the east end. The population did not spread out into the acres wheat stubble on section 26 when the crop was cut and stooked on August 8 but on August 21 the average in the stubble was 9 M. bivittatus per square yard extending about 12 yards into the field and somewhat lighter farther in. The population spread all through the acres stubble on section 35. The average was 8 to 10 M. bivittatus per square yard. On August 28 the grasshoppers were concentrated around the stooks. From September 1 to 15 M. bivittatus were concentrated in the heavy patches of slough grass and brome grass in the east half mile.

Estimates were made every eighth of a mile along the south side of this roadallowance. The average population along the south side of the road and the averages for each trip are shown in the following table (Table LI). The averages for the trips are plotted in graph 6 (Plate XXXI). This graph shows the fluctuation in the population during the study period.

Plate XXXVI

Map of the south roadallowance of Sec. 35, T. 3, R. 3E studied under observational area IV. The cross section of the roadallowance is shown at each end of the mile. The symbols are the same as described for Plate XXII.

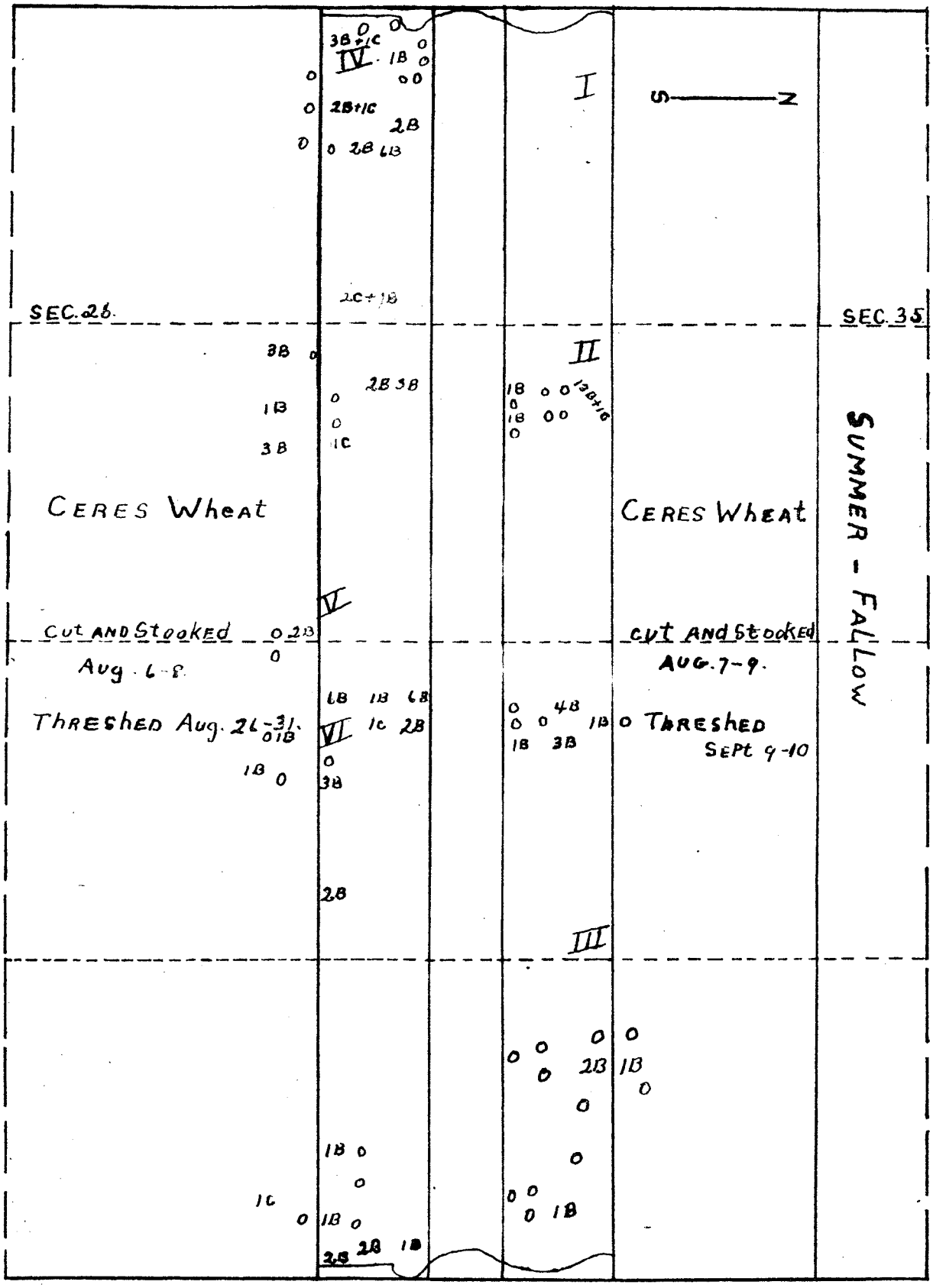

IV
I
S — N
SEC. 26.
SEC. 35
II
SUMMER - FALLOW
CERES Wheat
CERES Wheat
V
Cut AND Stooked
Aug. 6-8
cut AND Stooked
AUG. 7-9.
THRESHED Aug. 26-31.
THRESHED
SEPT 9-10
VI
III

Table LI

Population Estimates

(South side of roadallowance from west to east)

Date	Population per square yard for eighth mile divisions								Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
July 24	25	25	30	30	25	25	20	20	25
July 30	25	25	30	30	25	25	20	20	25
July 31	25	25	35	30	10	15	15	25	22.5
Aug. 5	15	20	25	25	12	10	10	10	16
Aug. 7	15	18	20	20	20	12	10	15	16.25
Aug. 10	15	15	18	18	20	12	10	15	15.3
Aug. 21	15	15	20	20	20	12	12	12	15.75
Sept. 7	1	1	1	1	2	2	3	4	1.8
Sept. 8	1	1	1	1	2	2	3	4	1.8
Sept. 16	1	1	1	1	2	2	1	1	1.25
Average population per square yard for the season									14.06

(4) Disease.- Some Empusa grylli was present on July 23 but was not very great. No further examples of the work of Empusa grylli were noticed until August 21 when a few freshly killed specimens of M. bivittatus were found dead up stems. No dead were found along here during the remainder of the season.

(5) Egg survey.- The map (Plate XXXVI) shows the results of the egg survey.

In this mile 81 square foot samples were examined and 86 M. bivittatus, 6 C. pellucida and 43 zeros were found.

The average adult population along the south side of the roadallowance during the period from July 24 to September 16 was 14.06 per square yard. The total number of egg pods deposited on the south side of the roadallowance in 34 square foot samples examined was 48 M. bivittatus, 4 C. pellucida and 13 zeros. Along the north side of the roadallowance in 27 square foot samples taken 26 pods of M. bivittatus, 1 C. pellucida and 18 zeros were obtained. In the corea wheat on section 26, 16 square foot samples were tested yielding the following pods: 11 M. bivittatus, 1 C. pellucida and 9 zeros. On section 35 in the corea wheat 4 square foot samples were recorded producing 1 M. bivittatus egg pod and 3 zeros while many other samples were examined but not recorded.

The average number of egg pods along the south side of the roadallowance was 1.33 per square foot. On the north side of the roadallowance the average was 1.0 egg pods per square foot. In the corea wheat the average was 0.75 on section 26 while on section 35 it was 0.25.

By looking at the soils map (Plate II) it will be seen that the soil on section 35 is classified as Osborne clay while that on section 26 is McTavish clay low phase. This may account for the difference in the number of eggs in the two corea wheat fields. Osborne clay is not as friable and is a wetter soil than the McTavish clay low phase. The stubble in section 35 was longer and heavier than on section 26 and this may have been the reason or there may have been a difference in the cultivation methods used.

The results of the egg survey are summarized in the following table (Table LII) which shows the average number of egg pods deposited per square foot for each area. The rating of the infestation for each area, based on the eggs found, is given.

Table LII
Results of Egg Survey

Location	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating[AA] based on egg survey
N. side-W. ¼ mile	0	0	0		
N. " ¼-½ "	3	6	15B + 1C	1.75	light
N. " ½-¾ "	4	3	8B	1.14	light
N. " E. ¼ "	2	9	3B	0.27	normal
S. " W. ¼ "	6	7	16B + 2C	1.38	light
S. " ¼-½ "	3	2	5B + 1C	1.2	light
S. " ½-¾ "	7	1	20B + 1C	2.62	light
S. " E. ¼ "	5	3	7B	0.87	normal
Corea wheat Sec. 26	7	9	11B + 1C	0.75	heavy
Corea wheat Sec. 35	1	1	1B	0.25	light
For the mile	38	43	86B + 6C[A]	1.14	light

[A] These data vary from those of Table LIII because of omissions in the records.

[AA] See page 198.

(6) Association and slope where eggs are found.- The data recorded relating to this topic during the egg survey are presented in the following table (Table LIII).

Most of the eggs were found in the following places: Timothy, Giant blue stem and roses, and there was a concentration of eggs in one spot on the north slope on which the soil was very loose.

Table LIII
Vegetation and Slope Preference of M. bivittatus for Oviposition

Vegetation	Slope	Sq. ft. samples with pods	Sq. ft. samples without pods	Total No. of pods	Av. pods per sq. ft.
Timothy		2	0	2B + 1C	2.0
Giant blue stem & roses	south	1	2	6B	2.0
Dandelion & timothy		1	0	2B	1.0
Pea sod		1	0	1B + 1C	1.0
Dandelion		3	3	10B	1.66
Pea and dandelion		0	1	0	0.00
Dandelion & brome		2	2	2B	0.5

Table LIII (Con'd.)
Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.
Giant blue stem		5	3	4B + 1C	0.5
Loose soil, edge of ceres		1	0	2B	2.0
Dandelion in ceres		2	3	4B	0.8
Edge of field		2	1	3B	1.0
South slope		7	4	20B	1.81
North slope		3	2	27B + 1C	5.4
Ceres		3	7	2B + 1C	0.2
Ceres edge		2	1	2B	0.66
		35	29	87B + 3C	

(7) Predators.- In the 64 square feet samples examined 5 carabid beetal larvae, 2 coarctate and 1 scarabaeoid blister beetle larvae were found. 2 wireworms were found also but were not reported as feeding on egg pods. None of the predators was found feeding on egg pods.

66.6 percent of the blister beetle larvae were in the coarctate stage when the egg survey was made on September 14.

In the 64 square feet examined 8 predators were found with 87 M. bivittatus and 5 C. pellucida egg pods. 2 wireworms were also found. The ratio of egg predators to egg pods was 1:11.5.

(8) General observations.- The north side of this road was neglected because it was generally getting late when the investigator reached this area on the return trip for the day. The south side of the road was worked on the way out in the morning so that the data are fairly complete. The decrease in the population between July 30 and August 4 is accounted for by the concentration of the grasshoppers along the edge of the ceres wheat during the wet weather of August 2 and 3 and the cool wind that prevailed on these days. The population remained at this level after the cutting of the crop on August 6 to 8. The average throughout the stubble was only 2 per square yard on August 8 but this increased until on August 21 the average was 9 per square yard 12 yards into the field. There were no records of the population along here from August 21 until September 7 because of the wet windy weather but during this time the population began to decrease as in the other plots. It will be noticed from

the table of estimates that the population remained higher in the east half mile after September 7 than in the west half mile. This higher population coincided with the area of dominance of Spartina michauxiana and Andropogon furcatus.

(9) Conclusions and summary.

(a) The dominant grasses along this mile were, in order of abundance Andropogon furcatus, Spartina michauxiana, Bromus inermis, Agropyron repens, Poa compressa and Phleum pratense. Aster, Solidago canadensis, Helianthus maximiliani, Artemisia ludoviciana and Rosa blanda were present. There were also a few plants of Populus deltoides, Fragaria virginiana and Elaeagnus argentea.

(b) M. bivittatus, C. pellucida and a few M. femur-rubrum were present on this plot.

(c) Very few M. bivittatus died of Empusa grylli along this mile.

(d) The average population per square yard for the period from July 24 to September 16 was 14.06 on the south side of the roadallowance.

(e) The average number of egg pods per square foot was 1.53 on the south side of the roadallowance, 1.0 on the north side, 0.75 in the corea stubble on section 26 and 0.25 in the corea stubble on section 35. The average for section 35 is high because many samples in which no eggs were found were not recorded. The egg infestation was rated as "light".

(f) There were not as many eggs in the corea wheat stubble on section 35 as on section 26 although the population through the stubble on section 35 was higher all through the period. This may have been due to a difference in the soil or to cultivation methods. The stubble on section 35 was longer and heavier than that on section 26 and may have been a factor.

(g) Most of the M. bivittatus eggs on this plot were found in timothy, Giant blue stem and roses, and there was a concentration of eggs in one spot on the north slope on which the soil was very loose.

(h) C. pellucida egg pods were found in poa, timothy, Giant blue stem and corea stubble.

(i) The ratio of egg predators to egg pods was 1:11.5.

(j) Two wireworms were found among the egg pods but there was no sign of feeding.

(k) 66.6 percent of the blister beetle larvae were in the coarctate stage when the egg survey was made on September 14.

(l) Between July 30 and August 4 the grasshoppers concentrated along the edge of the corea wheat during the wet, windy weather of August 2 and 3. The population concentrated in the slough grass and Giant blue stem grass during the latter part of the period. It apparently offered better protection than the timothy and poa of the west half mile.

6. Observational area V.
(West roadallowance of Sec. 36, T. 3, R. 3E.)

(1) General description.- Estimates were made along this road while walking between plots V and VI. This area was established on July 24.

The road was bordered on the east from south to north by a field of durum wheat, a piece of hayland (Plot V), durum wheat, barley, a plowed field, a field of ceres wheat, farm buildings, summer-fallow, and another field of durum wheat. On the west it was bordered by ceres wheat, summer-fallow, barley, ceres wheat, breaking, oats, barley, oats and durum wheat.

There was a low grade along this mile with a shallow ditch about a foot deep on each side of the road. The road was bordered by Amarantinus retroflexus, Rosa blanda and Orchard grass and the ditch on each side was filled with uncut Phleum pratense about one and a half feet high. The west side of the road had a gradual slope, about two yards wide, from the bottom of the ditch to the edge of the field, covered with Phleum pratense and Bromus inermis and the ditch was filled with the same type of vegetation. There was a grassy strip of land about five yards wide between the ditch and the crop on the east side of the road along which there was a wagon road.

(2) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXXVII). In all cases the plants are listed in order of abundance.

The vegetation at (VIII) was chiefly Phleum pratense which had been cut with the mower before July 15. There were many bare spots. Aster laevis, A. multiflorus, Rosa blanda, some Polygonum aviculare and Amarantinus retroflexus were present along the edge of the road. There was a strip of uncut Phleum pratense one and a half feet tall down the centre of the ditch.

Beside the barley field (IX) was covered chiefly with very luxuriant Andropogon furcatus with some Phleum pratense.

Beside the plowing on this level area there was Aster laevis, A. multiflorus, Solidago canadensis, Amarantinus retroflexus and Iva xanthifolia with some Phleum pratense and Andropogon furcatus.

At the half mile line (XI) the character of the roadallowance changed (Photograph Plate XII). The ditch was deeper, about two feet deep. The vegetation was much heavier

and consisted of Andropogon furcatus, Helianthus maximiliani, Solidago canadensis, Iva xanthifolia, Rosa blanda, Aster laevis and A. multiflorus and continued thus for the rest of the mile getting somewhat heavier toward the north.

On the west side of the road (XII) there was a shallow ditch with a gradual slope from the edge of the ditch up to the edge of the field. The chief grass on this slope was Phleum pratense with some Bromus inermis. There were patches of Aster laevis and Rosa blanda. Amaranthus retroflexus and Polygonum aviculare were present along the edge of the road.

The vegetation was similar for the rest of this half mile except that beside the barley field (XIII) there was more Rosa blanda, Aster laevis, A. multiflorus, Artemisia ludoviciana and Solidago canadensis.

Beside the oat crop (XIV) which had been stacked, the character of the roadside changed and the vegetation became chiefly Andropogon furcatus, Hordeum jubatum and Polygonum aviculare with some Rosa blanda, Aster multiflorus and Solidago canadensis.

The north half mile (XV) was very dense and covered with Andropogon furcatus, Ambrosia trifida, Iva xanthifolia, Aster laevis and A. multiflorus. Helianthus maximiliani, Rosa blanda and Artemisia ludoviciana were also present.

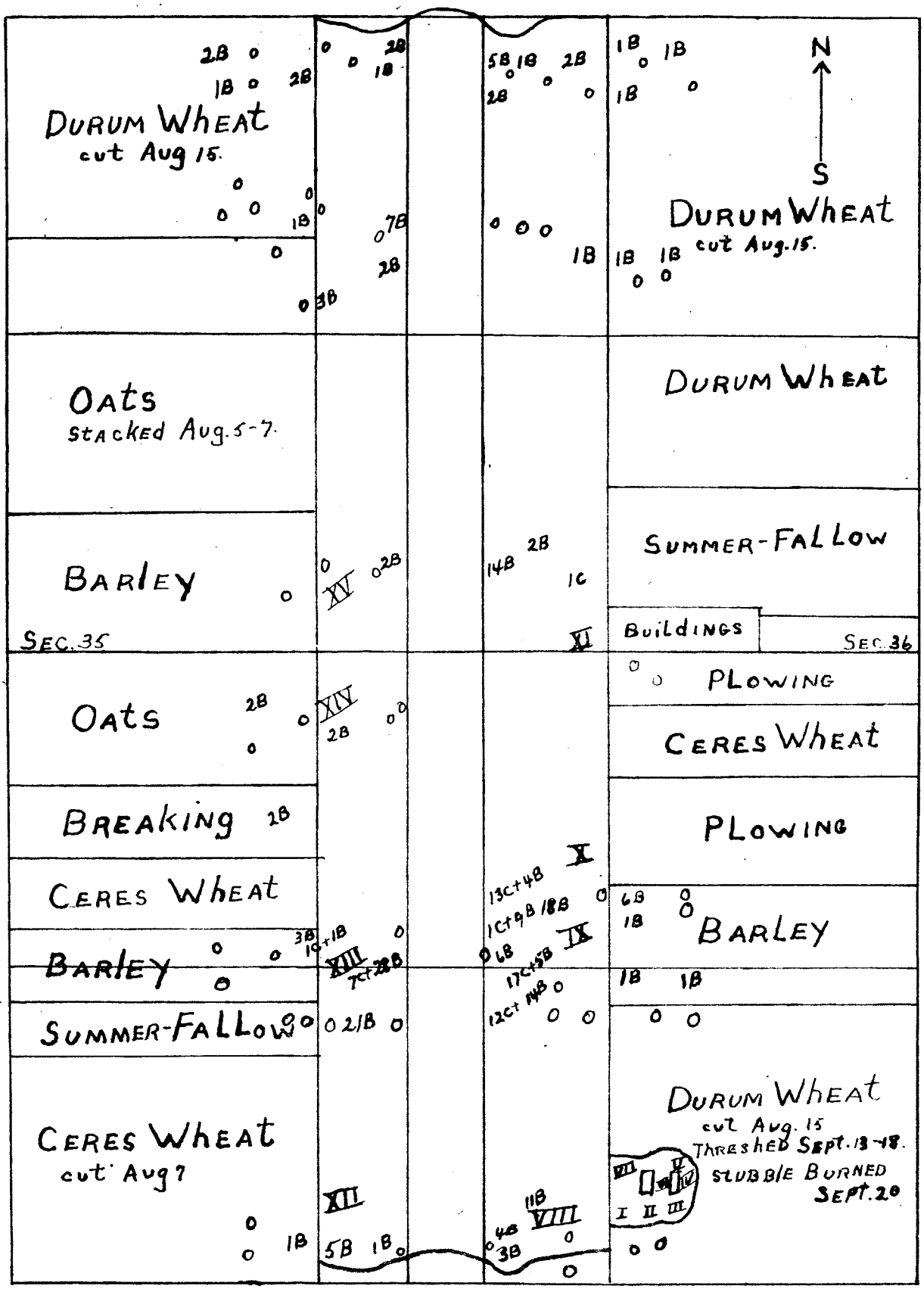
The vegetation remained the same for the rest of the mile except that it became heavier and there were a large number of Salix longifolia about three feet high.

The road was bordered by Amaranthus retroflexus, Rosa blanda and Orchard grass. The grasses occurring along this mile were, in order of their abundance, Phleum pratense, Bromus inermis, Poa compressa, Andropogon furcatus and Orchard grass with some Hordeum jubatum. The south half of this mile was chiefly grassy but the north half of the mile was covered with weeds ranging from two to five feet in height. In the north half mile of this road-allowance the predominant plants were, in order of their abundance, Rosa blanda, Aster, Polygonum aviculare, Solidago canadensis, Iva xanthifolia, Chenopodium alba, Helianthus maximiliani and a few Salix longifolia.

(3) Grasshoppers.- M. bivittatus was the major species along this mile. On July 18 there were very few grasshoppers in the north half mile and at the north end no grasshoppers were present. The percentage of maturity was much lower here than in the rest of the Arnaud district and on July 24 was estimated as 85 percent. C. pellucida were present along the edge of the barley on section 36 and along the edge of the hayland. On August 10 M. bivittatus were present in the ditch along the north half mile of the road where there were very few present formerly. On August 15 the population in the barley stubble on section 35 was estimated as

Plate XXXVII

Map of the west roadallowance of Sec. 36, T. 3, R. 3E., studied under observational area V. The cross section of the roadallowance is shown at each end of the map. The symbols are the same as described for Plate XXII.


DURUM WHEAT
cut Aug 15.
OATS
Stacked Aug. 5-7.
BARLEY
SEC. 35
OATS
BREAKING
CERES WHEAT
BARLEY
SUMMER-FALLOW
CERES WHEAT
cut Aug 7
XV
XIV
XIII
XII
XI
X
IX
VIII
N
S
DURUM WHEAT
cut Aug. 15.
DURUM WHEAT
SUMMER-FALLOW
BUILDINGS
SEC. 36
PLOWING
CERES WHEAT
PLOWING
BARLEY
DURUM WHEAT
cut Aug. 15
THRESHED SEPT. 13-18.
STUBBLE BURNED
SEPT. 20
I II III IV V VI VII

10 per square yard and there was some damage in the spook, the outside three rows having 60 percent of the heads removed. There was also damage to the stocked oats on section 35. Average population in the durum wheat on the north-west quarter of section 36 was 8 per square yard and in the durum wheat on the north-east quarter of section 35 averaged 8 per square yard. On August 28 the average population in durum stubble on the south-west quarter of section 36 was 2 per square yard with a maximum of 8 around the stooks.

Estimates were made every eighth of a mile from south to north along this randallowance. The estimates of the population and the average population per square yard for each trip are shown in the following tables (Tables LIV and LV). The averages for the trips are graphed in graph 1 (Plate XXXII). The average population during the study period is given on the tables as the number per square yard. The fluctuations in the grasshopper population during the study period are shown on the graph (Plate XXXII).

Table LIV

Population Estimates

(East side of roadallowance from south to north)

Date	Population per square yard for eighth mile divisions								Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
July 24	20	20	25	15	8	20	12	12	16.5
July 26	20	25	15	15	8	8	12	12	14.35
July 30	20	25	15	15	8	8	12	12	14.35
Aug. 3	20	18	10	4	15	2	8	8	10.6
Aug. 7	12	20	18	4	10	2	6	4	9.5
Aug. 10	12	10	18	6	12	6	8	6	9.75
Aug. 21	10	25	8	10	10	8	8	6	10.6
Aug. 28	8	4	10	10	6	6	2	3	6.
Sept. 8	6	4	6	6	3	1	1	1	3.5
Average population per square yard for the season									10.57

Table LV

(West side of roadallowance from south to north)

July 24	20	20	6	6	8	8	2	6	9.5
July 26	20	25	25	6	10	8	6	6	13.25
July 30	25	25	25	6	10	8	6	6	13.9
Aug. 3	20	6	3	12	10	2	6	6	8.3
Aug. 7	8	8	6	8	6	10	8	2	7.
Aug. 10	5	8	6	8	5	9	8	2	6.5
Aug. 21	8	15	10	4	4	8	10	2	7.6
Aug. 28	4	8	8	4	4	4	6	1	4.9
Sept. 8	3	4	4	4	0	2	0	1	2.85
Average population per square yard for the season									8.13

(4) Disease.- There was no Empusa grylli recorded on this roadallowance on July 24 and no dead observed. On August 15 there were a large number of dead both up the stems of plants and on the ground in the south half mile. Along the edge of the barley field on the east side of the road the average dead was 1 per two square yards. The dead were found chiefly on the ground, especially in the ditch, but a few were found up the stems of plants. On August 21, 5 dead were found in a square foot in the ditch and the average in the ditch on the east side of the road along the edge of the durum and barley fields was 12 per square yard. One fresh specimen which was not quite dead was found up a blade of grass. On September 7 and 8 a large number of dead were found in the durum stubble on the south-west quarter of section 36. The average was 3 per square yard with a maximum of 9.

On August 21 in an attempt to determine the rate at which the Empusa grylli was spreading, plants with dead M. bivittatus clinging to them were marked with strips of gauze. One piece of gauze was attached for each dead grasshopper. These plants were examined on August 28. In most cases the dead grasshoppers had fallen off but in one case the grasshopper was still clinging to the plant and in another, part was still there. In no case was a fresh dead grasshopper found one one of the marked plants although there were fresh dead on neighboring plants. This indicates that, although as many as 9 dead have been found clustered on one plant, the spores of Empusa grylli having been transferred from the dead grasshopper to the living grasshopper or from spores left on the plant, the infected grasshopper does not die there but may move to another plant before climbing to its death posture.

(5) Egg survey.- The map (Plate XXXVII) shows the results of the egg survey.

In this mile 99 square foot samples were examined and 205 M. bivittatus and 52 C. pellucida egg pods and 32 sores obtained.

The average population during the study period from July 24 to September 8 was 9.35 per square yard along this roadallowance. The average population along the east side of the road for the same period was 10.57 per square yard and along the west side of the road was 8.13 per square yard.

The total number of egg pods found along the roadallowance in 55 square foot samples was 176 M. bivittatus and 52 C. pellucida egg pods.

The average number of egg pods along the roadallowance was 3.2 M. bivittatus and 0.94 C. pellucida per square foot, and in the fall was 0.66.

The results of the egg survey are summarized in the following table (Table LVI) which shows the average number of egg pods deposited per square foot for each area. The rating of the infestation for each area and for the mile, based on the eggs found, is given.

Table LVI
Results of Egg Survey

Location	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating based on egg survey
E. side-N. ¼ mile	5	6	11B	1.0	normal
E. " ¼-½ "	3	0	16B + 1C	5.66	moderate
E. " ½-¾ "	5	2	42B + 31C	6B + 4.40	moderate
E. " S. ¼ "	4	6	32B + 12C	3.2B + 1.2C	moderate
W. side-N. ¼ mile	5	4	15B	1.66	light
W. " ¼-½ "	1	2	2B	0.66	normal
W. " ½-¾ "	3	3	31B + 8C	5.16B + 1.33C	moderate
W. " S. ¼ "	3	3	27B	4.5	moderate
Corea wheat Sec.35,S.	1	2	1B	0.33	light
Sum-fall.-Sec.35, S.	0	2	0	0.00	
Barley-Sec. 35 S.	1	3	3B	0.75	heavy
Breaking-Sec.35	1	0	2B	2.00	moderate
Oats-Sec. 35	1	2	1B	0.66	moderate
Barley-Sec.35	0	1	0	0.00	
Durum wheat-Sec.35	4	6	6B	0.6	moderate
Durum wheat-Sec.36,S.	1	4	1B	0.2	light
Barley, Sec.36	4	2	5B	1.5	very heavy
Durum wheat-Sec.36	5	4	3B	0.55	moderate
			205B + 82C	A 2.07B +	
For the mile	47	52	520	0.52C	moderate

A These data vary from those for Table LVII because of omissions in the records. AA See page 198.

(6) Association and slope where eggs are found.- The data recorded relating to this topic during the egg survey is presented in the following table (Table LVII).

The number of samples taken in each type of associate and slope was so small that the data are of little value for this plot.

Table LVII
Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.
Pea		2	0	29B + 29C	14.1
Pea	east	2	0	32B + 20C	16.0
Giant blue stem		3	1	11B	2.75
Orchard grass		2	2	7B + 1C	1.75
Couch		2	0	7B	3.5
Giant blue stem	west	3	2	5B	1.0
Pea & Dandelion			1	0	0.0
Open	east	3	0	27B + 1C	9.0
Bare & Dandelion	east	1	0	4B	4.0
Timothy	east	1	0	21B	21.0
Giant blue stem & Rag weed		1	3	3B	0.75
Open	level	6	4	9B	0.90
Barley		4	0	11B	2.75
Corea		1	0	2B + 1C	1.0
Oats		2	5	4B	0.57
Durum		9	11	11B	0.55
Summer-fallow			6	0	0.0
Unrecorded		6	1	33B	2.75
		48	48	213B	

(7) Predators.- In the 94 square foot samples examined 10 carabid larvae, 4 scarabaeoid blister beetle larvae and 21 coarctate blister beetle larvae were found. Of these, 2 of the carabid beetle larvae were observed feeding on M. bivittatus egg pods. One M. bivittatus egg pod was found infested with mites and one wireworm was found associated with the egg pods.

84 percent of the blister beetle larvae were in the coarctate stage by September 14.

In the 139 square feet examined 35 predators were found associated with 212 M. bivittatus and 52 C. pellucida egg pods. 2 wireworms were found associated with the egg pods. One M. bivittatus egg pod was infested with mites. The ratio of egg predators to egg pods was 1:7.54.

(8) General observations.- There was some spreading of the population into the stubble when the crops were cut. This spreading did not take place until a day or so after the crop

was cut. The graph indicates the trend of the population, flat on the two sides of the road running about parallel with the west side, a little lower than the east side. The graph indicates a shift in population from the east to the west side of the road between July 24 and July 26. It was also observed that during the wet windy weather, August 9 to August 25, M. bivittatus were present in the ditch in the north half mile on the east side of the road where the vegetation was heavy and where formerly there were no grasshoppers. The heavy vegetation apparently offered them protection.

There was quite an infestation of M. bivittatus eggs along this mile and more C. pellucida eggs than anywhere else in the Armand area as determined by the egg survey. There was also a large number of egg predators found. A plot/[illegible] along here for the study of egg survival and the effect of predators on the overwintering eggs.

(9) Conclusions and summary.

(a) The road was bordered by Amaranthus retroflexus, Rosa blanda and Orchard grass. The dominant grasses were Phleum pratense, Bromus inermis, Poa compressa, Andropogon furcatus and Orchard grass with some Hordeum jubatum. The south half mile was chiefly grass but the north half mile was covered with weeds ranging from two to five feet in height. In the north half mile of this roadallowance the dominant plants were, in order of abundance, Rosa blanda, Aster, Polygonum aviculare, Solidago canadensis, Iva xanthifolia, Chenopodium alba, Helianthus maximiliani and a few Salix longifolia.

(b) M. bivittatus and C. pellucida were present.

(c) M. bivittatus were found dead up stems of plants, apparently dead of Empusa grylli and others dead on the ground of an unidentified disease. Plants with dead M. bivittatus clinging to them were marked with a piece of white gauze for each dead grasshopper. A week later most of the grasshoppers had fallen off the marked plants but freshly killed specimens were clinging to neighboring plants. It was indicated that Empusa grylli, having been transferred to the living from dead grasshoppers or from spores on the plants, the infected grasshopper does not necessarily die on the same plant but may move to another plant before climbing to its death posture.

(d) The average population during the period from July 24 to September 8 was 9.35 per square yard.

(e) The average number of egg pods per square foot was 3.2 M. bivittatus and 0.54 C. pellucida along the roadallowance and 0.65 in the fields. The egg infestation was rated as "moderate".

(f) The number of samples taken in each type of

association and slope was so small that the data are of little value for this plot for M. bivittatus.

(g) C. pellucida egg pods were found in pea, Orchard grass and cereal stubble.

(h) The ratio of egg predators to egg pods was 1:7.54.

(i) 84 percent of the blister beetle larvae were in the coarctate stage by September 14.

(j) One M. bivittatus egg pod was infested with red mites and one wireworm was found associated with the egg pods.

(k) The population spread into the stubble to some extent where the crops were cut. There was a shift of the population from the east side to the west side of the road between July 24 and July 26. During the wet windy weather between August 9 and August 25 M. bivittatus sought protection in the heavy vegetation in the north half mile on the east side of the road. More C. pellucida eggs were found along part of this area than in any other part of the Armand area. This infestation of C. pellucida was bordering a field of barley that was sown late and was severely damaged before July 15. There were no C. pellucida eggs found in the barley stubble.

7. Observation area VI.
(South roadallowance of Sec. 36, T. 5, R. 3E.)

(1) General description.- Observations and estimates were made on the south side of this roadallowance after visiting plot VIII. This area was established on July 24.

The roadallowance was bordered on the north by a field of durum wheat and on the south from east to west by fields of oats, cereal wheat, oats, sweet clover, bush, summer-fallow and sweet clover.

There was a high graded road along here with a ditch three feet deep on the south side and a shallow ditch a foot deep on the north side of the road. On the south side of the road between the ditch and the field there was a level grassy strip about eight yards wide. There was a trail down the centre of this level area. The ditch on the north side was rather indefinite, the grade sloping down into a hollow and then there was a gradual slope up to the edge of the durum wheat field.

(2) Vegetation.- In the following description of the vegetation the Roman numerals refer to the locations marked on the map (Plate XXXVIII). In all cases the plants are listed in order of abundance.

The road was bordered on each side by Rosa blanda, Orchard grass and Bromus inermis.

The vegetation on the level area between the ditch and the fields on the south side of the road at the east end (I) was short and consisted of young Melilotus alba, Andropogon furcatus, Spartina michauxiana, Taraxacum officinale, Amaranthus retroflexus and A. graecizans. There were many bare spots and occasional clumps of Bromus inermis.

The vegetation remained the same in general along the edge of the oat field but by the corner wheat field (II) the vegetation was lighter and the crop ran out onto the grassy strip.

In the next half mile of the roadallowance (III) the sod was all cut up in September because the grain bins were hauled along here. There was some Amaranthus retroflexus and A. graecizans.

Along the fence line and in the openings in the bush (IV) there were small Populus tremuloides, Salix longifolia, Aster laevis, A. multiflorus, Solidago canadensis, Helianthus maximiliani and some Chenopodium alba. The bush consisted chiefly of Populus tremuloides, and Salix longifolia with a large Populus balsamifera in the north-east corner.

Along the edge of the summer-fallow and the sweet clover field on the north-west corner of the section (V) the grassy strip was cut up by the tractor and the cultivator. There were patches of Phleum pratense, Agropyron repens, Polygonum aviculare, Taraxacum officinale, Aster laevis and A. multiflorus but the ground was chiefly bare of vegetation.

The sweet clover in the field east of the farm buildings in the bush (VI) was about four feet high with a large amount of Chenopodium alba and Iva xanthifolia in it.

The bush east of the buildings (VII) consisted of Populus tremuloides and Salix longifolia with a large open space with Aster laevis, A. multiflorus, Rosa blanda, Solidago canadensis, Helianthus maximiliani, Andropogon furcatus, Phleum pratense and Poa compressa.

The vegetation in the ditch (VIII) was chiefly Agropyron repens, Poa compressa and Phleum pratense, Polygonum aviculare, Rosa blanda, Aster laevis, A. multiflorus, Artemisia ludoviciana, Taraxacum officinale and some Amaranthus retroflexus and Populus deltoides seedlings.

About an eighth of a mile west of the east corner in the ditch (IX) Spartina michauxiana and Andropogon furcatus became predominant.

A little further west (X) Andropogon furcatus was the predominant grass.

For the rest of the half mile there were occasional clumps of Bromus inermis and at the half mile line (XI) Phleum pratense two and a half feet tall predominated in the ditch with Andropogon furcatus, Rosa blanda, Aster laevis and A. multiflorus along the edge of the road.

The vegetation in the ditch (XII) was more weedy being chiefly Taraxacum officinale and Rosa blanda with some Phleum pratense, Andropogon furcatus, Salix longifolia Artemisia ludoviciana and A. multiflorus.

The vegetation was very uniform along the north side of the road, the same plants being represented but in varying amounts. This area was cut with the mower and raked before July 15. The plants along this side of the roadallowance (XIII) were chiefly Poa compressa with some Orchard grass, a few Aster multiflorus and A. laevis. There were also occasional plants of Chenopodium alba, Amaranthus retroflexus, Rosa blanda, Phleum pratense, Hordeum jubatum, Andropogon furcatus and Artemisia ludoviciana. At the east corner (XIV) there was a lot of Poa compressa, Rosa blanda and Amaranthus retroflexus.

At the half mile line (XV) there was some Aster laevis, A. multiflorus, Solidago canadensis and Amaranthus graecizans along the edge of the road. There was also an occasional Iva xanthifolia.

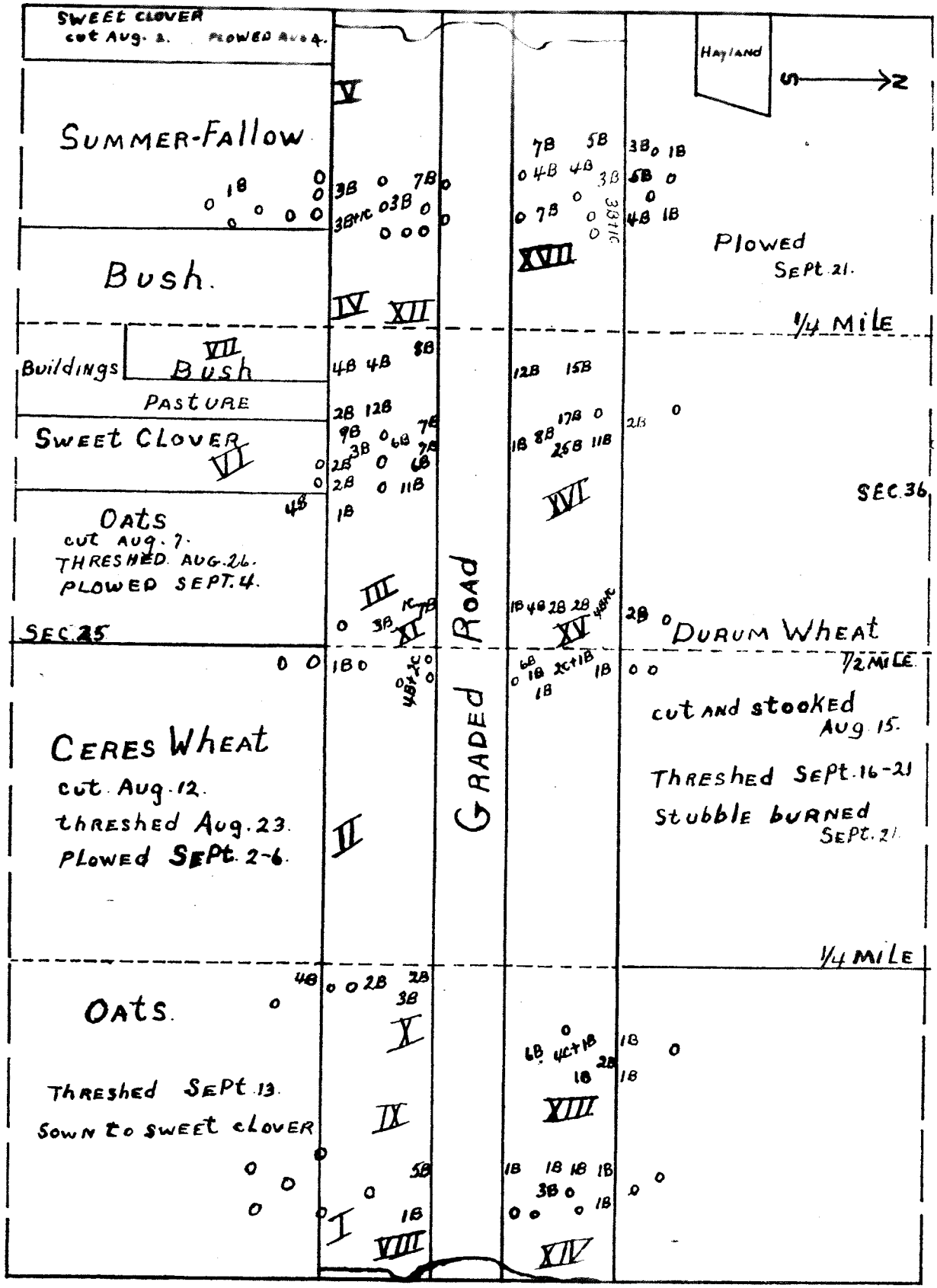
At (XVI) the vegetation was less grassy, there being more bare spots, Taraxacum officinale, Polygonum aviculare, Polygonum convolvulus and small plants of Aster. There were various grasses present, Hordeum jubatum, Poa compressa, Phleum pratense, Andropogon furcatus and Orchard grass. The area between the ditch and the field continued the same for the rest of the mile.

In the west quarter of the mile (XVII) the vegetation on the bank of the grade became chiefly Phleum pratense with some Bromus inermis, Taraxacum officinale, Aster laevis, A. multiflorus and Rosa blanda.

The road was bordered on both sides by Rosa blanda and Bromus inermis. The grasses along this mile were Andropogon furcatus, Poa compressa, Phleum pratense, Bromus inermis, Spartina michauxiana and Orchard grass. The predominant plants were Taraxacum officinale, Amaranthus retroflexus, Polygonum aviculare, Amaranthus graecizans, Aster, Solidago canadensis and Chenopodium alba.

Plate XXXVIII

Map of the south rondallowance of Sec. 36, T. 3, R. 3E., studied under observational area VI. The cross section of the rondallowance is shown at each end of the mile. The symbols are the same as described for Plate XXII.


SWEET CLOVER
cut Aug. 2. PLOWED Aug 4.
SUMMER-FALLOW
Bush.
Buildings
VII
Bush
PASTURE
SWEET CLOVER
VI
OATS
CUT AUG. 7.
THRESHED. AUG. 26.
PLOWED SEPT. 4.
SEC. 25
CERES WHEAT
cut. Aug. 12.
threshed Aug. 23.
PLOWED SEPT. 2-6.
OATS.
Threshed SEPT 13.
Sown to sweet clover
V
IV
XII
III
XI
II
I
VIII
IX
X
GRADED ROAD
XVII
XVI
XV
XIII
XIV
Hayland
S
N
Plowed
SEPT. 21.
1/4 MILE
SEC. 36
DURUM WHEAT
1/2 MILE.
cut AND stooKED
AUG 15.
THRESHED SEPT. 16-21
Stubble BURNED
SEPT. 21
1/4 MILE

(3) Grasshoppers.- The population along here was 95 percent M. bivittatus with the rest C. pellucida. C. pellucida were present on the north side of the road in the east quarter mile and in the west quarter mile. The south side of the road was 100 percent M. bivittatus. Estimates of population were made on the south side of the road.

The estimates of the population along the south side of this roadallowance are shown in the following table (Table LVIII) with the averages for each trip. The average population during the study period from July 24 to September 16 is given. The average population per square yard for the trips is graphed in graph 2 (Plate XXXII). This graph shows the fluctuation in the grasshopper population during the study period.

Table LVIII

Population Estimates

(South side of roadallowance from west to east)

Date	Population per square yard for eighth mile divisions								Av. pop. per sq. yd.
	0-1/8	1/8-1/4	1/4-3/8	3/8-1/2	1/2-5/8	5/8-3/4	3/4-7/8	7/8-1	
July 24	8	8	20	20	15	15	12	12	13.7
July 31	7	7	20	20	15	15	12	12	13.5
Aug. 7	15	25	25	15	15	15	20	25	9.75
Aug. 10	15	20	12	15	15	12	12	15	14.5
Sept. 8	8	0	1	8	0	0	0	2	2.37
Sept. 12	0	0	4	0	0	0	0	2	.75
Sept. 16	6	0	4	8	3	3	2	2	3.5
					Average population per square yard for the season				8.3

(4) Disease.- M. bivittatus were found dead on the ground along the fence by the sweet clover field and the bush in large numbers. The cause of their death is not known (Disease P. The disease was first noticed here on August 12. On August 22 two specimens were found dead up the stems of clover and grasses evidently dead of Empusa grylli. On August 22 the dead on the ground along the edge of the clover was 10 per square yard. The living population was 35 per square yard. Along the edge of the ditch the average number of dead was 6 per square yard with a living population of 30 per square yard. All the dead found were M. bivittatus.

On August 22 five quadrats, a yard square each in area, were marked out along the fence by the sweet clover field.

Quadrat I.- Half of this quadrat was covered with Solidago canadensis, Aster laevis and Rosa blanda about eight inches high while the other half had been cut with the mower.

Quadrat II.- Vegetation cut with the mower. There were many bare spots.

Quadrat III.- In cut grass and clover along the edge of the clover field.

Quadrat IV.- In cut grass and clover along the edge of the clover field.

Quadrat V.- In cut grass and clover along the edge of the clover field.

Table LII

Results

Date	Quadrat I	Quadrat II	Quadrat III	Quadrat IV	Quadrat V	Total
Aug. 22	9	13	25	32	20	99
Aug. 25	4	1	8 (3 fresh)	9 (2 fresh)	3	25
Aug. 29	1	0	0	4	6	11
Sept. 12	0	2	1	1	0	4
Total	14	16	34	46	29	139

Summary of Table

There were 99 dead in the five quadrats when they were marked out on August 14.

On the quadrats 40 died in 22 days.
Average dead per day for the five quadrats was 1.9.
Average dead per day per square yard was 0.38.
Average living population from August 22 to September 12 was 12.5 per square yard.
The daily mortality was 3.04 percent of the living population.

The quadrats were marked out along the fence with four stakes, one in each corner. The dead were removed when counted. On quadrat III and V five dead were replaced each time and subtracted from the count.

The count of dead for the period does not show that there were any more dead on quadrats II and IV due to these dead grasshoppers. If the disease is contagious and passed on from the dead grasshoppers it must be spread over an area greater than a square yard.

(5) Egg survey.- The map (Plate XXXVIII) shows the results of the egg survey.

In this mile 131 square foot samples were examined and 316 M. bivittatus, 12 C. pellucida egg pods and 36 zeros were found.

The average population along the south side of this road-allowance during the study period from July 24 to September 16 was 8.3.

The total number of egg pods found in 63 square foot samples along the roadallowance was 267 M. bivittatus and 12 C. pellucida. The average number of egg pods found along the roadallowance was 3.12 M. bivittatus and 0.12 C. pellucida per square foot. In the fields it was 0.83.

The results of the egg survey are summarized in the following table (Table LX) which shows the average number of eggs deposited per square foot for each area and for the mile. The rating of the infestation for each area and for the mile, based on the eggs found, is given.

Table LX
Results of Egg Survey

Location	Sq. ft. samples with pods	Sq. ft. samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating based on egg survey
N. side-W. $\frac{1}{4}$ mile	7	5	35B + 1C	2.82	light
N. " $\frac{1}{4}$-$\frac{1}{2}$ "	12	1	104B + 1C	8.00	moderate
N. " $\frac{1}{2}$-$\frac{3}{4}$ "	5	1	10B + 2C	2.00	light

Table LX (Con'd.)
Results of Egg Survey

Location	Sq.ft.samples with pods	Sq.ft.samples without pods	Total No. of pods	Av. pods per sq. ft.	Rating based on egg infestation[A]
N. side-E. ¼ mile	10	5	18B + 4C	1.47	light
S. " W. ¼ "	4	8	12B + 1C	1.8	light
S. " ¼-½ "	18	4	94B + 1C	4.3	moderate
S. " ½-¾ "	2	4	5B + 2C	1.16	light
S. " E. ¼ "	5	5	13B	1.30	light
Durum wheat-Sec. 36	9	10	20B	1.05	heavy
Oats, Sec. 25 E.	1	4	4B	0.80	heavy
Corn, Sec. 25	0	2	0	0.00	
Oats, Sec. 25	1	0	4B	4.00	heavy
Sweet clover, Sec. 25	0	0	0	0.00	
Summer-fallow, Sec. 25	1	7	1B	0.12	normal
For the mile	75	56	316B + 12C[A]	2.5	light

[A] These data vary from those for Table LXI because of omissions in the records. See page 198.

(6) Association and slope where eggs are found.- The data recorded relating to this topic during the egg survey is presented in the following table (Table LXI).

The data suggest that M. bivittatus showed a preference for burned areas, dandelion and loose soil. Timothy and couch were also favored.

Table LXI
Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq.ft.samples with pods	Sq.ft.samples without pods	Total No. of pods	Av. pods per sq. ft.
Timothy	south	6	1	25B	3.57
Timothy	north	4	2	24B	4.00
Timothy	level	5	3	29B	3.62
Timothy & Dandelion		3	1	12B	3.00
Couch	south	9	1	37B + 5C	3.70
Couch & Dandelion		5	1	42B	7.00
Poa		7	3	26B + 4C	2.6
Poa	north	4	1	16B	3.02
Poa, French weed & Dandelion		2	2	5B	1.25

Table LXI (Con'd.)
Vegetation and Slope Preferences of M. bivittatus for Oviposition

Vegetation	Slope	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.
Brome		4	2	13B	2.16
Spartina		4	2	5B	0.83
Giant blue stem		3	2	8B + 10	1.60
Orchard grass		3	4	12B	1.71
Burned area		1	0	8B	8.00
Dandelion & loose soil	south	5	1	60B	10.00
Summer-fallow		0	3	0	0.00
Durum wheat (?)		6	11	7B	4.11
French weed		0	2	0	0.00
Oats with sweet clover		1	8	4B	0.44
Dandelion	north	7	6	11B	0.84
		79	56	344B	

(7) Predators.- In the 135 square foot samples examined 7 carabid beetle larvae, 10 coarctate and 4 scarabaeoid blister beetle larvae and 4 bee fly larvae were found. None of these were found feeding on the egg pods. 2 wireworms were found associated with the egg pods. One pod of M. bivittatus eggs was found infested with red ants.

71.43 percent of the blister beetle larvae were in the coarctate stage by September 21.

In the 135 square feet examined 344 M. bivittatus and 10 C. pallucida egg pods were found with 25 predators. 3 wireworms were found associated with the eggs but none of these was reported as feeding on the eggs. One pod of M. bivittatus eggs was being carried away by red ants. The ratio of egg predators to egg pods was 1:14.16.

(8) General observations.- Between August 10 and September 8 the time spent on this plot, was spent on disease quadrats and estimates were neglected. Therefore, the graph of population is incomplete. The chief results obtained from this plot were those on disease.

(9) Conclusions and summary.
(a) The road was bordered on both sides by Hoss blends and Bromus inermis. The grasses along this mile were Andropogon

furcatum, Poa compressa, Phleum pratense, Bromus inermis, Spartina michauxiana and Orchard grass. The predominant plants were Taraxacum officinale, Amaranthus retroflexus, Polygonum aviculare, A. graecizans, Aster, Solidago canadensis and Chenopodium alba.

(b) The population was 95 percent M. bivittatus and the rest C. pellucida.

(c) Only two specimens of M. bivittatus were found up stems of plants apparently dead of Empusa grylli. Many died on the ground of an unidentified disease. Quadrats were marked out in an attempt to follow the rate of mortality due to this second disease. Five quadrats, a square yard in area, were used, on which the dead were counted as frequently as possible and removed each time. The daily mortality was found to be 3.04 percent of the average population. On two of the quadrats five dead were placed on them each time as a probable source of infection. The rate of mortality on these two plots was not any higher than on the other quadrats. If the disease is contagious it can be spread, apparently, over an area greater than one square yard.

(d) The average population per square yard for the period from July 24 to September 16 on the south side of the road was 8.3.

(e) The average number of egg pods per square foot found was 3.12 M. bivittatus and 0.12 C. pellucida along the roadallowance and 0.53 in the fields. The egg infestation is rated as "light".

(f) M. bivittatus showed a preference for burned areas and dandelion and loose soil. Timothy and couch were also favored.

(g) C. pellucida egg pods were found in couch, poa, and Giant blue stem.

(h) The ratio of egg predators to egg pods was 1: 14.16.

(i) 71.43 percent of the blister beetle larvae were in the coarctate stage by September 21.

(j) One M. bivittatus egg pod was found infested with red ants. Two wireworms were found associated with the egg pods.

VII. PLOTS DISCARDED.

Some of the plots chosen for study were later discarded in favor of more suitable areas. Among these discarded plots were the following roadallowances: the roadallowance north of section 34, T. 3, R. 3E., the roadallowance east of Sec. 3, T. 4, R. 3E., and the roadallowance east of Sec. 34, T. 3, R. 3E.

The first was a high graded road with a deep ditch on the south side. There were very few grasshoppers at the west end of the mile but at the east end the population on July 22 ran as high as 25 M. bivittatus per square yard in the false rag weed in the ditch. The grasshoppers were 80 percent mature. There was quite a large number of dead up the stems of plants in the ditch.

The second had a heavy concentration of both M. bivittatus and C. pellucida, about 65 percent M. bivittatus. Mortality due to Empusa grylli was very heavy along this mile. A few M. mexicanus and Combocerus clavatus were also present along the north-east quarter of Sec. 3. This was a mile of very heavy infestation.

The third had a population of 15 to 20 M. bivittatus per square yard at the north end but decreased toward the south to 5 per square yard at the south corner. There was a large population of Conocephalus sp. along the ditch on the west side of the road for the north half mile.

These three roadallowances were included in one trip and, when the population on all three of them was found on July 28 to have decreased since the last visit, they were abandoned in favor of new plots. The areas had not been studied thoroughly or long enough to be able to tell what had become of the population.

A new plot was established along the north roadallowance of Sec. 21, T. 3, R. 3E., on August 2 and an observational area started on the west roadallowance of Sec. 28, T. 3, R. 3E., On August 6 another study plot was established on the south roadallowance of Sec. 27, T. 3, R. 3E. These three areas made up part of the day's trip along with plots I and II. This trip replaced the former trip which had taken in the discarded plots.

VIII. SEASONAL HISTORY AND ECOLOGY OF THE GRASSHOPPER POPULATION.

1. Nymphs

The study area was not established until July 18 and at this time C. pellucida was 85 percent mature and M. bivittatus between 70 and 75 percent. Both species were present in stages from the second nymphal to the adult stage. On August 1 C. pellucida was reported as 100 percent adult and M. bivittatus 85 percent. On August 15 M. bivittatus was recorded as 100 percent mature in most places but in others was only 80 percent. Nymphs of M. bivittatus were present up until September 21.

The last second and the last third instar M. bivittatus nymphs were observed on August 10 and the last fourth instar M. bivittatus nymphs on September 8. Fifth instar M. bivittatus nymphs were present right up until September 21.

2. Adults.

Adult M. bivittatus and C. pellucida were present in the Armoud area when the study area was opened on July 16 and were still present on September 21. The population was very small after August 22. At this time the largest population was around the old stables on plot V among the heavy brome grass. The following graph shows the average population as determined by the estimates on the plots during different periods during the summer. This graph shows a gradual falling off of the population from the time that the study was started but some of the graphs show a temporary increase. This seems to indicate that the changes were local changes due to shifting of the population.

The average population for each plot during the different periods is tabulated and grouped into trips in the following tables (Tables LXII and LXIII). That for the whole area for each trip was calculated and plotted in the graph (Plate XXXIX). The graph shows a small decrease in the population in the area between trip 1 and trip 4, then a gradual increase and finally tapers off during the fall. The populations were taken along the roadallowances only. The decrease between trip 3 and trip 4 was due partly to the movement into the crop after cutting. The increase shown between trip 4 and trip 6 is attributed to a movement back onto the roadallowances shortly after the crops were cut as recorded for plots I, IV, VI, VII and VIII and also in some of the observational areas. It may be assumed that if the population for the crops had been included the graph of the population would have been a curve as shown by the dotted line.

Table LXII
Population Trend for the Detailed Study Plots

	Date	Average pop. per sq. yard for the detailed study plots							
		I	II	III	IV	V	VI	VII	VIII
Trip 1	July 22		18.2						
	23	14.7							
	24					25	12.2	12.2	10
	26						14.0		14.1
Trip 2	July 30	11.6	14.92			30		11.72	11.9
	31					10.5	14.7	12.62	12.8

Table LXII (Con't.)
Population Trend for the Detailed Study Plots

	Date	Average population per square yard for the Detailed Study Plots							
		I	II	III	IV	V	VI	VII	VIII
Trip 3	Aug. 2		14.9	12.5					
	3					20	13	12.2	9.3
Trip 4	Aug. 6	13.1	12.5	11.6	13.25				
	7					12.2	10.5	11.37	9.7
Trip 5	Aug. 9	11.2	12.8	13.0	17.0				
	10					14.5	9.16	10.7	9.3
	14	11.1							
Trip 6	Aug. 21					16.75	12.3	20.1	10.7
	23	12.6	12.5		22.0				
Trip 7	Aug. 28					11.25		3.92	7.8
	29	3.5							
Trip 8	Sept. 5			2.5	2.0				
	7					3.5			
	8					5.0	3.62	2.12	4.2
Trip 9	Sept. 12								1.8
	14		1.75	2.6	1.5				
	16								2.1
	17								

Table LXIII
Population Trend for the Observational Areas.

	Date	Av. pop. per sq. yd for observational areas I	II	III	IV	V	VI	Av. pop. per sq. yd. for the trip for pl.& ob. areas
Trip	July 22							
	23							
1	24		13.1		25	13	13.7	15.35
	26		16.18			13.8		
Trip	July 30		13.0	2.37	25	14.12		
2	31		15.9		22.5		13.5	14.2
Trip	Aug. 2	14.43						
3	3		14.92		16	9.4		13.66
Trip	Aug. 6	15.18		3.0				
4	7		14.47		16.25	6.2	9.75	11.55
Trip	Aug. 9	15.88		3.88				
5	10		12.18		15.3	6.12	14.5	11.96
Trip	Aug.14			5.12				
6	21		18.1		15.75	9.1		13.04
	23			3.5				
Trip	Aug. 28					5.4		
7	29			1.72				5.60
Trip	Sept. 5							
8	7				1.8			
	8	3.5	5.83	.75		2.87	2.37	3.07
Trip	Sept.12						0.75	
9	14			0.5	1.8			
	16				1.25		3.5	2.0
	17		5.11					

Plate XXXIX

Graph of the trend of population for the Armand area between July 22 and September 17. The dotted line indicates what is considered to be the true course of the population trend.

SEASONAL TREND OF POPULATION.
Population per sq. yd.
0
5
10
15
July
26
4
August
11
18
25
1
September
8
15

3. Oviposition.

Female M. bivittatus were found with their abdomens in the ground after July 16. The first eggs were not obtained until July 25. M. bivittatus were observed ovipositing from this date up until September 21 when the investigator left the area.

C. pellucida was first observed ovipositing on July 30 when eggs were obtained. Very few C. pellucida were observed ovipositing during the season in the Arnaud area. When the adult female C. pellucida were examined the ovaries appeared to be immature and in the majority of cases looked like small yellow fat bodies. This immaturity may have been due to disease or to the late hatching of the eggs in the spring. No data were obtained on this point.

4. Flights.

There were very few flights of grasshoppers in 1935 in Manitoba. Those that were observed in the Arnaud area are tabulated in the following table. These flights all followed after showers of rain and occurred generally during the hottest part of the day.

The most unexpected flight occurred on August 20. It rained every day from August 15 until August 19. It rained very heavily on August 18 and until noon on August 19. The grasshoppers were inactive until noon on August 20. The maximum temperature on this date was 70° F. and there was a slight breeze from the north west. The cloudiness was 5 (Weather P. 24). The flight consisted of three flights at three different levels with about 10 grasshoppers present in the field of vision at one time. It was believed that the swin flight was coming from further north, where the temperature was probably higher, and was joined during the afternoon by local grasshoppers when the temperature rose somewhat. Again on September 5 it had rained during the night but the sun came out and was quite warm by 9 A.M. A strong wind got up about 11 A.M. and it became cooler. The flight was noticed at 11 A.M. but it did not last more than an hour. The maximum temperature for the day was 66° F.

The occurrence of flights was recorded on the tables prepared by H. H. Painter in 1934 for distribution among the grain elevator men and agricultural representatives throughout Manitoba. The table needs no explanation as used in 1934 but as used by this investigator there was a minor change in the method of recording. The first change was under "abundance" under which heading it was attempted to make some measure of the number of grasshoppers flying. This was done by putting down the number of grasshoppers

that the observer estimated he could see within his field of vision while looking in one direction. Again under "cloudiness" the method of recording was changed. Under this heading the cloudiness was recorded as explained under weather (Weather P. 24). Furthermore, there was no attempt to record the velocity of the wind as miles per hour. The wind was recorded as explained under Weather (P. 24). It is believed that with these few minor changes the table is ideal for keeping a record of the conditions under which flights occur.

Table LXIV

Record of Flights

Date	Wind Direc. & velocity Direc.	Miles per hr.	Direc. of flight	Height in air	Density of flight	Temp. when noted	Time when noted	Cloudiness	Duration of flight	Date of last rain
July 27	N.W.		S.E.	low	a few	86°	2 P.M.	clear		July 26
July 30	W.		S.W.	1	"	90	2.30 P.M.	1		July 29
Aug. 7	S.E.		W.	1	"	91	12 A.M.	1	12A.M.-3P.M.	Aug. 7
Aug. 8	S.E.		N.	1	"	87	12.30A.M.	1		Aug. 7
Aug. 9	N.W.		S.E.	1	just a few	83	12 A.M.	1	12A.M.-3P.M.	Aug. 7
Aug. 10	S.E.		N.W.	1	"	86	1.30 P.M.			Aug. 9
Aug. 13	N.W.		S.E.	1	"	79	10.30A.M.	1	10.30-4.30P.M.	Aug. 11
Aug. 20	N.W.	strong	S.	low & high	10	68	1 P.M.	5	1A.M.-4.30P.M.	Aug. 19
Aug. 21	S.W.		N.	1	4-5	78	11.30A.M.	4	11.30-5.30P.M.	Aug. 19
Sept. 5	N.	sl.br.	S.	1	a few	57	11 A.M.	1	11A.M.-2 P.M.	Sept. 3
Sept. 14	E.	sl.br.	S.	very low	"	62	12.30A.M.	1	12.30-3.30P.M.	Sept. 13
Sept. 16	S.& S.E.		N.E.	" "	"	75	11 A.M.	1	11A.M.-3 P.M.	Sept. 15

3. Grasshopper Habitats.

Careful notes were kept to try and determine the association preferred by grasshoppers but, although considerable data have been accumulated, several years' work will have to be done before any definite conclusions can be reached.

Criddle (1933b) classifies M. bivittatus as a very general feeder, feeding on almost any kind of plant. C. pellucida, on the other hand, he classifies as a more restricted feeder on grasses and a few broad-leaved plants.

In the Arnaud area this was found to be true. C. pellucida was found generally where there was a thick sod of Poa compressa, Phleum pratense, Bromus inermis or Andropogon furcatus when the grass was not too tall. On the other hand, M. bivittatus was present in all types of vegetation in the Arnaud area. Some M. bivittatus were even found in Canadian thistle.

C. pellucida although selecting the grasses mentioned above, was found in open areas among weeds and brush where there was some grass. This was evidently because of the protection offered against the weather. They were also found adjacent to a barley field on Sec. 36 which was sown late and considerably damaged in the spring. The vegetation along this half mile was very constant but these grasshoppers laid their eggs in the roadallowance bordering this crop and did not spread over the half mile.

M. bivittatus also sought protection during wet windy weather and was found amongst heavy vegetation of false rag weed, golden rod, aster and lamb's quarter where there were none present during the warm weather of July and the beginning of August. They also concentrated around the stacks for protection. This seeking of protection was observed on several of the plots.

There were not enough C. pellucida present in the Arnaud area to make any comparison of their food plants with those of M. bivittatus. It is hoped that in future work we will learn the associations that the different species of grasshoppers like. This preference may be found to change during the different stages of development.

M. bivittatus was found in fields of flax, barley, rye, durum wheat, thatcher wheat, corns wheat, oats, sweet clover, and corn. They were also present in the gardens in beans, corn, sunflowers, beets, potatoes, nasturtiums, onions and other garden crops.

It was difficult to compare M. bivittatus and C. pellucida in habit for although C. pellucida was well represented when the study started, the majority of them moved out shortly afterward. The differences in vegetation selection observed between the two species are presented in the above section on vegetation. In regards reactions to weather the impression received during the first part of the study period was that C. pellucida was much more sensitive to changes in temperature, wind, cloudiness and rainfall than M. bivittatus. Very little data were collected on these reactions. Those observed in connection with oviposition are recorded under that section (P. 152).

6. Damage to natural vegetation.

The roadallowances were of a remarkably different appearance to what they were a year ago. In 1934, due to the dry weather and the ravages of the grasshoppers, it was possible to drive along a road and tell whether there were grasshoppers there or not. This year the grasshoppers had very little effect on the vegetation as it grew faster than they could eat it down. This was due to the frequent showers of rain. It was necessary to get out of the cars and walk around this year before you could even guess whether there were grasshoppers present. The damage to natural vegetation was very slight.

7. Damage to crops and gardens.

The vegetation on the roadside, as pointed out above, provided sufficient luxuriant food for the grasshoppers this year. The grasshoppers were late hatching and, as the spring was cool and wet, they were inactive and stayed on the roadsides where the vegetation was luxuriant. Even when they did go into the crops the grain was well developed and the amount of damage done was not noticeable in most cases. There was some damage to crops, however, and marginal feeding was evident around most of the crops in the Arnaud area. Damage in many cases occurred just before cutting and after stooking, especially in the case of rye, barley, oats and flax.

After the crops had been cut M. bivittatus seemed to move in a body into the gardens, destroying them almost completely in many cases. In the gardens they attacked corn, beans, sunflowers, beets, potatoes and nasturtiums. Several farmers reported this moving in of the grasshoppers into their gardens and two of them said that the first thing that they attacked was the onions, even eating part of the bulb. Hitchener (1933) refers to the damage done to onions by grasshoppers.

Mr. Lilljerd, the owner of Sec. 1, T. 3, R. 3E., estimated the damage to his crop of rye as about 15 percent and to his wheat as 5 to 10 percent. His crop of flax in the section north of Sec. 1 was damaged to the extent of 20 to 25 percent by M. bivittatus. His garden was severely damaged as follows: beans, 70 percent, corn 40 percent, sunflowers 35 percent and the beets, potatoes and nasturtiums to some extent.

IX. OVIPOSITION AND EGG INFESTATION.

The first M. bivittatus eggs were found on July 25. Although females had been observed with their abdomens in the ground before this date no eggs had been found. The first C. pellucida eggs were obtained on July 30.

1. Reactions to moist soil.

On August 24 M. bivittatus was found ovipositing in a ditch where there had been water on August 22. The moisture was down three-quarters of an inch from the surface. On August 17 at 11 A. M. 2 M. bivittatus females were observed ovipositing on the south slope of the grade where the soil was still wet enough, from the rain of August 15, 16 and the morning of the 17, to be rolled into a ball. Again on September 7 at 3 P. M. a M. bivittatus female was found ovipositing, although the earth was still moist at the surface from the rain of September 6.

2. Reaction to burned vegetation.

In several small areas, where coils of hay had been burned along the south slope of a grade, and the ground and grass had been burned also, as many as 8 M. bivittatus females could be observed ovipositing in a square yard under weather conditions when there would be no ovipositing in the surrounding area. The same was observed in similar areas over the study area. This choice of burned areas for the oviposition of eggs by M. bivittatus is further illustrated in the results of the egg survey as shown under "Association where eggs are found" and is tabulated in the following table in comparison with the average pods per square foot over the rest of each area.

Table LXV

M. bivittatus Egg Pods Found in Burned Areas in Comparison with the Average per Square Foot for the Mile.

Plot	Sq.ft. samples with pods	Sq.ft. samples without pods	Total No. of pods	Av. pods per sq. ft.	Av. pods per sq. ft. for the mile
Detailed VII	2	0	33	1.5	0.59
Obs.Area II	1	0	23	22.0	1.2
Obs.Area VI	1	0	58	8.0	3.12

3. Weather conditions under which oviposition takes place.

M. bivittatus was observed ovipositing as early as 9.10 A. M. and as late as 6 P. M. This species normally oviposits during the warm part of the day between 9 A.M. and 5 P. M. From the data presented in table LXVI and from other observations made, it was concluded that oviposition becomes general for M. bivittatus at temperatures above 70° F. with soil temperatures also above 70° F. and with the sun shining to some extent at least.

On August 7 oviposition was general in the morning but none was observed during the afternoon until 5 P. M. This was believed due to the high temperature. The air temperature at 2 P. M. was 92° F. in the shade, the soil temperature in the sun at the surface was 98° F. and the cloudiness was valued at 1. M. bivittatus were observed ovipositing at air temperatures as high as 94° F. with a corresponding soil temperature of 98°F. but the cloudiness at this time was recorded as 6. M. bivittatus was reported as ovipositing at a soil surface temperature of 106° F. but at this time the air temperature was only 81° F. Thus, the upper limit of oviposition must be around 94° F. air temperature with a soil temperature around 106° F.

The lower limit of oviposition is still more indefinite. The lowest temperature at which oviposition was believed to be general was 57° F. air temperature in the shade and with a soil surface temperature of 71° F. in the shade. M. bivittatus was not observed ovipositing generally at temperatures as low as this. Individual specimens were found ovipositing in many cases under conditions which were formerly believed to be unsuitable. Some of the conditions under which oviposition was observed to be taking place are recorded in table LXVI. It may be the case that, as weather conditions were changeable, and on the whole unsuitable for grasshoppers, the gravid females were obliged to oviposit their eggs under these unsuitable conditions when the eggs became mature.

It may be that the females were not really ovipositing at these temperatures as recorded.

When a female was found with her abdomen extended and inserted into the ground she was considered to be ovipositing after July 25 when the first eggs were found. This attitude on the part of a grasshopper does not, however, necessarily indicate that she is laying eggs. She may put her abdomen into the ground when the sun is shining and then when the sun goes under a cloud

or when the wind gets up, withdrew it without laying any eggs. Many of the observations recorded in the preceding table were made along the south slope of the grade south of Sec. 31, T. 3, R. 4E., where oviposition seemed to be very general but where very few eggs were found during the egg survey. This seems to point to the fact that some other criterion of when a grasshopper is ovipositing will have to be developed.

Another difficulty encountered at the beginning of the oviposition period was the difference in maturity of the grasshoppers in different areas. Thus, on August 6 in a trip west of town there was very little oviposition although the weather was believed to be ideal, while on August 7 on a trip east of town, oviposition was general although the weather was much cooler than on August 6. This was believed to be due to a difference in the maturity of the grasshoppers on the two sides of the town.

Table LXVI

Data on Oviposition

Date	Time	Air T.	Soil T.	Wind	Cloudiness	Remarks
July 25	9.30 A.M.	84° F.	95° F.			First ovip. biv. on hard surface of the road. Ground so hard that it could be cut with a knife. Just like hard rubber.
July 30	9.30 A.M.	82				Biv. ovipositing.
	11 A.M.	87				Cam. ovipositing in school yard.
July 31	9.30 A.M.	77		N.W.		Biv. ovip. and Cam. on edge of barley field on west slope.
	2.30 P.M.	83		N.W.at.		ovipositing ceased.
Aug. 3	2.30 P.M.	76	84	N.W.		Biv. and Cam. ovip. shaded by grated road from wind.
Aug. 6	11.10A.M.	82		W.	5	Biv. ovipositing.
	11.30A.M.	82		W.	5	Cam. and Biv. ovip. Soil still wet from rain August 3.
	1 P.M.	87		S.E.br.	2	Biv. ovip.
	2.10 P.M.	88	105	S.el.br.	2	No ovip. (very little ovip. today although very warm. S.T.105°while on Sat. S.T.70° at 10.10 A.M. there was a great deal of ovip. perhaps due to a difference in maturity as Sat. trip east of town and today W.
	3 P.M.	87				Biv. ovip. in cinders and gravel along rr.
Aug. 7	10 A.M.	82				Cam. ovip.
	1 P.M.	92		S.E.br.	1	Biv. and Cam. ovip.
	2 P.M.	92	98	"	1	Very little ovip. (Biv.)
	3 P.M.	84	90	"	3	Ovip. seemed to start again although none all P.M.

Table LXVI (Con'd)
Data on Oviposition.

Date	Time	Air T.	Soil T.	Wind	Cloudiness	Remarks
Aug. 8	10.30 A.M.	81° F.	106° F.	N.W.		Biv. ovip.
	3-5 P.M.					Biv. ovip. all along railway track in cinders and gravel. In one case eggs were found in a crack in a tie which was filled with gravel.
Aug. 10	10.30 A.M.	76	90	S. br.	8	Biv. ovip. on E. slope of the ditch bank in timothy cut for hay and ovip. quite general in hayland around old buildings.
	1.30 A.M.	88	98	S.E.	1+	Cum. ovip. sun shining and hot but clouds around horizon and sky heavy.
	3 P.M.	84	90	S.W. st.br.	9	Biv. ovip. on N. slope of grade protected from winds and in pasture.
Aug. 14	10.50 A.M.	86	90	S. st.wd.	4	Biv. just starting to ovip. in drift soil in shelter of weeds.
	11.30 A.M.	86	90	S. st.wd.	4	Biv. ovip. on hard road with no protection from wind.
	1.15 P.M.	94	98	S. st.wd.	6	Biv. ovip. after slight shower of rain at 12.30A.M. Wind very strong.
Aug. 15	9.50 A.M.	84	94	S. st.wd.	1	Biv. ovip. on level and on south slope.
	10.00 A.M.	85	92	S. st.wd.	1	Cum. ovip. (warm S. wind blowing 12 mi. p. hr.) Biv. ovip. general.
	10.55 A.M.	88	101	S.	1+	Biv. ovip. on E. slope of N.&S. road. Warm S. wind.
	11 A.M.	88	97	S.	very heavy	Biv. ovip. in oat stubble.
	11.40 A.M.	90	97	S.	5	Wind getting stronger but biv. ovip. on N. side of grade.

Table LXVI (Con'd.)
Data on Oviposition

Date	Time	Air T.	Soil T.	Wind	Cloudiness	Remarks
Aug. 15	12 A.M.	90° F.	95° F.	S.	8¼	Sun overcast but ovip. general on N. side of grade.
	4 P.M.	77	88	N.W.st.	9	Biv. ovip.
	4.10P.M.	77	83	N.W.	9	Biv. ovip. on S. slope and on level.
	4.20P.M.	76	81	N.W.	9	Biv. ovip. in ditch where water on Tues. Moisture down ¾" from surface.
	4.30P.M.	86	79	N.W.	10	Biv. ovip. on N. slope.
	5.20P.M.	74	77	N.W.	10	8 Biv. ovip. in 1 sq.yd. in strong cool N.W.wind in burned area.
	6 P.M.	70	74	N.W.	10	Biv. ovip.
Aug. 17	11 A.M.	63	75	N.E.	1	2 Biv. ovip. although it rained all night of Aug. 15 and all day Aug. 16, cleared up after 3 A.M. Aug. 17. Biv. ovip. on S. slope of grade where soil still wet enough to roll into a ball even on the surface. Cau. inactive
	2 P.M.	70	77	N.E.br.	5	Biv. ovip.
	2.30P.M.	70	93 (sun shining)	"	5	Biv. ovip. all along the S. slope of grade.
	2.55P.M.	71	78	"	5¼	Biv. ovip.
Aug. 20	2.10P.M.	69	72	N.W.	5	2 biv. ovip. between planks of sidewalk.
Aug. 21	10.40 P.M.	76		S.W.	1	1 biv. ovip.
	11.30 P.M.	77		S.	4	Biv. ovip. in rye stubble
	5.45 P.M.	77		S.E. quite cool	5	Biv. still ovip.
	6.15 P.M.	69		N.W.	7	Biv. still ovip. Very cool.
Aug. 22	2 P.M.	83	95		5	Biv. ovip. in gravel.
Aug. 23	11 A.M.	82	93	S.E.st.wd.	6	Wind quite strong-biv. ovip.

Table LXVI (Con'd.)
Data on Oviposition

Date	Time	Air T.	Soil T.	Wind	Cloudiness	Remarks
Aug. 28	10.40 A.M.	59° F.	74° F.	N.W.st.br.	7	Wind cool. biv. ovip. on E. slope of grade. Very cool Aug. 27.
	2 P.M.	60	75	N.	9	Wind not quite so cool.
	3.15 P.M.	59	68	N.W.	8	Biv. ovip.
	4.30 P.M.	57	71	N.W.(cool)	9	Biv. ovip.
Aug. 29	11 A.M.	60	69	N.W.(cool)	9	Wind very cool. Showers in west. Biv. ovip. on S.F. 2 yds from rr.
Aug. 30	2 P.M.	57	75 (in sun)	N.W.	5	Wind very cold. 2 biv. ovip. on burned area on S. slope of grade.
	2.15P.M.	57	74 (65) (in sun)	N.W.	5	Biv. ovip. in durum stubble in shelter of old buildings.
Sept. 7	3 P.M.	62	68	S.W.	10	Biv. ovip. Fairly warm S.W. wind. Ground still moist from recent rain.
Sept. 10	4.50P.M.	62	70 when sun shining	N.W.(cool)	8	Biv. ovip.
Sept. 17						Biv. ovip.
Sept. 18						" "
Sept. 19						" "
Sept. 21						" "

4. Association where eggs are found.

The slope and the type of vegetation in which eggs were found was recorded during the egg survey in an attempt to show where grasshoppers prefer to lay their eggs.

As very few C. pellucida egg pods were found the data are very incomplete for this species. By examining the tables for vegetational and slope preferences of M. bivittatus for egg laying, in which the C. pellucida egg pods found are also tabulated, under each plot it will be found that C. pellucida shows a preference for pea, couch, timothy and brome sod and giant blue stem grass. The majority of these eggs were found in heavy sod where the grass was not more than three inches high.

In the case of M. bivittatus it will be observed from the table included under each plot that the order of preference was loose soil, timothy sod, giant blue stem, couch, brome and pea sod. It was evident in all cases that loose soil or drift soil was selected where possible for ovipositing by M. bivittatus, especially if there was an area which was open to the sun but protected from the wind by heavy vegetation of weeds. This is the reason eggs were found among orchard grass, rag weeds and pig weeds in quite large numbers in some cases.

Eggs of M. bivittatus were found in barley, durum, rye and corns stubble and along the edge of plowing and summer fallows. In the case of stubble fields it was found that the greatest concentration of eggs was in the first two rows of stubble along the outside edge of the field and that pods became fewer further in. M. bivittatus eggs were found in a garden, also, around weeds and among the potatoes. This was probably due to the protection offered by the foliage to the grasshoppers ovipositing in the bare, loose soil. Eggs were also found among French weed, spurge and knot weed.

5. Slope where eggs are found.

The data collected for the slope preferred by M. bivittatus for oviposition are presented under each plot in the table for vegetation and slope preferences of M. bivittatus for oviposition. A great deal of data were collected on this topic but in many cases it was found that the vegetation on the different slopes was not the same and, therefore, some of the selection may have been due primarily to the vegetation. By an examination of the tables under each plot it will be noticed that, in general, the south slope contains more eggs than the north slope or the level ground. It is not clear whether the north slope is preferred to the level or not but the data seem to

point to the level being preferred to the north slope. In the case of the east and west slopes, the evidence is not so convincing, although it supports the preference for the east slope most strongly. In one case only did the west slope contain a greater number of egg pods per square foot than the east slope and this west slope was very loose soil with weeds offering protection to the grasshoppers. These slopes were not compared with the level ground as to the eggs that they contained.

6. Type of soil where eggs are found.

It was observed during the egg survey that in many cases the soil within a mile would vary greatly in friability. It was found that one could have a good idea whether there would be any eggs or not in a sample as soon as the texture of the soil was tried. If the soil was loose and friable, eggs were generally found. On the other hand, if the soil was hard and clay-like, eggs were seldom found.

The most outstanding example of this was observed in the case of two cereo wheat fields, one on Sec. 35 and the other on Sec. 26, T. 3, R. 3E. The population was greater in the second field throughout the season but the egg infestation was much greater in the first. It was observed that the soil in the second field was much looser and more friable than in the first. On examining detailed soils map of this area, reproduced in Plate II, (J. H. Ellis, unpublished), it was found that the soil on Sec. 35 was McTavish Clay (low phase) while that on Sec. 26 was Osborne Clay, (P. 11). This difference may be due to the different soil associate and its treatment after breaking. A difference in organic content will produce this difference in friability between two clays.

This effect of a difference in friability on egg distribution was also noticed in the east roadallowance of Sec. 31, T. 3, R. 4E. This area has not been surveyed by Prof. Ellis, so the soil associate is not known. The soil along this mile was very hard and unfriable. Very few eggs were found although the M. bivittatus population was high throughout the season reaching 35 per square yard in some areas. It was found that, wherever the soil was loose, there was a heavy concentration of eggs, as for example, around ant hills. In the west half of the south roadallowance of this same section, although the population was about 5 per square yard during the egg laying season, very few eggs were found. In the east half mile on the south side of this roadallowance the living population was very little heavier at any time but the egg infestation was much more severe. The soil was much more friable in the east half mile than in the west. The soil along this mile had all been disturbed by the building of the graded road in

the spring of 1935. Much of the sub-soil was probably brought to the surface.

The type of ground, whether soft and powdery or hard and baked, has some effect on oviposition. The less friable soils contain fewer eggs than the friable soils. This friability may be due to a difference in the organic matter content. It may be due to a difference in the soil associate or to the methods of cultivation and crop rotation. With the assistance of the maps of the soil associates more interesting data on this subject will be collected next spring.

7. Relationship of egg infestation to adult population.

As a preliminary study of the egg infestation to be expected from a given adult population in July, August or for the season, ratios have been calculated as shown in the following table, (Table LXVII) for each detailed study plot and observational area and the averages taken.

Table LXVII
Relationship of egg infestation to adult population

Plot	Average adult pop. per square yard			Av. egg pods in Sept. per		No. pods to pop. of 1		
	July	Aug.	July 15-Sept.17	sq.ft.	sq.yd.	July	Aug.	July 15-Sept.17
I	13.1	10.3	11.1	0.99	8.91	0.68	0.87	0.8
II	14.04	11.77	13.0	3.85	34.65	2.47	2.94	2.66
III		12.4	8.32	1.14	10.26		0.83	1.23
IV		17.42	11.15	2.74	24.66		1.41	2.21
V	18.5	14.96	13.83	3.33	29.97	1.62	2.00	2.16
VI	13.6	11.24	10.87	2.17	19.53	1.43	1.73	1.79
VII(1)	9.42	10.3	9.15	1.13	10.17	1.08	0.99	1.11
(2)	15.0	12.7	12.25	1.42	12.78	0.85	1.60	1.04
VIII	12.2	9.36	8.64	2.16	19.44	1.59	2.08	2.25
Observational Areas								
I		15.16	12.24	1.62	14.58		0.96	1.19
II	14.87	14.93	12.89	1.2	10.8	0.73	0.72	0.84
III	2.37	3.45	2.60	0.24	2.16	0.91	0.62	0.83
IV	24.2	15.82	14.06	1.53	13.77	0.57	0.87	0.98
V	13.64	8.07	9.35	3.2	28.8	2.11	3.57	3.08
VI	13.6	12.12	8.3	3.12	28.08	2.07	2.32	3.38
Average						1.34	1.53	1.7
Minimum						0.57	0.62	0.8
Maximum						2.47	3.57	3.38
Probable error						0.298	0.316	0.342

The table shows an average ratio of the average population present in July to the egg pod infestation in September of 1: 1.34 with extremes of 1:0.57 and 1:2.47; for the average population in August of 1:1.53 with extremes of 1:0.62 and 1:3.57; and for the average population for the season of 1:1.7 with extremes of 1:0.8 and 1:3.38. These ratios have a statistical meaning as shown by the probable error calculated for each ratio by the Bessel formula (Wardle P.39, 1929). The probable error for the first ratio is plus or minus 0.298; for the second ratio is plus or minus 0.316; and for the third is plus or minus 0.342. Each of these is less than one-quarter of the uncorrected datum and the ratios are, therefore, significant for 1935 in the Arnaud area.

8. Egg Infestation.

As already pointed out C. pellucida laid very few eggs in the Arnaud area in 1935 although adult specimens were present. It is interesting to compare conditions in this area with those considered as typical C. pellucida habitats. Uvarov (1928) refers to Ball 1915 who described the breeding grounds of this species as dry, strongly alkaline places with scanty vegetation. The Arnaud area does not fit in with this description as the soil has a slightly acid A horizon with a pH of 6.70 (Ellis, unpublished). The soil is a meadow-prairie associate and has a tall, dense vegetation in ordinary seasons. Thus, the area would seem to be unsatisfactory to C. pellucida except in the dry years of grasshopper outbreaks when the vegetation may be less dense. Criddle (1923) characterized the areas chosen for egg laying by C. pellucida as uplands, generally, with a dryish aspect and with Agropyron smithii present as the chief attraction. This, likewise, does not correspond to the character of the Arnaud area. Although this area does not appear to be a typical breeding ground for C. pellucida, it does become infested in years of grasshopper outbreaks. This may be the reason for the paucity of eggs of this species in the fall of 1935 as the summer was very wet as compared to recent years.

M. bivittatus on the other hand, Criddle (1931) is "primarily an inhabitant of low lands and weedy or shrubby areas." (Criddle 1931 P.17). This description is adaptable to the Arnaud area. There were a large number of eggs of this species deposited in the Arnaud area in the fall of 1935.

The method used in the egg survey is described under "Methods" (P37). Under each plot the egg survey for the area is included in a table giving the details for the smaller division of the plot. In the following table the data for each plot as a whole are presented (Table LXVIII). The rating

of the different parts of the study areas are indicated in the map of infestation (Plate XL).

The rating of the infestation for each plot and for each section of the plot is calculated on the basis of the following table (Table LXVIII) adapted from that used by the U. S. Bureau of Entomology (14th. Rept. 1933 P.22). In the table used the egg pods required for a given infestation are divided by two to allow for the greater number of eggs present in M. bivittatus egg pods as compared to those of C. pellucida or M. mexicanus. The rating in each case is even then considered to be rather low. The area, by this rating, is placed in the "light" area but by the Manitoba classification should be placed at least in the "moderate" rating.

Table LXVIII
Number of egg pods which determine the rating of an infestation

Egg pods per square foot		
In fields	At field margins and roadsides	Rating
.125	1	normal
.187	1.5	light
.25	2.0	light
.375	6.0	moderate
.5	8.0	moderate
.75	12.0	heavy
1.0	16.0	heavy
1.5	24.0	very heavy
2.0	32.0	very heavy

Table LXIX

Summary of the Egg Infestation of the Detailed Study Plots.

Plot	Square foot samples examined with eggs	Square foot samples examined without eggs	Egg pods found	Av. pods per square foot	Rating
I					
Roadallowance	27	42	68B	0.99	normal
Fields	10	27	22B	0.59	moderate
II					
Roadallowance	46	50	369B + 1C	3.85	moderate
Fields	13	36	31B + 1C	0.65	moderate
III					
Roadallowance	36	46	94B + 1C	1.14	light
Fields	15	32	20B	0.43	moderate
IV					
Roadallowance	19	23	113B + 2C	3.58	moderate
Fields	2	12	2B	0.14	normal
V	11	19	39B + 13C	1.73	moderate
VI					
Roadallowance	33	25	117B + 9C	2.17	light
Fields	8	9	23B	1.35	heavy
VII					
Roadallowance	23	61	94B + 20C	0.89	normal
Fields	7	46	9B + 1C	0.19	light
VIII					
Roadallowance	48	29	197B + 10C	2.[illegible]9	light
Fields	11	18	20B + 2C	0.76	heavy

Table LXX

Summary of the Egg Infestation of the Observational Areas.

Observational Area	Square foot samples examined with eggs	Square foot samples examined without eggs	Egg pods found	Av. pods per square foot	Rating
I					
Roadallowance	39	34	116B	1.62	light
Fields	9	34	26B	0.60	moderate
II					
Roadallowance	36	61	117B + 20 + 1 nax. + 1?	1.2	normal
Fields	4	8	5B	0.415	moderate
Headlands	6	3	34B	3.78	moderate
III					
Roadallowance	8	36	12B + 1C	0.29	normal
Fields	1	13	1B	0.07	normal
IV					
Roadallowance	30	31	74B + 5C	1.29	light
Fields	8	12	12B + 1C	0.69	moderate
V					
Roadallowance	29	26	176B + 52C	3.2B + 0.94C	moderate
Fields	18	26	29B	0.66	moderate
VI					
Roadallowance	63	33	257B + 13C	3.12	light
Fields	12	23	29B	0.83	heavy

Plate XL

Map of rating of egg infestation for the Arnaud area.

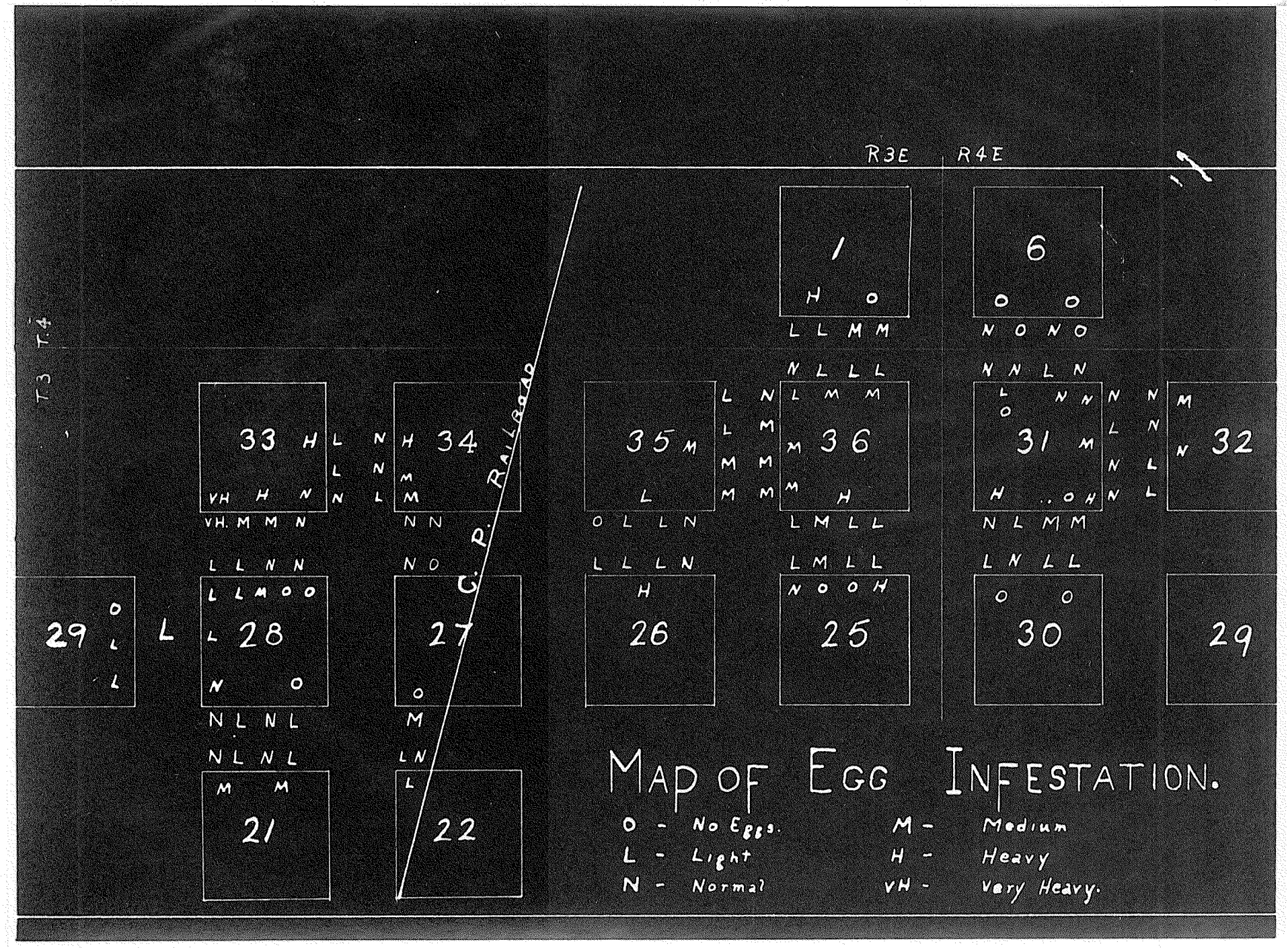

R3E
R4E
T3
T4
C. P. Railroad
MAP OF EGG INFESTATION.
O - No Eggs.
L - Light
N - Normal
M - Medium
H - Heavy
VH - Very Heavy.

Table LXXI
Summary of the Egg Infestation for the Arnaud Area

	Sq.ft. samples examined		Egg pods found	Av. pods per sq. ft.	Rating
	with pods	without pods			
R.all.	454	519	1869B + 128C	2.05	light
Fields	118	296	239B + 5C	0.565	moderate

X. PARASITES AND PREDATORS.

Once a week, at least, during the season 50 living specimens of C. pallucida and M. bivittatus were collected by sweeping with a net. The abdomen was pulled off and squeezed out and examined for internal parasites. No Sarcophagidae larvae were found in the Arnaud area during the study period. A farmer asked what kind of a worm would be likely to come out of a two-striped grasshopper if it were squeezed. Apparently, his son had squeezed one and a worm was found inside. This may have been a larva of a Sarcophagidae but probably was the Nematode, Mermis subnigrescens which is known to occur in grasshoppers in other parts of Manitoba. This farm was outside the study area and the investigator had no way to visit the territory. The Sarcophagidae larva that is known to occur in grasshoppers in Manitoba is Sarcophaga kellyi (Criddle 1931).

During the egg survey a large number of egg predators were found. These were blister beetle larvae, both the carotate and scarabaeiform stage, carabid larvae and adults, and bee fly larvae. In the spring of the year grasshopper egg predators were collected from the Arnaud area by Mr. H. H. Painter and Mr. H. W. Moore. These egg predators were reared by Mr. Moore and sent to Ottawa for identification. The carabid beetle was found to be Percosia obesa (Say), the blister beetle was Meloebasis subglabra Fall and the bee fly was Systoechus vulgaris Loew.

The carabid beetle, Percosia obesa, feeds on grasshopper eggs both in the adult and in the larval stages. Larvae were present in May and after August 15. Adults were observed throughout the study period from July 15 to September 21. The larvae are true predators going from one pod to another often completely destroying several egg pods. The ratio of carabid larvae to egg pods in the Arnaud area was 1:33.6. M. bivittatus egg pods

were more heavily infested than C. pellucida pods. The relationship of carabid larvae to egg pods is shown in Table LXXIII.

The blister beetle, Macrobasis subglabra, can be found in the larval stages inside the grasshopper egg pods. Blister beetles undergo a hypermetamorphosis. (Comstock 1925, P. 191). The triungulin, the carabeid, and the first and second scarabaeoid larvae feed on grasshopper eggs. The coarctate larva, in which it is generally believed to hibernate, does not feed but is a pseudopupal stage. The sixth larval stage is again active and is termed the scolytoid larva. This stage although active is not known to feed and changes into the pupa. In the Arnaud area the scarabaeoid stage, the coarctate and the pupa were present in May. In the fall the scarabaeoid and the coarctate stages were found. The coarctate stage was occasionally found inside the egg pod as well as in earthen cells adjacent to the egg pods. The adult beetles were observed at Hayfield, Manitoba on July 6 in white sweet clover. The ratio of egg predators to egg pods in the Arnaud area in the fall of 1935 was 1:11.5. M. bivittatus egg pods were again more heavily infested than those of C. pellucida. The ratio for the different plots is shown in Table LXXIII. During the egg survey, between September 9 and 21, the blister beetle larvae in the Arnaud area were 79 percent in the coarctate stage and the remainder were in the scarabaeoid stage. As it is doubtful whether the scolytoid larva feeds, the bulk of the damage to be done by this predator to the grasshopper eggs must have been completed by this time. The percentage of the blister beetles in the coarctate stage on the different plots is shown in Table LXXII.

Table LXXII
Stages of the Blister Beetle Larvae

Detailed Study Plot	Date survey made	Coarctate larvae	Scarabaeoid larvae	Percent in coarctate stage
I	Sept. 9	16	4	80.0
II	Sept. 9	31	7	81.8
III	Sept. 21	10	4	71.4
IV	Sept. 21	10	3	77.0
V	Sept. 16	2	3	40.0
VI	Sept. 12	17	5	77.27
VII	Sept. 12	9	0	100
VIII	Sept. 20	12	2	85.7
Obs. Areas				
I	Sept. 19	14	1	96.33
II	Sept. 15	6	0	100
III	Sept. 11	2	5	28.6
IV	Sept. 14	2	1	66.6
V	Sept. 14	21	4	84.0
VI	Sept. 21	10	4	71.43
Total		162	43	79.0

Table LXXIII

Ratio of Egg Predators to Egg Pods for the Different Plots and for the Entire Area

Detailed Study Plot	Sq. ft. Samples	Egg Pods	Blister beetle larvae Nos. found	Pods per predator	Bee flies Nos. found	Pods per predator	Carabids Nos. found	Pods per predator	Pods per predator
I	126	115B	20	5.75	4	28.7	5	23	4.22
II	139	466B + 3C	36	12.6	2	234	21	22.3	7.56
III	116	107B + 1C	14	7.7	1	108	12	9	4.0
IV	56	110B + 2C	13	8.6	11	10.2	5	20.4	3.8
V	26	39B + 13C	5	10.4	0		2	26	9.0
VI	70	140B + 9C	22	6.7	5	28.8	6	24.8	4.5
VII	171	61B + 20C	9	9	3	27	7	11.5	4.26
VIII	114	229B + 6C	14	16.3	4	57.5	7	32.8	9.16
Observational Areas									
I	108	144B	15	9.6	1	144	10	14.4	5.4
II	146	178B + 3C	6	29.7	0		2	89	2.6
III	48	13B + 1C	7	2	0		1	14	1.75
IV	64	57B + 5C	5	30.8	0		5	18.4	11.5
V	94	212B + 32C	25	10.6	0		10	26.4	7.54
VI	135	344B + 10C	14	25.3	4	88	7	50.6	14.16
For the area	1405	2237B + 134C	205	11.5	35	67.4	100	23.6	6.94

The bee fly, Systoechus vulgaris, also feeds on grasshopper eggs in its nymphal stages. In the fall of 1935 the ratio of bee fly larvae to egg pods was 1:67.4. The infestation of bee fly larvae was much smaller than that of blister beetle and curculid larvae. This may have been due to the scarcity of C. pellucida egg pods. Criddle (1923) found that "the larvae of bee flies were much more numerous in the egg-mass of Cnemula than in those of Melanoplus, while blister beetle larvae, on the other hand, showed a marked preference for the eggs of the latter genus." There was a large flight of adult bee flies observed on July 19 in the Arnaud area. The infestation of bee fly larvae on each plot is shown in Table LXXIII.

Red mites, Eutrombidium locustarum (Walsh), were present as nymphs on the grasshoppers in 1935, particularly on M. bivittatus, occupying their customary position between the wings. As far as is known, these mites do not do any particular harm to the grasshopper but it is certain that if a grasshopper has several of these mites between its wings it will not be able to close them properly and, therefore, they get broken and prevent the grasshopper from flying. It is suspected that they suck some of the body juices from their host but no apparent harm results. During the egg survey several M. bivittatus egg pods were found infested with adult mites. These mites had sucked the juice out of the eggs, destroying part, at least, of the egg pod. (Howard 1918).

Wireworms were found associated with the M. bivittatus egg pods. Of the sixteen wireworms found three were inside partly destroyed egg pods. The evidence pointed to the fact that they had been feeding on these egg pods.

It may be added that a species of red ant was also found around the egg pods in some cases. This may have been an accidental association as the soil around the ant hills is loose and M. bivittatus is known to like loose soil to lay its eggs. In several cases, both in 1935 and 1934, ants were found carrying off the freshly deposited eggs as soon as the female withdrew her abdomen from the ground.

There were very few birds in the study area and at no time was any wild bird found feeding on grasshoppers or their eggs. There were, however, several flocks of turkeys, owned by the farmers in this area, which fed almost entirely on grasshoppers. Several farmers said that they would not have had any gardens in 1934 if it had not been for their hens and turkeys keeping down the grasshoppers.

There was a striking absence of small mammals as well as of wild birds about Arnaud.

XI. DISEASE.

M. bivittatus in the Arnaud area seemed to be dying from two different diseases. The organism causing the first group to die was the fungus Empusa grylli Fr. and was definitely identified on dead specimens sent to Ottawa. Those that died of this fungus died in the characteristic attitude of grasshoppers suffering from this disease. That is, they were found clinging to the stems of plants and grasses with their fore legs and the hind legs spread apart in a very characteristic attitude. It is believed that they climb the plants because of a temperature or humidity tropism which is stimulated by the infection. C. pellucida also died to some extent of this disease. Those that died of the second disease were all M. bivittatus and they died on the ground. Specimens sent into Ottawa did not contain Empusa grylli. They did, however, contain other fungi and bacteria as follows:

Report received from Mr. Pinonin of the Division of Botany on December 19, 1935 on specimens of M. bivittatus sent in from Arnaud, Manitoba on August 15.

"Fungi observed by microscopical examination.
Penicillium brevicaule Saco.
Alternaria sp.

"Fungi isolated by plating.
Helminthosporium tetramera McKim.
Penicillium brevicaule Saco.
Aspergillus flavipes (Bain & Sart) Thom. & Church
Alternaria sp.
Monosporium sp.

"Bacteria.
1. Dirty yellow rod-shaped, motile
2. Chromogene - colonies, pink in colour
Penicillium brevicaule Saco. previously recorded as an insect parasite.

It is thus apparent that the grasshoppers that died on the ground did not die of Empusa grylli but of some other disease that has not been identified. Although the grasshoppers that die of Empusa grylli generally are found clinging to the stems of plants, it seems that this is not always the case. At Mayfield, Manitoba, in the spring of 1935 grasshoppers were found dead on the ground which were reported to be infected with Empusa grylli and in several incidences the conidiophores were observed by the author and Mr. W. R. Allen under the microscope. Later specimens were found dead up the stems of plants in the same area. It was believed that due to the cold wet weather

the second and third instar nymphs, which were found dead, were not active enough to climb the stems of plants even when infected by this fungus. Later, when the weather became warmer, dead were found up the stems of plants. In the Armaud area it was thought that those dying on the ground might also be dying of Empusa grylli. It was suspicioned that this was not true because in most cases where the grasshoppers were dying up the stems, none were found on the ground and vice versa but in a couple of cases, specimens were found dead on the ground and others up stems. It would seem that if they were dying of the same disease both types would be present in every case. The only reason why they would behave differently if they died of the same organism, would be because of different conditions as occurred at Hayfield. In some cases both types occurred under similar conditions. The examination and report by Mr. Timonin supports the fact that there were two different disease organisms attacking the M. bivittatus.

In an attempt to ascertain the rate of mortality due to each of these diseases, quadrats were marked out on which the dead were counted. These quadrats and the methods used are discussed under Detailed Study Plots I and III, and Observational Areas V and VI. There is a discussion of the disease present on the other plots under each plot also. Table LXXIV presents in summary form the extent of disease among the grasshoppers during the period from July 19 to September 21 in the Armaud area.

Table LXXIV

Summary of Occurrence of Disease on the Study Areas

Detailed Study Plot	Empusa grylli	Unidentified Disease
I	Mortality due to this fungus was very heavy on July 23. Maximum dead was 25 per sq. yd. Continued to a lesser extent throughout the season. All dead observed were M. bivittatus.	Quadrats established on Aug. 14. Daily mortality 3.46% of the living population.
II	Active to a small extent throughout the season. Both M. bivittatus and C. pellucida.	1st grasshopper in this found dead of this disease on Aug. 12 on this plot.
III	Quadrats established on Aug. 2 and on Aug. 22. Daily mortality was 2.23% of the population.	Not present.
IV	Very few dead found.	Very few observed.
V	3 to 9 per square yard on Sept. 7 and 8.	1 per sq. yd. on Aug. 21. More on Sept. 7.
VI	Dead in ditch and along the edge of the rye field throughout the season. July 24 5 dead per sq. yd. along the edge of the rye.	None observed.
VII	Very few.	None
VIII	To some extent.	None

Table LXXIV (Con'd)

Summary of Occurrence of Disease on the Study Areas

Observational Areas	Empusa grylli	Unidentified Disease
I	Abundant on Aug. 2 up the streams of oats 20 yards into the field. Present to some extent during the rest of the season.	None.
II	Abundant on July 13. No more until Aug. 21. C. rail. also attacked. Still present Sept. 16.	Evident between Aug. 10 and 21 in large numbers. Still evident on Sept. 16.
III	A few on Aug. 15 and on Aug. 29.	None.
IV	Present on July 23. A few on Aug. 21.	None.
V	Large number on Aug. 15. Large number on Sept. 7 and 8, 3 per sq. yd. with a maximum of 9.	Large number Aug. 15. Aug. 21, 8 per sq. yd. in ditch and 12 per sq. yd. along the edge of the fields. Sept. 7 and 8, - a few.
VI	Aug. 22.- 2 M. bivittatus dead.	Aug. 12.- large number dead. Aug. 22.- 10 per sq. yd. along edge of sweet clover field and 6 per sq. yd. along the edge of the ditch. Quadrats marked out on Aug. 22. Daily mortality was 3.04% of the living population.

XII. SUMMARY.

1. The intensive study area at Arnaud is intended to be a long term project, the object of which is "to determine the biological and environmental factors which cause extensive fluctuations in grasshopper populations, with the practical end in view of being able to predict or prevent grasshopper outbreaks."

2. According to Uvarov's phase theory locusts undergo transition from a solitary to a migratory phase under suitable conditions. Rubtzov has shown that non-swarming grasshoppers show smaller but wholly analagous changes to those of locusts. Criddle has shown that similar changes take place in Manitoba grasshoppers.

3. Uvarov in his reservation theory divides the locust infested areas into "reservations" (or breeding centres) and "invasion areas". It is thought that the Arnaud area may be a "breeding centre".

4. Even if Arnaud is not a "breeding centre" very valuable data will be collected on the biological and environmental factors affecting grasshopper abundance.

5. The only work done along this line, except that of Uvarov and his co-workers on locusts, has been done by Parker and Shotwell in the United States and by Buckell in British Columbia. None of this work has been published.

6. The objects of the study at Arnaud are to start the work on the long term project, to graph the population for the season, to gather phenological, meteorological and seasonal data for the different nymphal and the adult stages; to make an egg survey to forecast the number of grasshoppers expected the following year, to check the accuracy of this forecast and to determine the destruction of the eggs to parasites, predators and weather conditions, in the spring; to determine the effect of different bordering crops and the treatment of these crops on the grasshopper population; to determine the environment and plant associations preferred by the various species of grasshoppers during their different stages of development; to determine the differences in behavior of the various grasshoppers, especially M. bivittatus and C. pellucida; to estimate at different seasons the damage done to crops, gardens and native vegetation by grasshoppers; to determine to what extent the grasshoppers are diseased and parasitized and to determine the rate of mortality due to these causes. As well as the above objects it was also the aim of the study this year to determine the area

that one man could study in a project of this type and to test out the methods suggested and improve on them, if possible.

7. The Arnaud area was chosen because it has been severely infested with grasshoppers from 1931 to 1935 and there are records of infestation in the years prior to 1931. The area is also representative of conditions of a large portion of the Red River Valley.

8. Arnaud is situated in the Red River Valley which is the bed of glacial Lake Agassiz. The area is a very flat plain with an altitude of 794 feet and a gradual fall to the west of 0.43 feet per mile and to the north of 0.07 per mile.

9. The soil was formed from the fine lacustrine sediments deposited in the lake. The Red River Valley is in the soil zone of the black earth and is of the "Red River Combination". The soil is McTavish clay, a phytohydromorphic associate of Red River Clay with Osborne Clay, a hydromorphic associate in the more poorly drained areas. There is also an intermediate soil associate present termed McTavish Clay (low phase).

10. The native vegetation is a tall prairie associate with groves of poplar and willow. The dominant plants are giant blue stem, slough grass, prairie blue grass, aster, golden-rod, sage and roses. This vegetation has been much disturbed by cultivation and only remnants exist of the native vegetation along the roadallowance. It is supplemented by weeds, dandelion, false rag weed, lamb's quarter and red root pig weed and others.

11. The most important grasshoppers were M. bivittatus and C. pellucida. The egg predators were bee fly larvae (Systoechus vulgaris), blister beetle larvae (Nemobaenis subglabra), and carabid beetle larvae (Pterostia obesa). Mites (Entrombidium locustarum), ants and wireworms were also found feeding on the egg pods. The fungus Empusa grylli was killing off M. bivittatus and to a lesser extent C. pellucida. A second disease was not identified.

12. The study of the effect of climate on grasshoppers is a long term project. Some data are presented regarding the effect of weather on the activity of grasshoppers and are presented under the sections on oviposition, flights and as general observations under the study plots.

13. Climate is recognized as a predominant factor in the study of grasshopper periodicity and control. Criddle attempted to correlate grasshopper and locust outbreaks with sunspot and weather cycles. In recent years it has been found that climatic boundaries correspond to some extent with those of "reservations".

14. A weather shelter was erected and observations made which are presented in tables and graphs as maximum, minimum, mean and range of temperature and humidity. The rainfall is presented in inches. The wind and sunshine records are also tabulated. A summary of the temperature and rainfall data for the Morris meteorological station is given. A continuous hygrothermograph record was kept.

15. Eight detailed study plots and six observational areas were selected and divided into two trips each of which was covered twice a week. The average population per square yard was estimated by walking over the area. General observations were made on the maturity, distribution, mortality, flights and temperature reactions of the grasshoppers. In the fall an egg survey was made during which a record was kept of the number of egg pods per square foot, the locations in which they were found and the predators present.

16. The detailed study plots were selected because of the grasshoppers present, the plant communities represented, the direction of the roadallowance, the neighboring crops, disease and proximity to the daily route of travel. The observational areas were on the route of travel between the plots.

17. The vegetation on each detailed study plot and on each observational area has been described in detail for locations indicated on the maps by Roman numerals. The grasshopper population has been described and the average population per square yard graphed. The following topics have been dealt with, disease, egg survey and predators. The graph of the trend of population has been discussed and the reasons given for the fluctuations. Each plot has been summarized and the conclusions drawn.

18. The seasonal life history of the population has been recorded from July 17 to September 21 with the dates of occurrences of nymphs, adults, oviposition and flights.

19. The plant associations which C. pellucida and M. bivittatus preferred and the differences between these species are given together with the damage to native vegetation, crops and gardens.

20. Conditions under which M. bivittatus and C. pellucida were observed ovipositing and the habitats in which they prefer to lay their eggs, determined from the egg survey, are recorded.

21. The egg infestation for each plot is dealt with and is summarized for the area in a table and on a general map. The ratios of the adult population in July, August and for the study period, to the number of egg pods deposited are tabulated for the plots and calculated for the area.

22. The ratio of the different predators to the number of egg pods is calculated for each plot and for the area from the results of the egg survey.

23. The fungus Empusa grylli and a second disease which has not been identified were encountered. Three different quadrat methods for determining the mortality due to disease with the results obtained are described. The frequency of disease is summarized for the area in a table including each plot.

XII. CONCLUSIONS.

1. Armaud may be a permanent breeding area for M. bivittatus but it is doubtful if this will be the case for C. pellucida.

2. Intensive study areas will enable us to forecast grasshopper outbreaks and to determine the factors which cause fluctuations in grasshopper populations.

3. Conditions in the Armaud area are representative of the Red River Valley.

4. The soil of the Armaud area is a meadow-prairie associate and has been developed from fine lacustrine sediments. The modification of these clays may have an influence on grasshopper distribution.

5. The native vegetation is a tall-prairie formation. Modification and disturbance by cultivation and pasturage have created conditions favorable to grasshoppers.

6. M. bivittatus and C. pellucida were the major species of grasshoppers present with a significant number of M. femur-rubrum and M. dawsoni with a few M. mexicanus and other species.

7. The following meteorological data should be kept on an intensive study area: (a) Rainfall, (b) Standard air temperature, (c) Standard soil temperature, (d) Soil temperature at one inch, (e) Maximum and minimum air temperatures, (f) A continuous hygrothermograph record, (g) Hours of sunshine. A record of the velocity and direction of the wind and a record of the rate of evaporation would also be of value.

8. It was found that detailed information for an area of eight square miles could best be obtainedby the selection and intensive study of small representative areas supplemented by scouting. Observational areas on which population estimates are made may be selected on the route of travel between the detailed plots.

9. The most satisfactory methods of recording the population of an area is to estimate the population observed for small areas and average the results.

10. The use of a large number of quadrats, a yard square in area, is satisfactory for studying the mortality due to the unidentified disease from which the grasshoppers die on the ground but it is necessary to make counts at least once every day.

11. In the study of the mortality due to Empusa grylli the most satisfactory method is to take large quadrats, several square yards in area, and mark the plants by means of a piece of gauze for each dead grasshopper clinging to them. The quadrats should be visited every day and counts made.

12. For an intensive egg survey of a mile of roadallowance it is believed that, at least, a hundred and fifty square foot samples should be made in representative locations on the roadallowance and in the adjoining fields.

13. On July 18 C. pellucida was 85 percent mature and was present in stages from the second instar to the adult. By August 1 they were 100 percent adult.

14. On July 18 M. bivittatus was 70 and 75 percent mature and was present in stages from the second nymphal to the adult. In most locations this species was mature by August 15. Second and third instar M. bivittatus were last observed on August10 and the last fourth on September 5. Fifth instar nymphs were still present on September 21.

15. Adults of M. bivittatus and C. pellucida were present in the Arnaud area on July 18 and were still present in reduced numbers on September 21.

16. In 1935 in this area M. bivittatus began to oviposit on July 25 and continued to do so until after September 21. C. pellucida began on July 30 but laid very few eggs as the ovaries did not mature in most cases.

17. Twelve minor flights of grasshoppers occurred between July 27 and September 16. They all took place shortly after a rain.

18. Grasshoppers in 1935, in some cases, but not all, moved into the stubble one or two days after the crops were cut and fed on the green weeds present, then moved back onto the roadallowances after August 23 apparently for protection from the strong winds and the rain. At this time there was also a movement into the gardens where they did considerable damage.

19. C. pellucida was found where there was a thick sod of Poa compressa, Phleum pratense, Bromus inermis or Andropogon furcatus.

20. M. bivittatus was present in all types of native vegetation in the Arnaud area and in fields of flax, barley, rye, durum wheat, thatcher wheat, ceres wheat, oats, sweet clover and corn. They were also found in the gardens feeding on beans, corn, sunflowers, beets, potatoes, onions and nasturtiums.

21. C. pellucida is more sensitive to temperature, wind, cloudiness and rainfall than is M. bivittatus.

22. It was indicated that M. bivittatus and C. pellucida cease activity at air temperatures above 92° F. in the shade if the soil temperature is above 98° F.

23. There was very little damage done to the native vegetation along the roadallowance in 1935 as the frequent rains permitted it to grow faster than the grasshoppers could consume it.

24. The damage done to crops in the Arnaud area was not great in 1935 but marginal feeding was evident in most cases. Most of the damage after July 15 occurred just before cutting and after stooking, especially in the case of rye, barley, oats and flax. The general damage to crops due to grasshoppers was about 10 percent.

25. Oviposition becomes general for M. bivittatus at air temperatures above 70° F. with soil temperatures above 70° F. and with the sun shining to some extent at least. It was indicated that oviposition ceases at high temperatures. Oviposition will take place at temperatures below 70° F.

26. M. bivittatus will oviposit in wet soil after a rain if the weather conditions are suitable. Concentrations of eggs were found in areas where the vegetation had been burned. M. bivittatus were observed ovipositing in cinders, gravel and in cracks in planks and railroad ties filled with gravel or earth.

27. The majority of the C. pellucida eggs were found in poa, couch, timothy, brome and giant blue stem sod.

28. M. bivittatus shows a preference for loose soil for ovipositing, especially when it is an area open to the sunshine but protected by weeds and grasses, and for the following types

of vegetation, in order of preference, timothy sod, giant blue stem, couch, brome and poa sod. McTavish Clay is of a looser texture than McTavish Clay (low phase) or Osborne Clay and more eggs were found where it was present. A preference was also shown for south and east slopes.

29. The ratio of the average population for July to the egg pods found in September was 1:1.34 with extremes of 1:0.57 and 1:2.47; that for the popul tion in August was 1:1.53 with extremes of 1:0.62 and 1:3.57; and that for the average population for the season from July 22 to September 14 was 1:1.7 with extremes of 1:0.8 and 1:3.38.

30. The egg survey shows the Arnaud area to be in the "light" area by the United States ratings but by the Manitoba rating should, at least, be in the "moderate" category of infestation for 1936.

31. Sarcophagidae and Nematode parasites were not present in the Arnaud area in 1935.

32. The ratio of blister beetle larvae (Macrobasis subglabra) to egg pods was 1:11.5; that for carabid larvae (Pterostichus obtusa) was 1:23.6; and that for bee fly larvae (Systoechus vulgaris) was 1:67.4. The ratio of egg predators to egg pods for the area was 1:6.94.

33. 79 percent of the blister beetle larvae were in the coarctate stage by September and, therefore, most of their damage to the eggs must have been completed. The red mite, Entrombidium locustarum, was commonly found as nymphs on adult grasshoppers and as adults feeding on a few egg pods. Wireworms and ants were also suspected of being egg predators. Birds and small mammals which commonly feed on grasshoppers and their eggs were absent. Turkeys and chickens were helpful in many cases in preventing grasshopper damage to gardens.

34. Empusa grylli Fr. was the most important factor in reducing the grasshopper population but in quadrats established to study the disease, the daily mortality was found to be quite low. This was because the disease occurred in restricted areas of high mortality whichshifted before quadrats could be established. In one location where this disease was first observed a maximum of 25 dead per square yard was found where the living population was 25 per square yard. This disease attacked both M. bivittatus and C. pellucida.

35. An unidentified disease was encountered which caused M. bivittatus to die on the ground. The effect of this disease was first observed on August 12 and it was still active on September 18. The daily mortality determined by the quadrat method was 3.04 percent of the living popul tion but at the time of establishment 10 dead were found per square yard where the living popul tion was 35 per square yard.

XIV. ACKNOWLEDGEMENTS.

The writer wishes to take this opportunity to express his sincere thanks to Prof. R. A. Wardle, of the Zoology Department of the University of Manitoba, for his interest and direction in his M. Sc. studies.

The author gratefully expresses indebtedness to the Entomological Branch Grasshopper Research Committee, consisting of E. H. Buckell (ch.), H. L. Seamans, K. M. King, E. D. Bird co-operated with by J. H. Parker and R. L. Shotwell, of the U. S. Bureau of Entomology, and assisted by Mr. H. G. Crawford, Chief of the Division of Field Crop and Garden Insects, Entomological Branch, Department of Agriculture, which drew up the research project outline for the Intensive Study Areas, at the Lethbridge meeting in April, 1935, which has been followed as a basis for this study.

The author is greatly indebted to Dr. A. Gibson, Dominion Entomologist, who has released the paper for thesis purposes, through the recommendation of Mr. H. G. Crawford, who had read the paper and followed the work with interest.

Grateful acknowledgement must be paid to Dr. E. E. Bird, Entomologist in charge of the Dominion Entomological Laboratory, at Brandon, Manitoba, under whose direction the data presented in this paper were gathered. He also photographed the representative parts of the study plots and helped very materially with the printing of the maps and graphs. His assistance in the preparation of the paper is also gratefully acknowledged.

Mr. R. H. Handford, of the Brandon Entomological Laboratory, has also been of great assistance in discussing the work and offering many helpful suggestions.

The writer also desires to acknowledge the aid given by Prof. J. H. Ellis, Soils Division, Department of Agronomy, University of Manitoba, for his great assistance with the sections on geology and soils and the use of unpublished data and maps; Prof. C. W. Lowe, Botany Department, University of Manitoba, for the identification of plants; and also by Prof. A. V. Mitchener, Department of Entomology, University of Manitoba, for his liberal loan of literature.

Eumasa crylli and other organisms found in specimens of dead grasshoppers were identified by Mr. Timonin, assistant under Dr. Gussow, Chief of the Division of Botany.

The reared predators were identified by Mr. W. Brown, Systematic Division of the Entomological Branch.

Assistance in the history of the Arnaud area and a general discussion of the Red River Valley was received from Mr. H. E. Wood, Extension Department of the Manitoba Government.

The maps of the study plots and of crops were redrawn by Mr. R. Cunningham. Thanks are also given to the many friends and the parents of the author for helpful suggestions.

XV. BIBLIOGRAPHY.

REFERENCES

Bird R. D. 1927 - A Preliminary Ecological Survey of the District Surrounding the Entomological Station at Treesbank, Manitoba. Ecology, Vol. VIII, No. 2, April 1927.

Bird R. D. 1939 - Biotic Communities of the Aspen Parkland of Central Canada. Ecology, Vol. XI, No. 2, Pages 356-442.

Buckell E. R. 1921 - Influence of Locusts on the Ranges of British Columbia. Rept. Ent. Soc. Ont. 1921, P. 23.

Buckell E. R. 1935 - First Report of the Canadian Committee on Grasshopper Research. March 1935. (Typed).

Clements F. E. 1926 - Plant Successions and Indicators. H. W. Wilson Co. New York City, 1926.

Comstock J. H. 1925 - An Introduction to Entomology. The Comstock Publishing Co. Ithaca, N. Y. 1925.

Criddle N. 1923 - Some Phases of the Present Locust Outbreak in Manitoba. Ann. Rept. Ent. Soc. Ont. 54:19-23.

Criddle N. 1925 - Summary Report. Treesbank Laboratory. 1925.

Criddle N. 1931 - Grasshopper Control in Canada East of the Rocky Mountains. Dom. of Canada Department of Agriculture. Bull. 143 New Series.

Criddle N. 1932 - The Correlation of Sunspot Periodicity with Grasshopper Fluctuations in Manitoba. Can. Field Naturalist. Vol. XLVI, No. 9.

Criddle N. 1933 - Notes on the Habits of Injurious Grasshoppers in Manitoba. Can. Ent. 65: 97-102, May 1933.

Criddle N. 1933 b - Studies in the Biology of North American Acrididae Development and Habit. Grain Exhibition and Conference. Regina 1933. Vol. II.

de Gryse J. J. 1932 - Technique and Methods in the Study of Climatic Factors in Connection with Biological Investigations. 23rd and 24th Ann. Rept. Quebec Soc. for the Protection of Plants, 1930-32.

Ellis J. H. 1935 - Soil Types Occurring in the Red River Valley Plain. Scientific Agriculture 15:5, Jan. 1935.

Ellis J. H. (unpub.) - Unpublished data on the soil types occurring in the Red River Valley Plain.

Elton Charles 1927 - Animal Ecology. MacMillan Co., New York, 1927.

Faure J. C. 1932 - The Phases of Locusts in South Africa. Bull. Ent. Res. Vol. XXIII, pt. 3, Sept. 1932.

Faure J. C. 1933 - The Phases of the Rocky Mountain Locust (M. mexicanus (Saus.)) J. Econ. Ent. 26:3:706.

Gray 1908 - Gray's Handbook of the Flowering Plants and Ferns of the Central and Northeastern United States and Adjacent Canada. Re-arranged and revised by B. L. Robinson and M. L. Fernald. American Book Co. 1908.

Gray H. E. 1929 - Construction of a Psychrometer for Small Spaces. Ecology X:3:355.

Hayes and McCulloch 1922 - Reciprocal Relation of Soil and Insects. Ecol. Vol. III, No. 4, 1922.

Hebard M. 1925 - Orthoptera of South Dakota. Proc. of Acad. of Nat. Sciences Phil.P. 122, 1925.

Hebard M. 1928 - Orthoptera of Montana. Proc. of Acad. of Nat. Sciences of Philadelphia, 80: 1928.

Hebard M. 1932 - The Orthoptera of Minnesota. Tech. Bull. 85, Univ. of Minn. Agric. Exp. Sta.

Howard C. W. 1915 - A Preliminary Report on the Trombidiidae of Minn. 17th Ann. Rept. State Entomologist of Minn. 1915.

Jackson V. W. 1924 - A Standard Method of Plant Survey for Agricultural Forecast. Sc. Agric. IV: 11, p. 352. July 1924.

Jackson V. W. 1924 - Vegetational Succession in the Red River Basin. Sc. Agric. IV:10 p. 301.

Johnston W. A. 1934 - Surface Deposits and Ground Water Supply of the Winnipeg Map Area, Manitoba. Geol. Survey, Dept. of Mines. Memoir 174, Ottawa 1934.

Lethbridge Report 1935 - Report of the Canadian Committee on Grasshopper Research, March, 1935.

Macoun J. 1882 - Manitoba and the Great North West. World Publishing Co. Guelph Ont. 1882.

Marvin C. F. 1915 - Psychrometric Tables. U.S.D.A. Weather Bureau.

McMartin 1935 - The Locust Fungus. Its Artificial Cultivation. S. Afrian Sugar Journ. 18:7: p. 521-523. Rev. Appl. Ent. 23:4:161, 1935.

McMartin A. 1935 - Locust Research at Exp. Sta. - Exp. with Empusa grylli. S. Afrian Sugar Journ. 18:11:649-651. Rev. Appl. Ent. 23:6: p. 278, 1935.

Mitchener A. V. 1933 - Grasshoppers and their Control in Manitoba. Rept. World Grain Conference and Exhibition, Regina 1933, Vol. II.

Parker J. R. 1925 - Grasshopper Migrations and Modifications. (Rev. of Uvarov, 1923) Ecology 6: p. 455-459.

Parker J. R. 1926 - Some Effects of Temperature and Moisture upon the Action of Grasshoppers and Their Relation to Grasshopper Abundance and Control. International Congress of Entomologists. Ithaca, N.Y. August 1925: Vol. II.

Parker J. R. 1930 - Some Effects of Temperature and Moisture upon Melanoplus mexicanus Saussure, and Camnula pellucida Scudder. Bull. 223, Univ. Montana, Agric. Exp. Sta. Bozeman, Montana.

Pickett A. D. 1935 - Some Observations of an Outbreak of the Two-striped Grasshopper (M. bivittatus Say) in Nova Scotia. Canadian Entomologist 67:2:24-27. Orillia 1935. Rev. Appl. Ent. 23:6:285, 1935.

Riley C. V., Packard, Jr. A. S., Thomas Cyrus 1877 - First Annual Report of the U. S. Entomological Commission for the Year 1877 Relating to the Rocky Mountain Locust, Washington, 1877.

Rubtsov I. A. 1933 - Estimates by Sweeping. Plant Protection No. 1, 1932, P. 69-80. (in Russian) Leningrad, 1932. Rev. Appl. Ent. 21:2: 51-52, 1933.

Rubtsov I. A. 1935 - Phase Variation in Non-swarming Grasshoppers. Bull. Ent. Res. 26;4:499.

Tansley A. G. & Chipp T. F. 1926 - Aims and Methods in the Study of Vegetation. Br. Empire Veg. Comm. and Crown Agents for the Colonies. London, 1926.

Treherne R. C. & Buckell E. R. 1924 - The Grasshoppers of British Columbia with Particular Reference to the Influence of Injurious Species on the Range Lands of the Province. Circ. 25, Ent. Br., Dom. Dept. of Agric.

Upham Warren 1895 - The Glacial Lake Agassiz. U.S. Geol. Survey. Wash. 1895. Vol. XXV.

Uvarov B. P. 1921 - A Revision of the Genus Locusta L. with a New Theory as to the Periodicity and Migrations of Locusts. Bull. Ent. Res. XII, pp. 135-163, 1921.

Uvarov B. P. 1928 - Locusts and Grasshoppers. Imperial Bur. of Ent. London 1928.

Uvarov B. P. 1929 - Phases of Locusts and Their Interrelation. Bull. Ent. Res. XX, pt. 3, p. 261, 1929.

Uvarov B. P. 1932 - Ecological Studies on the Moroccan Locust in Western Anatolia. Bull. Ent. Res. XXIII, pt. 2, p. 273, 1932.

Uvarov B. P. 1933 - Ecology of the Moroccan Locust in Iraq and Syria and the Prevention of its Outbreaks. Bull. Ent. Res. XXIV, pt. 3, P. 407, 1933.

Uvarov B. P. 1934 - Locust Problem in Africa. Pub. 1934. Reprinted from "African Affairs Report." for 1933, Vol. V. (in French).

Wardle R. A. 1929 - The Problems of Applied Entomology. Manchester University Press, 1929.

Weaver & Clements 1929 - Plant Ecology. McGraw Hill, 1929.