

AN ECOLOGICAL STUDY OF Melanoplus
mexicanus mexicanus (Saunders)

BY

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AN ECOLOGICAL STUDY OF *Melanoplus*
mexicanus mexicanus (Saussure)

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AN ECOLOGICAL STUDY OF Melanoplus
mexicanus mexicanus (Saussure)

The Lyleton study area was established in Manitoba by the Entomological Branch of the Dominion Department of Agriculture in 1936 as a long-term project on the study of economic grasshoppers.

Prof. Spencer's statement (Leth. Rept. 1935) sums up the status of the grasshopper to date. "For five thousand years at least, Man has grumbled at and suffered from the ravages of grasshoppers, we are not yet attacking the problem in a logical way. The recent devastating outbreaks in central Canada and the United States have resulted in a resumption of the usual frantic application of last-minute measures of control. With the exception perhaps of Parker's researches, very little close study has been directed to the biology of grasshoppers in the field since Riley's classical work . . .". Uvarov (1928) despairing the lack of knowledge of the causes of periodic outbreaks of solitary grasshoppers said, ". . . the only hope of finding the actual causes of mass outbreaks lies in detailed studies of the natural balance between the numbers of grasshoppers and their enemies in connection with the fluctuations of ecological conditions". The characteristic feature of grasshopper outbreaks as compared with locust outbreaks he considers to be the gradual increase and decrease of population. The gradual decrease he attributes to the activities of natural enemies while sudden decline of population is practically always the result of fungous diseases. Regarding future studies of grasshopper abundance Uvarov (1928) states, "Studies in the periodicity of grasshoppers must consist in the first place in a careful research into their ecology, particularly the influence of external conditions on their development . . .". "This can most profitably be done by field studies on ecology and numerical balance of grasshoppers and their enemies over a sufficiently long period of years."

The Canadian Grasshopper Research Committee meeting at Lethbridge (Leth. Rept. 1935) tabled a comprehensive plan, "A Detailed Outline for the Intensive Study of Economic Grasshoppers in Typical Environments Where Previous Extensive Outbreaks Have Been Known to Occur" which had as an objective "the determination of the biological and environmental factors which cause extensive fluctuations in grasshopper populations, with the practical end in view of being able to predict and prevent grasshopper outbreaks". The Arnaud study area, commenced in 1935, was the first study initiated towards the above objective and Moore (1935) has reviewed the development of the conception of grasshopper study areas.

It has not been possible to carry on in its entirety the study of economic grasshoppers mentioned above on either study areas but the fluctuations of grasshoppers in relation to physical factors and to some extent in relation to biological and environmental factors has been attempted. The results of two years' work at Lyleton principally on Melanoplus mexicanus mexicanus (Gauss.) are here presented.

II. GENERAL DESCRIPTION OF THE LYLETON AREA

1. Geology

(1) Glacial lakes.-- During the Pleistocene epoch Manitoba was covered by the last continental ice sheet, which upon recession formed two large glacial lakes, Lake Souris covering the southwest portion of the province, and Lake Agassiz the eastern part. These lakes were separated by two terminal moraines. Lake Brandon was formed later than Lake Souris and arose between the larger lakes, finally emptying into Lake Agassiz. (Upham 1889).

At first, drainage from Lake Souris was southward by the Souris river, thence eastward in North Dakota by the Sheyenne and James rivers to the south end of Lake Agassiz. Further recession of the ice sheet permitted effluence southeastwardly by way of Lang's valley, Pelican lake and Pembina river to

Lake Agassiz. A deeply eroded valley today marks this path of egression through the moraines (Upham 1889). The last outlet of Lake Souris occurred in the vicinity of the present city of Brandon. The Assiniboine river eroded a channel about 15 miles wide as it entered Brandon.

(2) Deltas deposited by the Assiniboine.

In Saskatchewan a glacial lake extended northeastward from the basin of the south Saskatchewan. Concerning the egression of this lake by way of the Qu'Appelle valley, Upham (1889) says: "The outflow of the Saskatchewan glacial lake, fed by the melting ice fields of an immense area reaching west to the Rocky mountains, took its course east by this trough-like channel or valley, entering the Assiniboine at Ft. Ellice (Lazare) and reaching the border of Lake Agassiz at Brandon". Where the Assiniboine entered Lake Souris a large delta was built of fine, clayey silt and sand. It covers the country from Griswold, Oak Lake and Virden south to Hartney and Lauder (Plate I).

Another important delta of the Assiniboine was formed where it entered Lake Agassiz. Wallace describes it as "... extending eastward from Brandon 75 miles to Portage la Prairie, northeastward 50 miles to Gladstone and east southeastwards 80 miles into the Boyne (Morris) river valley. The sand deposited in this delta has now been to a large extent reasserted as sand dunes."

(3) The Lake Souris basin.— The glacial Souris river valley forms the bottom of Lake Souris basin. From an elevation of 1,400 feet at the international border, the valley slopes to an altitude of 1,300 feet 50 miles north. Rushing waters eroded a valley 100 feet or so below the general level of the terrain. The banks of glacial river Souris are abrupt. The valley is three-quarters to a mile in width. The present Souris river, 20 to 30 yards wide, courses the level valley, running northeastward to join the Assiniboine.

The position of the Souris river and Lake Souris basin is shown in plates I and II. The edges of Lake Souris basin rise a little above the 1,500 foot contour.

PLATE I

The glacial lakes and rivers of egression.
Photographed from Geological Survey, Memoir
174.



MAP 254A
Surface Deposits

WINNIPEG SHEET MANITOBA

Scale, 1 inch to 10 Miles

PLATE II

The Lake Souris basin. Reproduced by permission of J. H. Ellis from an unpublished map of the land classification of southwestern Manitoba.

ASPEN GROVE OR PARK

RESTON
Oxbow medium heavy loam
 Clay loam soils of mixed type developed on till with undulating topography with numerous basin-like depressions or aspen ringed swales. Sometimes stony and fields spotted with non-arable depressions well-water limited locally. Trees occasionally killed by drought in the south. Some eroded knolls.

DELAU
 Imperfect. Generally good agricultural land
 (b) Souris loamy sands
 Sands to loamy sands with much subsoil of inferior agricultural value except where texture is better than average
 Difficultly broken due to sandy texture

WINNAD
 (a) Dunes and wet sands
 Not suitable for general agriculture. Maybe utilized for forestry wet areas adapted to range and hay land

DELAU
 (c) Souris fine sands
 Light textured soils of fair agricultural value. Drifts badly unless under cover, protection

LAKE SOURIS BASIN

TILSON
 (f) Best Gravely subsoil
 Coarse textured over gravelly subsoil. Not suitable to general agriculture. May be utilized as range land

BERNICE
 (f) Souris loamy fine sands
 (g) Sandy, good ag. land, but modified drift sand sand

DELAU
 (e) Souris heavy fine loams
 Medium fine loams with smooth topography excellent general agricultural land. Subsoil moderately moist. Soil requires careful handling to prevent drifting

LAKE SOURIS BASIN

RESTON
 (f) Souris
 Sandy loams to fine loams
 Formerly good agricultural soils but on large areas severely injured by soil drifting. Requires careful farming. Subsoils are moist to northern portion and they thrive. Could be made good mixed-farming land
 Chief problem is soil drifting

BERNICE
 (f) Souris loamy fine sands
 (g) Sandy, good ag. land, but modified drift sand sand

DELAU
 (e) Souris heavy fine loams
 Medium fine loams with smooth topography excellent general agricultural land. Subsoil moderately moist. Soil requires careful handling to prevent drifting

TILL PLAIN

WINNAD
 (b) Good agricultural land fairly heavy on river banks
 Mixed sandy loams single and modified drift, often with thin strata of gravel, silt, and clay
 Sometimes more or less stony
 Surface texture variable
 Fairly good agricultural land, but subject to periodic drought

BERNICE
 (f) Souris loamy fine sands
 (g) Sandy, good ag. land, but modified drift sand sand

DELAU
 (e) Souris heavy fine loams
 Medium fine loams with smooth topography excellent general agricultural land. Subsoil moderately moist. Soil requires careful handling to prevent drifting

Rolling slopes

WINNAD
 (b) Good agricultural land fairly heavy on river banks
 Mixed sandy loams single and modified drift, often with thin strata of gravel, silt, and clay
 Sometimes more or less stony
 Surface texture variable
 Fairly good agricultural land, but subject to periodic drought

BERNICE
 (f) Souris loamy fine sands
 (g) Sandy, good ag. land, but modified drift sand sand

DELAU
 (e) Souris heavy fine loams
 Medium fine loams with smooth topography excellent general agricultural land. Subsoil moderately moist. Soil requires careful handling to prevent drifting

Level phase

WINNAD
 (b) Good agricultural land fairly heavy on river banks
 Mixed sandy loams single and modified drift, often with thin strata of gravel, silt, and clay
 Sometimes more or less stony
 Surface texture variable
 Fairly good agricultural land, but subject to periodic drought

BERNICE
 (f) Souris loamy fine sands
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DELAU
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Level phase

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2. Soils

(1) Topography and drainage of Lyleton district.-- The Lyleton district is level in topography with a northeasterly slope. Northward the slope is toward the lower portion of Lake Souris basin. The eastward slope of the terrain from the Saskatchewan boundary to the Souris river valley is 7 feet per mile. The country immediately surrounding Lyleton is slightly rolling where transversed by the Gainsborough creek and Antler river.

Drainage is northward under the lacustrine deposit. The underlying boulder till, the bottom of glacial Lake Souris, forms a natural reservoir. The lower portions of the basin have a deeper lacustrine deposit with abundant sub-soil moisture even during periods of drought. Oak Lake, in the northern part of the lake basin, results from this northward seepage of water (plate I). After years of abundant rainfall the water table expands towards the edge of the basin and more abundant sub-soil moisture covers a larger area. As drought increases in severity the water table recedes northward. The Souris river, flowing northeasterly, vitiates in a small way this excellent natural drainage by intercepting run-off in its vicinity.

(2) Soil associates of the Lyleton district.-- Soils of the Souris association (figure 1, plate III) were developed on lacustrine sediments deposited in and modified by glacial Lake Souris. Creeks flowing down from the higher till plains east and west, sorted their suspended materials to form deltas, of coarse to fine materials. Consequently, soil textures vary greatly even over a small area. Ellis (unpublished) has to say, in part of the Souris soil association: "The textures of the soil are generally relatively light, although some heavier textured soils of the association are situated in the southern part of the Souris soil area. The latter soils are developed on stream-borne material deposited by creeks flowing into glacial Lake Souris (Plate II). The best soils in the association are of heavy texture. Their water retention power is high and drifting is not as severe as in the lighter textures, but they have not the sub-soil water which is found in the latter. The soils of light textured sandy loam to very fine sandy

loams have drifted severely and from some fields two feet of soil has been blown away."

(3) The soil of the Lyleton study centre.--
The study centre, as outlined in figure 1, plate III, in general coincides with a deposit of fine material, likely deposited by a stream entering Manitoba through section 18, township 1, range 29 to glacial Lake Souris. Deposition as it entered Manitoba forms the parent material of the Souris light, sandy loam associate. The Souris fine loam developed from the finer alluvium.

The soil associates of the study centre are shown in figure 2, plate III. Most of the area is classified as fine loam, one of the heavier textures commented on by Ellis. Soils in this portion of the area vary in texture from fine sandy loam or very fine sandy loam to clay loams. The sandy loams are composed of approximately 50 percent fine sand, 35 percent silt, and 15 percent clay while the clay loams would contain roughly 20 percent clay, 35 percent silt, and 45 percent fine sand. Under native vegetation, a cloddy to columnar structure is manifest in these soils. Cultivation has greatly depleted the fibrous organic matter responsible, under native sod, for the structure in this associate.

The area of Souris fine loam (figure 2, plate III) may be roughly divided by the middle road north into fine sand loam on the west and very fine sandy loam on the east. Such a division is based on the detailed survey of southwestern Manitoba by Ellis.

The Souris light sandy loam enters the study area along the west and north sides. Developed on coarser material, soil textures vary from loamy sands (about 75 percent sand, 15 percent silt, and 10 percent clay) to sandy loams. The sand separate of these classes, however, is much coarser.

The Bede loamy coarse sand associate enters the study area along the Gainsborough creek. Ellis (unpublished) describes the association as consisting of "soils developed on gravel and coarse sandy alluvial deposit laid down in plains and further modified by wave action. The parent material may consist of gravel, cobbles or coarse sand with gravel admixed".

PLATE III

Fig. 1. Soil associates of the Lyleton district.

Fig. 2. Soil associates of the study area.

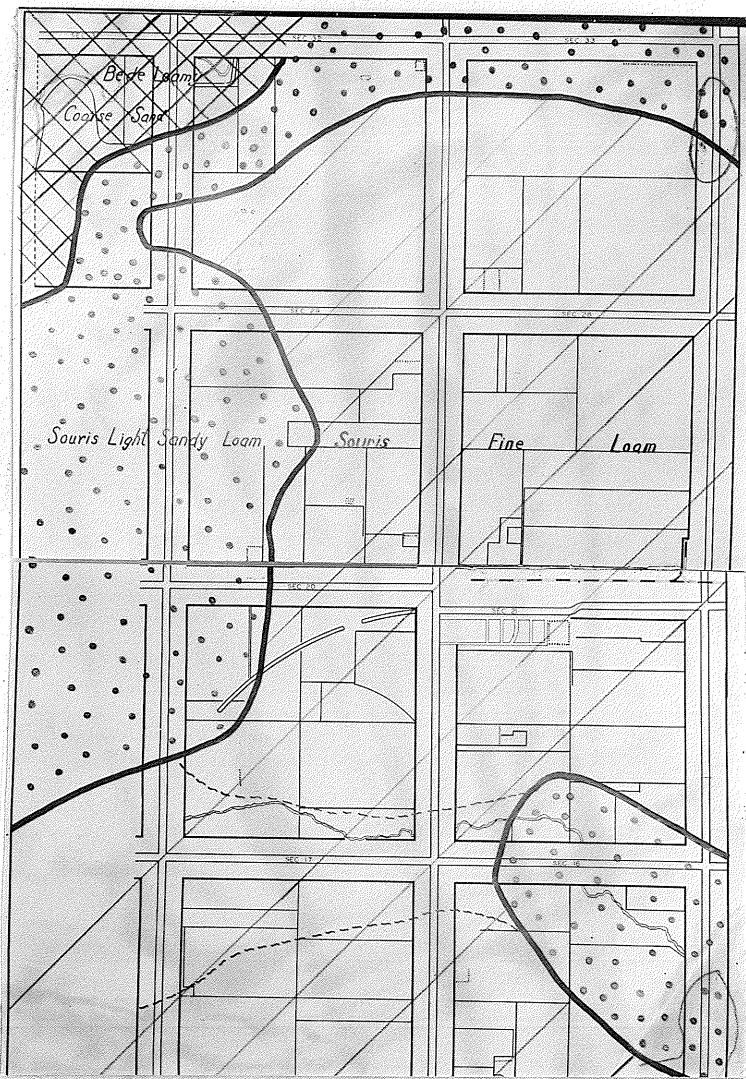
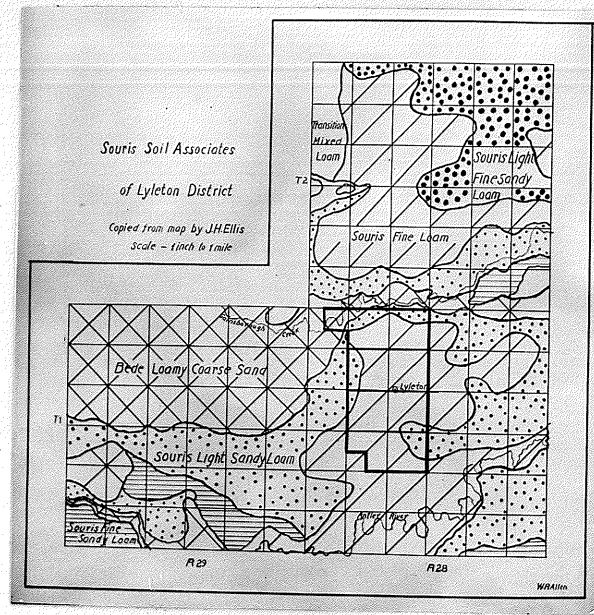


PLATE IV

Figs. 3 and 4. A light dust storm in progress.

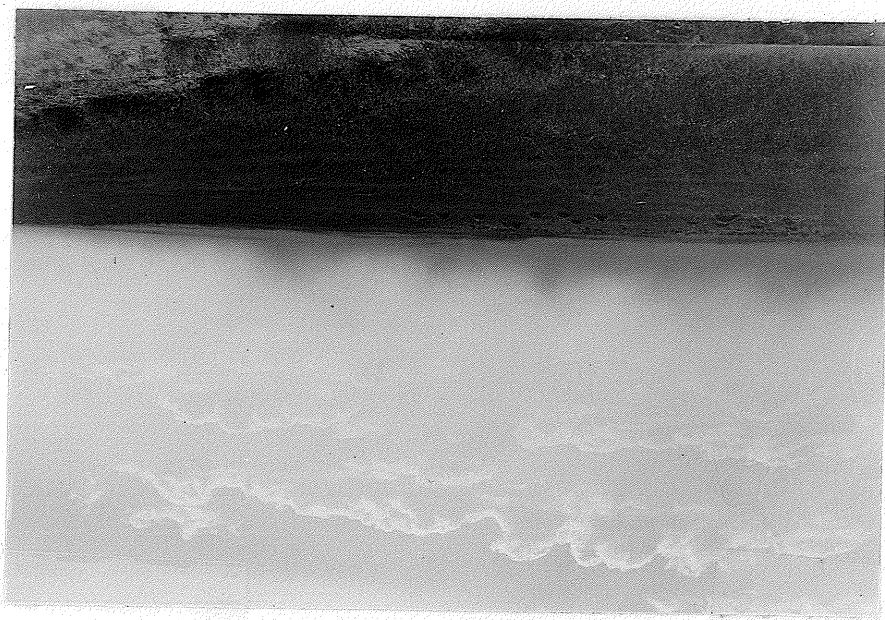
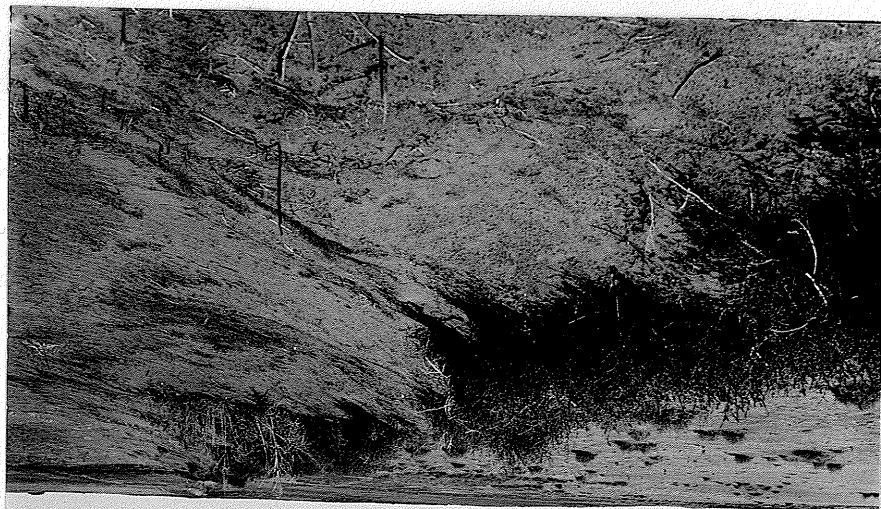


PLATE V

Fig. 5. A view showing how the northwest part
of section 29 was badly eroded.

Fig. 6. A view of the northeast corner of the
same section.



Surface soil textures vary from clay loams to coarse sandy loams and are structureless to granular. Wind erosion and irregular deposition make it possible to find gravel on the surface. Demarcation between the associates is irregular and considerable overlapping occurs along all the boundaries.

A temporary creek runs south of sections 20 and 21 (figure 2, plate III). The area along the creek marked by a broken line is very similar to the Souris light sandy loam jutting in from the east. Sand, gravel and modified drift form the parent material. The soil is coarser in texture than that surrounding it and fine gravel may be found on the surface.

(4) Soil erosion.— Soil drifting was quite severe over the whole area during the very dry season of 1934. Severe storms in mid-May, 1936, were followed by lighter storms in early September. In 1937 the same seasons brought light storms and drifting. Plate IV shows a light storm in progress on September 14, 1937.

Sheet erosion caused by wind is apparent by the presence of blown ridges along many field margins. Also, there are small light-colored patches over the area where the sub-soil close to the surface has been exposed. The surface soil and organic matter having been removed, a nitrogen deficiency is evident in plants grown on these small patches.

The area damaged most seriously by wind was the north half of section 29. Views shown in figures 5 and 6 of plate V indicate the extent of erosion. Wheat was seeded over most of this area in 1936 but wind erosion bared the land, leaving the work of reclamation to Russian thistle. By the end of 1937 most of this area was vegetated. A description may be found in the section on vegetation.

The southeast quarter of section 29 blew badly in the fall of 1937. A portion, last sown to barley in 1935, and a field which grew wheat in 1936 were fallowed late in the season. A ridge, one to one and a half feet high, was formed at their western edge after a couple of high winds.

PLATE VI

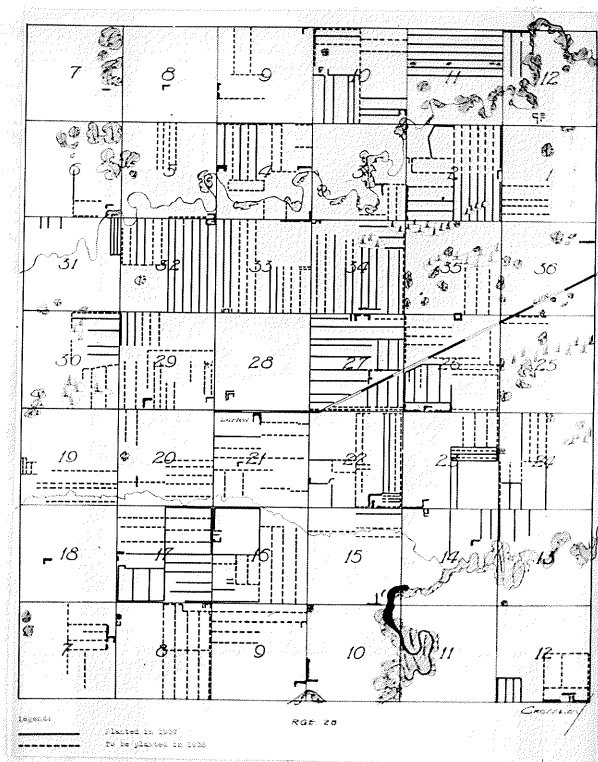
Figs. 7 and 7A. Young caragana plantings.



Another area susceptible to soil drifting encompasses the east half of section 33, the north-east half of section 33, and the northeast and south-west quarters of section 28. In 1935 section 28 became a sub-station of the Experimental Farms Branch where a system of strip farming was started.

The cultivated land on section 20, north-west and southeast quarters, and the northeast quarter of section 21, and the southeast quarters of sections 17 and 16 have drifted during the periods of high wind, but the crops were not seriously affected in 1936 and 1937.

A system of caragana field shelter belts has been implemented under the Prairie Farm Rehabilitation Act plan. The accompanying illustration is reproduced by permission of the Dominion Forest Nursery Station, Indian Head, Saskatchewan, and shows the plantings made in 1937 and 1938.



Illus. 1. Caragana planting 1937 and 1938 in 42-section block.

In all, 166 linear miles of caragana (Caragana arborescens) have been planted. Figures 7 and 7A, plate VI show the young seedlings in the cultivated strips.

3. Climatic Regions

The classification of the climates of North America received the attention of Thornthwaite (1931). He found it possible to establish formulas from precipitation, evaporation and temperature figures that give indices for areas which coincide with the major vegetation regions of North America. His indices of precipitation and temperature effectiveness for various areas outline remarkably well soil and vegetational types which are known to be expressive of the extent climatic conditions. Halliday (1937), classifying the forests of Canada, found forest types showed in general good correlation to climatic areas outlined by Thornthwaite's method. In conjunction with the work of Halliday, Ellis (unpublished) has devised a more detailed climatic and vegetation map of Manitoba. He characterizes southwestern Manitoba, the area which encompasses Lyleton, as "the southwest plain section having a precipitation effectivity of 42.2 and a temperature efficiency of 36.3".

Further north and surrounding the southwest plains is found what Ellis terms "the Prairie Aspen Oak", a section with precipitation effectivity and temperature efficiency of 43.2 and 37.3 respectively.

4. Vegetation and Cultivated Crops

(1) Classification of the north Great Central Plain.- Shantz (1924) classified the great central plain east of the Rocky mountains and west of the hundredth meridian as a short grass plain. He distinguished it from the tall grass prairie by differences in vegetation and soil. Rainfall over the area of the short grass plains varies from 10 to 22 inches which precedes or occurs during the growing season. Only the surface soil becomes periodically moist. As a result, the soils are characterized by an accumulation of calcium carbonate which forms in a layer 6 to 20 inches below

the surface, and delimits the surface soil seasonally moistened from a permanently dry subsoil. Shantz's Grama-western needlegrass association typified by western North Dakota and portions of South Dakota closely resembles the vegetational type found in southwestern Manitoba. The dominant grasses of this association are short Grama grass, Bouteloua gracilis (H.B.K.) Lag., Stoud, and the taller western needlegrass, Stipa comata Trin & Rupr. Shantz also includes the fact that many plants from both the pure short grass and tall grass areas are found throughout the association. As sub-dominants he names purple cone flower, Rhinnacea (Brauneria) angustifolia (D.C.), silvery psorale, Psoralea argophylla Pursh., and June grass (Koeleria cristata (L.) Pers.

The classification of the great central plains by Weaver and Clements (1929) is in many respects similar to Shantz's. The Grama-western needlegrass association of Shantz is included in what they choose to call the mixed prairie Stipa-Bouteloua association. Concerning the mixed prairie association they said in part "this community owes its name to the fact that the climax comprises both mid and short grasses on more or less equal terms while the four major mid grasses (Stipa comata, Sporobolus cryptandrus, Agropyron smithii, and Koeleria cristata), together with Bouteloua gracilis and Aristida purpurea are found practically throughout. They vary much in importance and with regional dominants form various combinations within the association."

Hansen (1934) working in Golden Valley county, North Dakota, characterizes the vegetation as mixed prairie "consisting of the taller dominant grasses, Stipa comata Trin & Rupr. and Agropyron smithii Rydb. and the shorter dominant grasses and sedges, Bouteloua gracilis (H.B.K.) Lag., Carex filifolia Nutt., and C. stenophylla Wal. This type, with minor changes in dominants, is widespread in the northern great plains and along the foothills of the Rocky mountains." A more detailed study of the vegetation types in about the same district led Hansen (1938) to conclude that a type he defines as "the Grama-needlegrass sedge type" . . .

"where protected from excessive grazing, mowing or other use (the vegetation) has apparently reached stabilization as far as this is possible under the severe climatic fluctuations". "In years of favorable rainfall, the cover is fairly dense". The dominants are practically those mentioned above by the same author in 1934; Boutelous gracilis, Stipa comata, Carex filifolia, being the chief dominants. Carex stenophylla, Agropyron smithii, Koeleria cristata are sub-dominants.

(2) Classification of the study area and communities.- The Lyleton study area is situated at the northern edge of the great central plains and is described below.

(a) Results of plant survey.- A detailed reconnaissance survey of the vegetation of the area was conducted by Dr. S. E. Clarke and J. L. Boulton, between July 7 and 18, 1938. They described the vegetation as mixed prairie formation in the transitional zone between the mixed prairie and tall grass prairie. The areas of native relict vegetation as roadallowance and unploughed fields were thoroughly surveyed. The method used on the roadallowance was a method of listing. On each mile of roadallowance 0.1 mile lengths were taken and the species of grasses and forbs most prevalent were separately listed and rated in order of abundance. When the roadallowances were divided into more distinct types the listing units were made smaller, and when the vegetation was more homogeneous as few as four stops were made per mile.

The surveyors have provided us with a very comprehensive report, in which the relative prevalence of the important species in each list quadrant has been tabled. In the pastures a slightly different method of listing the vegetation was used. Here the dominant species of grasses and forbs were rated for each different type of vegetation, which also have been tabled. This material has been freely used to establish and classify the vegetation of the study area. Table 1 was prepared to show the dominant vegetation found on each mile of roadallowance, the location being indicated by the corresponding number of the key to table 1. The figures 1, 2, 3, 4 etc., used

* Nomenclature used follows Rydberg (1932).

Table 1.

The Relative Abundance of Grasses and Forb Species
on the Roadside

Plant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<u>Grasses:</u>																							
<u>Astropyron smithii</u>	1	1	1	1	2	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<u>Stipa viridula</u>					3	3	2	3	4	2	2	2	2	3	2								6
<u>S. comata</u>	2	4	3	1	3	4	3	3	4					2	3			4					2
<u>S. spartea</u>					3	4	4										2						
<u>Carex Aleocharis</u>	3	3	5													5		2		4			5
<u>Bouteloua gracilis</u>	4									4						4		3					4
<u>Poa pratensis</u>									2														2
<u>Bromus inermis</u>									1		3	3	3				3		3				4
<u>Spartina pectinata</u>										4													3
<u>Calamovilfa longifolia</u>																							
<u>Hordeum jubatum</u>																							

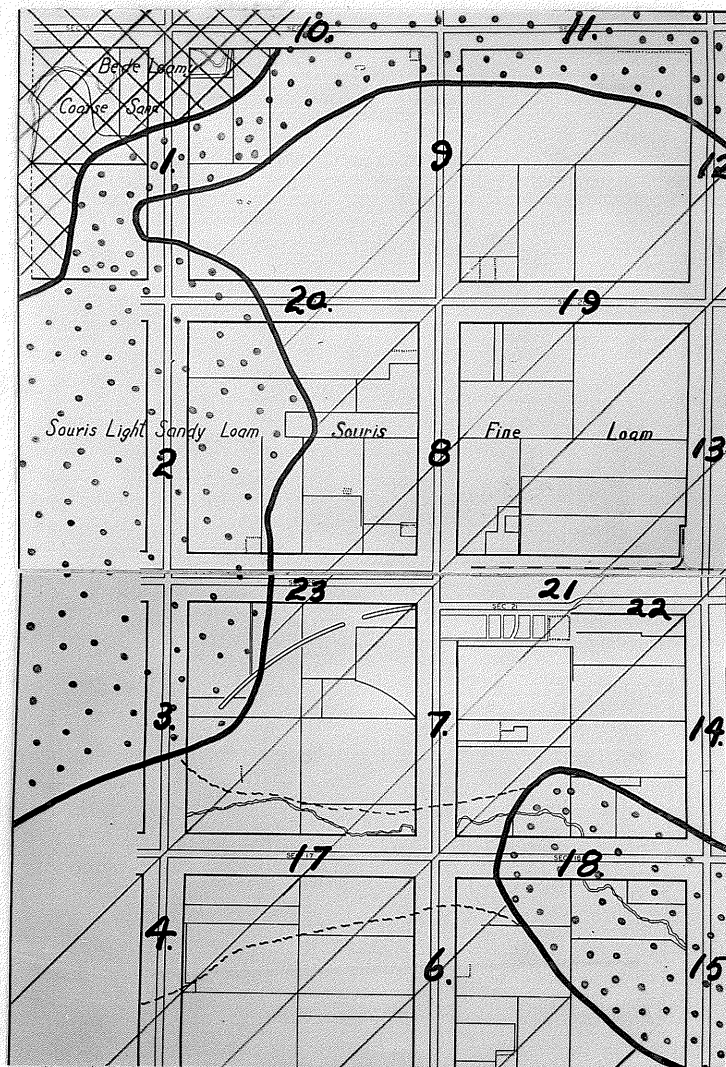
Table 1. (cont'd.)

The Relative Abundance of Grass and Forb Species
on the Roadallowances

Plant	Location																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Forbs:																						
<u>Cyclachaena xanthi-1</u>					2	1	1	2	2	3	1	2	1	1	1	1	2	3	1	2	3	
<u>folia</u>																						
<u>Artemisia frigida</u>											4							1				
<u>A. annululodes</u>	3		1															2	1			
<u>Salsola Pestifer</u>	4								3		4	1	2	3	3	2				3	4	
<u>Rosa sp.</u>	2		2	3																		
<u>Helianthus sp.</u>		1	3	1	1	2	2	1	1	2	3		3	2	2	3	1	4	2		1	2
<u>Euphorbia sp.</u>	2															4						
<u>Oxyria sp.</u>	3																					
<u>Persicaria coccinea</u>																						
<u>Polygonum erectum</u>					3					1	2					5		2				1

Key to Table 1.

Key to location of roadallowances for which
the important grasses and forbs have been indi-
cated in table 1.



5.

16.

in the table indicate the relative importance of the most important grasses and forbs present. Table 1 shows Agropyron Smithii and the Stipas, particularly Stipa viridula and S. comata, were the dominant grasses. Boutelous gracilis was not showing up well when the survey was conducted but undoubtedly should rank next in importance, followed by its intimate associate Carex Eleocharis. The important forbs listed were false ragweed, Lyolachna (Iva) xanthifolia, sweet clover, Helilotus sp., Russian thistle, Salsola Festifera, and species of Artemisia. Therefore, the study area can be considered as dominantly an Agropyron-Stipa-Boutelous community in which the following typical communities can be recognized.

(i) Highland grassland type.-

Boutelous-Carex-Stipa community. In this Boutelous gracilis, Carex Eleocharis, and Stipa comata appear in this order of importance, and Chrysopsis villosa is an indicative forb species. On the study centre this grassland type occurs on the Bode loamy coarse sand and Scuris light sandy loam soil types (figure 2, plate III) described on page 7.

(ii) Intermediate grassland types.-

Stipa-Boutelous. The community is at present composed mainly of the grasses, Stipa viridula, Stipa comata, Boutelous gracilis along with Carex Eleocharis and Agropyron Smithii.



Illus. 2. A Stipa-Boutelous community on roadallowance No. 16.

Illustration 2 shows the community. Stipa viridula is much more evident than a view in the other direction would have shown because the Stipa was growing profusely after the drought years.

Stipa-Agropyron and Agropyron-Stipa. These communities cover most of the area. Agropyron Smithii and Stipa viridula are the most important grasses, along with Stipa comata and many of the forbs, in particular false ragweed, Russian thistle and sweet clover. Illustration 3 is a view of this community.



Illus. 3. A Stipa-Agropyron community on roadallowance No. 14.

Agropyron. An Agropyron community is found in many parts of the area where A. Smithii may exist as a pure stand or mixed with forbs in various degrees. Places may even be found where it is just beginning to form an undergrowth.

Agropyron-Bromus-Poa mixed communities composed of Agropyron Smithii, Bromus inermis and Poa pratensis of small extent occur.

Agropyron-Calamovilfa. This community is found particularly on the western third of the study area, and particularly where a recovery is being made on drift soil. Illustration 4 shows such a community in which Agropyron Smithii and Calamovilfa longifolia are the dominant grasses.



Illus. 4. Recovery to Agropyron Smithii and Calamovilfa longifolia. Note the patches of false ragweed. Roadallowance No. 4.

The intermediate types of communities covered most of the roadallowance area when the intensive plant survey was completed in 1936 and in most locations represent the recovery made by the grasses. When the study centre was initiated

in 1936 fully half of the roadallowance area, severely damaged by erosion, fostered societies of false ragweed, Russian thistle, bind weed, Milvaderkia convolvulus, lamb's quarters and worm wood, Artemisia biennis, either in pure or mixed stands. Sweet clover seed blown from the fields also became established in many of the ditches as the following illustration shows.



illus. 5. A roadside dominated by sweet clover. Roadallowance No. 6.

Agropyron Smithii was the first grass to come back and in some places it completely smothered the weeds. In other locations Stipa viridula came to its assistance. In sandy locations, Calamovilfa longifolia either assisted it or first became established. At a few points Agropyron repens competed with it for

dominance. Bromus inermis (likely escaped from cultivation) and Poa compressa have joined with it in places to form a sod.

(iii) Lowland grass type.--

Poa-Hordeum. Low meadow grassland with Poa species being well represented, especially Poa palustris, P. compressa and P. pratensis. Hordeum jubatum is often dominant and often subdominant. Agropyron pauciflorum, Elymus Macounii, Calamagrostis sp., Muhlenbergia squarrosa and Carex species are also common.

Spartina-Salix. Small slough along the road-allowance contained a community composed of Salix sp. and Spartina pectinata. Poa palustris was usually present and Carex sp. Glyceria grandis, Fluminea festuacea and forb forms, such as Persicaria coccinea and Artemisia biennis may be associated. Illustration 6 shows this type of slough.



Illus. 6. A small slough on roadallowance No. 15.

(b) Reversion on the study area.-- A large proportion of the land on the study area was out of cultivation when the study was started. During the drought period the farmers were allowed only enough seed to sow 100 acres, consequently much of the land was weedy. Ruderals, such as false ragweed, Artemisia biennis, Leptilon canadensis, bind weed and rose grew profusely where the land had been idle for two to three years. The extent of this area in the early part of 1936 may be seen by referring to plate VII. Some of the reverted areas will be here described.

(i) Southeast quarter of section 29.-- The field labelled on the crop plan as barley stubble, first-year reversion, was vegetated in 1936 by a thick growth of Russian thistle, accompanied by Ambrosia coronopifolia and false ragweed. During 1937 sweet clover became very abundant and was combined with the mustards and French weed, Thlaspi arvense. The Russian thistle practically disappeared.

On the same quarter the fields which grew oats and wheat in 1936 were not ploughed until late in 1937 and on each the important plants were: Russian thistle, roses, bind weed, false ragweed, peppergrass (Lepidium densiflorum), lamb's quarters and Ambrosia coronopifolia.

(ii) North half of section 29.-- A wheat crop sown in 1936 was completely blown out. Russian thistle, wild millet (Setaria viridis), Chamaesyce alptosperma and skeleton weed formed a dense patchy cover during the first season. The same plants in combination with sweet clover and several other forbs formed a more extensive cover in 1937.

(iii) Southwest section 29.-- The field marked two to three-year reversion on plate VII in 1937 grew mostly perennial plants of which gumweed (Grindelia perennis), sweet clover (Leptilon canadense), Aster ericoides, tall coneflower (Lepachys columnifera), and Solidago dumetorum were the most important. False ragweed and Russian thistle were the existing annuals.

(iv) Southwest quarter of section 20.-- The two to three-year reversion adjoining the

Agropyron reversioners in 1936 grew about the same plants as the other two to three-year reversioners, but during 1937 Agropyron repens spread through it leaving only small patches of ruderals.

(v) Southwest quarter of section 32.- The quarter section was last cropped in 1930 and in recent years has been used as a hay land. Agropyron repens is the dominant grass and patches of A. Smithii may be found throughout. In large islands the following forbs are found: Gumweed, sweet clover, Artemisia frida, Rosa sp., Solidago dumetorum, Artemisia gnaphaloides, Lepachys columifera, Aster ericoides, Artemisia patularis, etc.

(vi) The succession which seems to follow on idle land in the Lyleton district appears to be Russian thistle first and with a few plants, such as skeleton weed, Chamaesyce glyptoserpa, and wild millet forms a patchy vegetation. Average to better precipitation fosters the abundance of more mesophytic ruderals, such as false ragweed, lamb's quarters, Artemisia biennis and Lepilon canadensis. After three or four years, gumweed, Aster ericoides, tall coneflower, Solidago sp., Artemisia gnaphaloides, and sweet clover are likely to appear. From then on the grasses, Agropyron repens and Agropyron Smithii, first appear as clumps which spread rapidly. The Agropyrons reach control in eight to ten years and by then Stipa may just be entering from the edge.

(c) Cultivated crops grown.-- The important crops grown on the study area during both seasons were: wheat, oats, barley, fall rye, millet, corn and sweet clover. The crop plans, plates VII and VIII, show the crop in each field during 1936 and 1937.

5. Animal Life

The animal life of the Lyleton area is similar in nature to that found throughout southern Manitoba.

(1) Mammals.-- The most abundant mammal is the common gopher, Citellus richardsonii (Sabine).

PLATE VII

Cropplan 1936.

Lyleton Study Centre

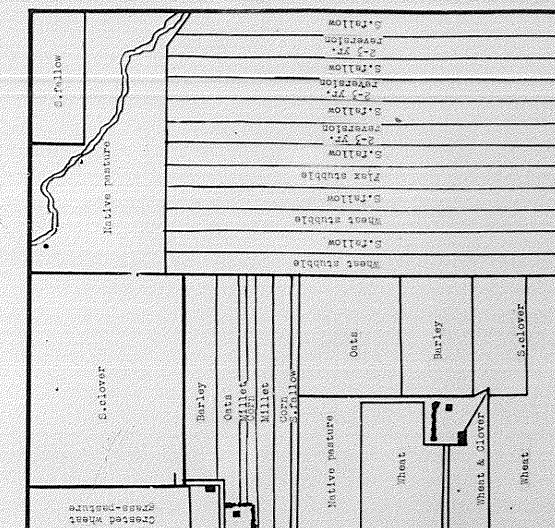
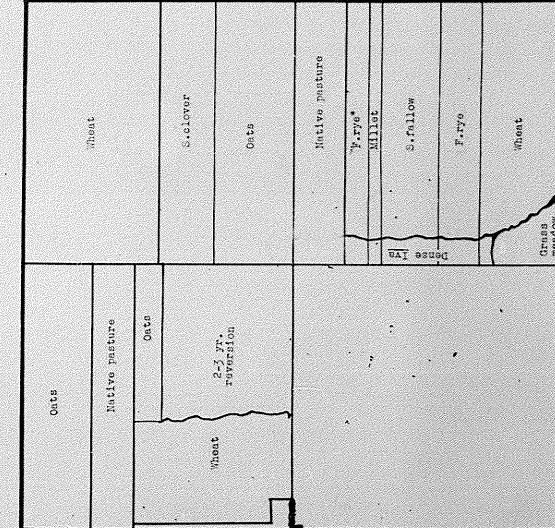
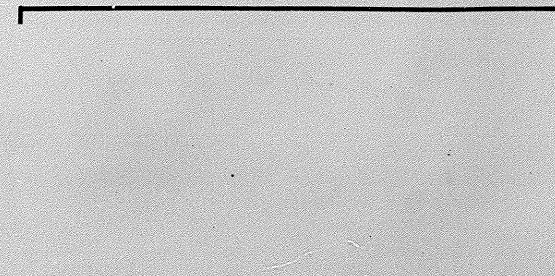
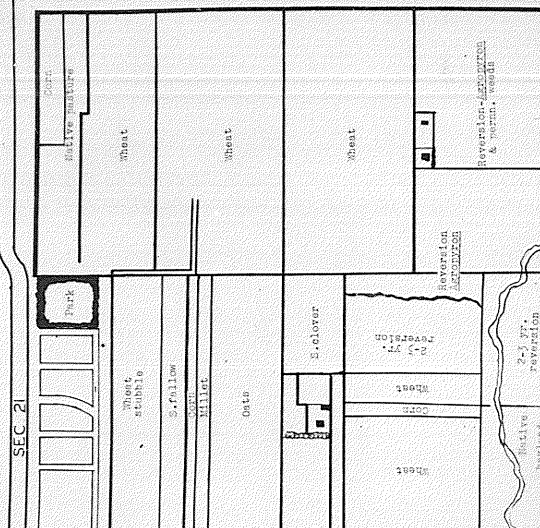
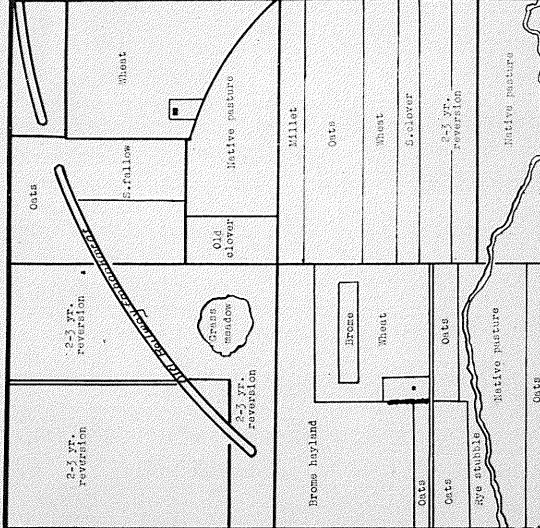
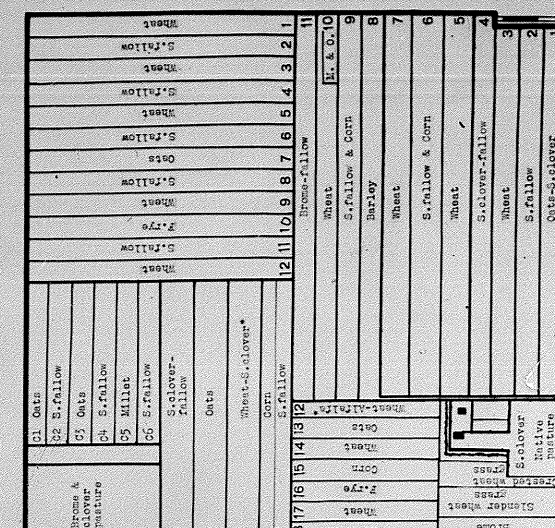
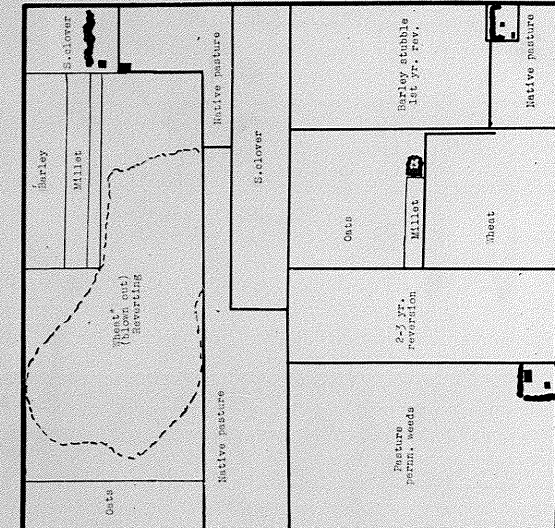
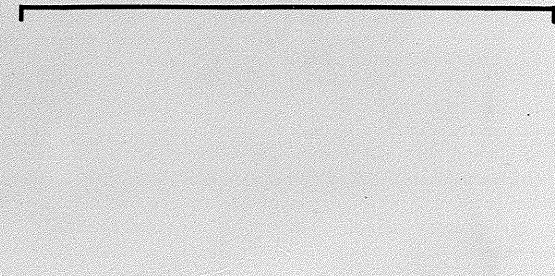
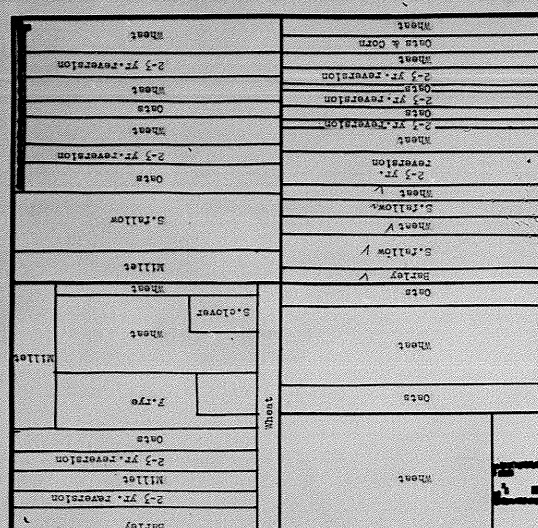
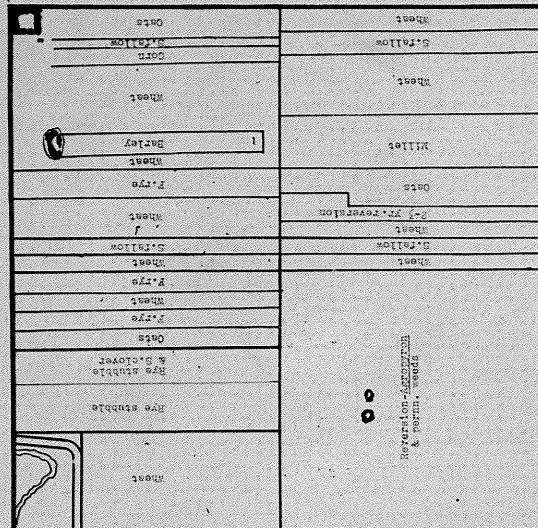
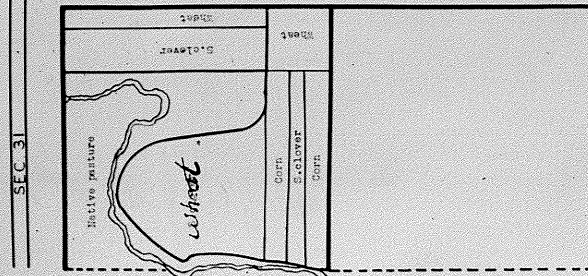
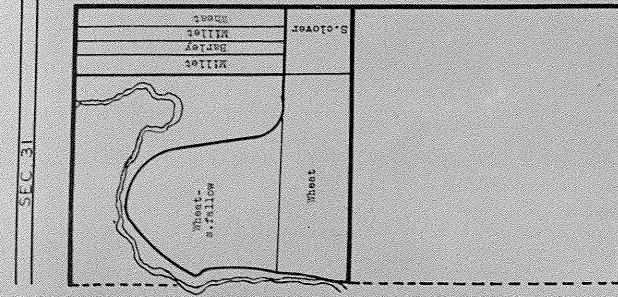


PLATE VIII

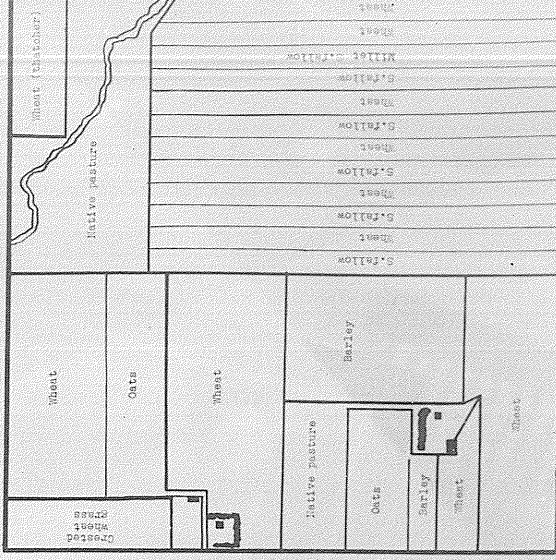
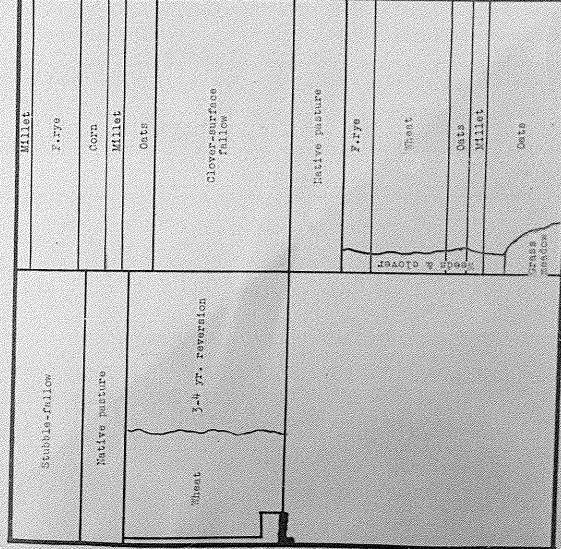
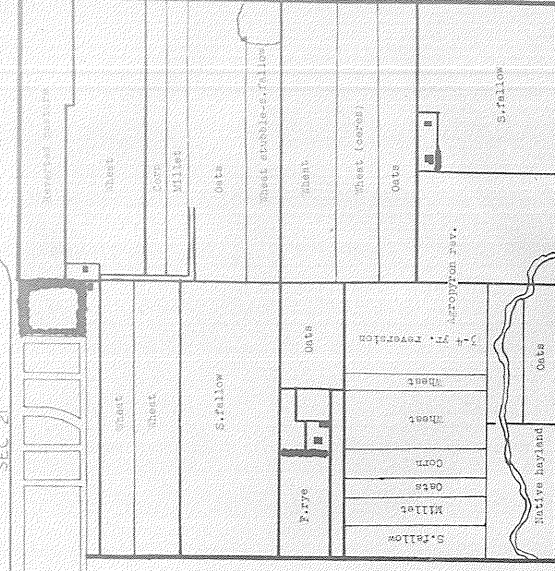
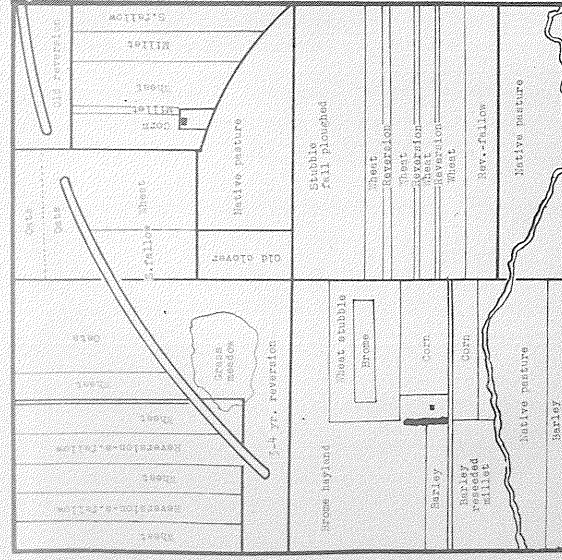
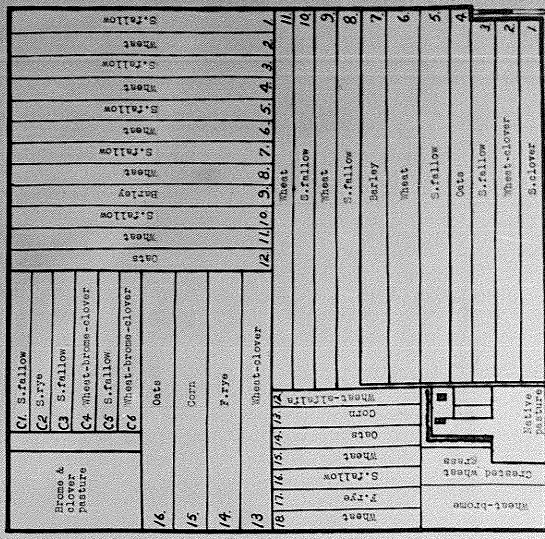
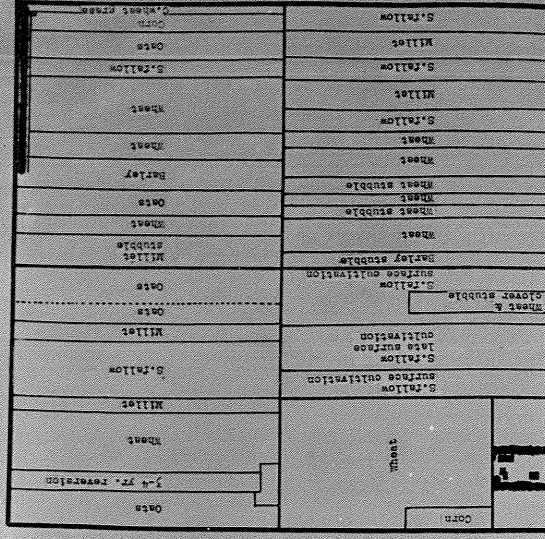
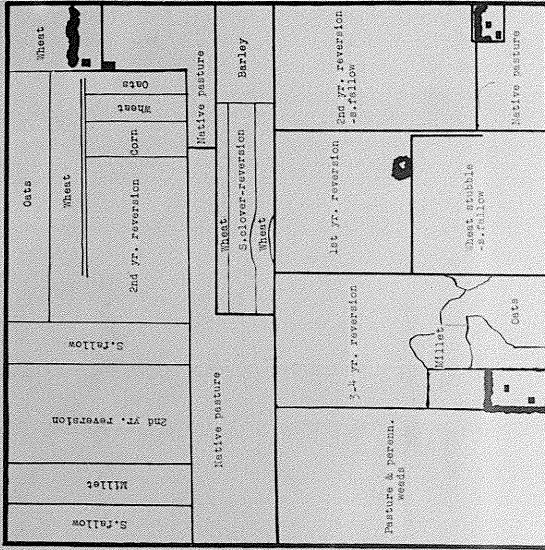
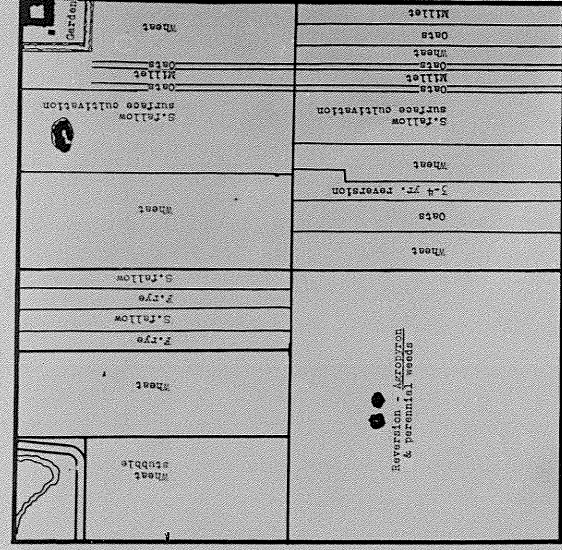
Crop plan 1937.



Lyleton Study Centre



Map of Crops 1937



The thirteen-striped gopher, G. tridecemlineatus, occurs but in much smaller numbers. White-tailed Jack rabbits, Lepus townsendii campbelli Hollister, are at present at their minimum. In 1934 they were very numerous in southwestern Manitoba.

(2) Birds.-- Birds found on the study centre are listed below in order of importance as grasshopper predators:

Arkansas kingbird	<u>Tyrannus verticalis</u> Say
Eastern kingbird	<u>Tyrannus tyrannus</u> (Linnaeus)
Eastern meadowlark	<u>Sturnella magna magna</u> (Linnaeus)
Prairie horned lark	<u>Otocoris alpestris praticola</u> Henshaw
Vesper sparrow	<u>Poocetes gramineus gramineus</u> (Gmelin)
Brewer's blackbird	<u>Euphagus cyanocephalus</u> (Wagler)
Red-winged blackbird	<u>Agelaius phoeniceus arctolegus</u> Oberholser
Chestnut-collared longspur	<u>Calcarius ornatus</u> (Townsend)
Franklin's gull	<u>Larus pipixean</u> Wagler
Crow	<u>Corvus brachyrhynchos brachyrhynchos</u> Brehm.
Burrowing owl	<u>Speotyto cunicularia</u> L.

All these insectivorous birds, with the aid of English sparrows, [Passer domesticus domesticus (Linnaeus)], domestic turkeys and chickens, destroy many grasshoppers.

(3) Insects.-- The insect fauna of the district has not been studied but it is expected to be similar to that of southern Manitoba. However, the occurrence of several species of Orthoptera not found in other parts of the province suggests that the fauna contains additional species from the southwest. Hypochlora alba (Dodge) and Phostolictes nebrascensis (Thomas) are the most prominent in this faunal difference. The blister beetles characteristic of the study centre are Necrobasis murina Lec. and Epicauta maculata Say. The former species was exceedingly abundant in 1937, causing severe damage to caragana.

III. GENERAL METHODS OF STUDY

Weather data were collected to accompany the seasonal study of grasshoppers and for possible correlation of factors of the weather complex with the seasonal ecology of the grasshoppers.

Three main surveys of the area were used to determine the relative abundance of grasshoppers and these surveys also yielded information on the relationship of population to plant communities, to the natural environment, and to artificial changes of this environment. The dependability of the egg survey used generally for forecasting the possible outbreak of the ensuing year, was studied by comparison with the following nymphal survey, but several years' data are necessary to make such a study conclusive. For a yearly comparison a ratio between the adults present at adult survey time to eggs present in the fall was calculated. From the egg survey data a detailed study of egg-laying sites and a quantitative study of the egg predators were possible.

Weekly and bimonthly changes in population were studied on study plots where the trend of population throughout the season could be more readily followed. Collections of grasshoppers from the study plots were examined to determine the percentages of the important species present and the development of the predominant species, Melanoplus mexicanus mexicanus (Saunders), since it formed 60 to 90 percent of the grasshopper population. In addition, the material collected was dissected to determine the percent parasitism due to dipterous parasites.

Studies on behavior were undertaken mainly on the study plots but other points of the area where interesting observations could be made were utilized as the opportunity arose. The flight data, phenological and crop conditions, crop damage, predation by birds and mammals, the presence or absence of disease, and the grasshopper species of the area are topics covered by general field observation.

IV. WEATHER

1. Relationship of Weather and Grasshopper Abundance

An intimate relationship exists between weather and grasshopper abundance. Increased temperatures and decreased precipitation accompany grasshopper outbreaks. In fact, Parker (1933) states that "in every instance outbreaks have been preceded by two to four years during which either rainfall has been below normal during May and June or temperatures have been above normal during July, August and September. In most instances both conditions have prevailed with temperature showing the most significant departure". Thus, he considers weather the most important natural factor governing grasshopper abundance. The pattern of weather conditions mentioned seems to have preceded at least three major outbreaks since 1873. Parker (1930) states that Riley in 1878 considered Ft. Shaw, Montana, to be the heart of the permanent breeding ground of Melanoplus spretus (Walsh), and that the years from 1873 to 1875 were years of severe outbreak. From weather data collected at Ft. Shaw, Parker indicates that this last outbreak of Melanoplus spretus (Walsh) was accompanied by the above set of weather conditions. Preceding the 1920-'23 outbreak at Ft. Shaw a similar set of weather conditions was in attendance but lack of moisture was not as acute.

Bird et al (unpublished), reviewing weather conditions preceding the outbreak of 1931-'34 in Manitoba, concur with the opinion expressed above by Parker. They also point out that in the years before and during the outbreak high spring temperatures and dry autumns were prevalent, allowing the grasshoppers optimum conditions for development and increase.

The late Norman Criddle, who for many years studied grasshopper conditions in Manitoba, wrote in 1933 that "the rapid rise of grasshoppers from normal to epidemic numbers apparently is brought about by various factors, such as favorable weather and an absence of natural enemies, while the reduction may be

due to unfavorable weather or entirely to disease, parasites and predators". In other writings Criddle puts more stress on the absence of parasites and predators as a factor responsible for the rise from normal to epidemic population. Experience gained by the workers in western Canada during the 1931-34 epidemic cannot substantiate this premise in its entirety. Temperature and precipitation seemed to be the important factors concerned. Parasites and predators could not be shown more abundant after the crest of the outbreak than before it. On the other hand, relatively cool, inclement weather in the spring of 1935 fostered the spread of the disease, Empusa arylli Fr., in Manitoba and started the recession of the outbreak in this province.

2. Instruments Used at Lyleton and Records Taken

(1) Air temperature.-- A weather shelter of the Stevenson type was used to house the following instruments: (a) minimum thermometer, (b) maximum thermometer, and (c) hygrothermograph. A view of the weather station appears in figure 8, plate IX.

The thermometers used were similar to those employed by the Meteorological Service of Canada. The thermometers were hung on the back wall of the shelter approximately 4 feet from the ground.

(2) Soil temperature.-- A record of soil temperature was obtained from a soil thermograph operated on study plot 1. Figure 9, plate IX shows the instrument in situ. The stake at the lower left hand corner marks the position of the bulb. The photograph shows how the drift ridge forms a gentle southern exposure sparsely covered in the spring with false ragweed. The bulb of the thermograph was placed one inch beneath the soil and occupied the bare space, partly in view, between the stake and the fence. The bulb was placed across the small ridge and lay north and south. The vegetation was removed as it grew up around the bulb site.

(3) Relative humidity.-- The hygograph portion of the hygrothermograph obtained a continuous record of relative humidity.

(4) Precipitation.-- Rainfall was measured by means of rain gauge of the 3-inch "Snowden" pattern. The instrument was set on the surface of the soil and secured to a stake.

(5) Evaporation.-- Evaporation from a free water surface was measured during the season of 1937.

The evaporation tank was constructed according to the specifications for the United States Bureau's class "A" land pan (Hedel 1919). The tank built of galvanized iron was 4 feet in diameter and 10 inches high. The bottom was carefully pleated and soldered to avoid warping. Instead of a stilling well for measuring the depth of water a simple glass gauge was constructed after the design used by Moore at Arnaud, Manitoba, in 1936 (Brandon Tech. Rept. 1936). This gauge consisted of a 10-inch length of a graduated burette, a 7/8 inch right-angle elbow pipe and a baffel arrangement assembled as follows: The glass tube was fastened into the upright elbow pipe which was fixed to the side of the tank close to the bottom. The elbow pipe led the water into the graduated tube where it reached the same level as the water in the tank. The graduated tube, marked off in 0.1 cubic centimetres, was calibrated so that the loss in cubic centimetres by evaporation could be converted to inches of evaporation. In order to diminish the fluctuations of the water column in the gauge, caused by slight movement of the water in the tank, a baffel was necessary. The baffel was constructed of a large bottle fitted with a two-holed stopper. Into one of the holes a glass tube was inserted and extended to the bottom of the bottle. Through it the water from the tank was free to pass into the bottle by a second glass tube which was connected with a stopper in the elbow joint by means of a short rubber tube. The water was thus able to pass from the baffel bottle to the elbow and fill the graduated tube. The rubber tubing between the bottle and the elbow joint was fitted with a clamp so that the surge of water could be further decreased by narrowing the passage to the graduated tube.

This measuring device was considered ample for measuring daily, or what seemed more important, weekly and monthly evaporation.

PLATE II

Meteorological Instruments

Fig. 8. A view of the weather station at Lyleton.

Fig. 9. A view of study plot I showing the soil thermograph in position.



The evaporation tank was protected from roving animals by a wire mesh cage (see figure 8, plate IX).

(6) Hours of sunshine.-- To obtain an estimate of the hours of sunshine a Campbell-Stokes sunshine recorder was used. The instrument was placed on a 4 foot stand as it appears in figure 8, plate IX.

(7) Wind.-- The wind velocity was measured with a cup-type anemometer. The instrument was mounted on a two and one half foot base (see figure 8, plate IX).

3. Methods of Reading and Calculating Data

The meteorological instruments at the weather station shown in figure 8, plate IX were read or checked twice daily. In 1936 the readings were made at 7:00 a.m. and 7:00 p.m. but during the following year morning readings were taken one hour later.

The weather station was opened on May 15, 1936 and operated until October; in 1937 the station was open from April 20 until October 31. The instruments operated for these periods were: (a) maximum thermometer, (b) minimum thermometer, (c) hygrothermograph and (d) rain gauge. For various reasons the other instruments were not operated for the entire season.

(1) Temperature.-- The minimum temperature was read in the morning and the maximum in the evening. The thermograph which obtained a continuous record of the air temperature was checked against the standard air temperature in the morning and evening. The weekly graph was used to compute daily mean temperatures and also weekly and monthly mean temperatures, employing the following methods. A daily biological mean was calculated from Geddes' formula (de Cryse 1932). The method consists of averaging the hourly temperatures from midnight to midnight. The daily mean temperatures were calculated by this method in 1936 but a slightly different and much shorter method devised by Moore (1937) was employed the following year. Moore's method differs in that the mean height of the thermograph curve is

obtained by means of a special celluloid rule reading in mean temperature. (Brandon Tech. Rept. 1937).

The weekly mean temperatures are arithmetic means of the daily mean temperature. Similarly, the monthly mean temperatures are based on the daily mean temperatures.

(2) Soil temperature.- The soil thermograph was installed on May 31 and ran till October 30, 1936. The following year records were begun on May 7 but were only taken until October 10.

The instrument was not kept with those at the weather station and was only checked weekly when the graph was changed. The instrument was checked by inserting a pocket thermometer into the soil beside the bulb to approximately the same depth. The soil temperature data were subject to errors which could not be corrected. The instrument was checked weekly but the error which had accrued throughout the week could not be compensated. Furthermore, such mishaps as the exposure of the bulb by wind and the shading of the soil surface by an occasional plant could not be accounted for. Consequently, a deviation of roughly 4 to 6 degrees Fahrenheit from the true soil temperature should be allowed.

The mean soil temperatures are tabled in Appendix III and were calculated by the same methods used for mean air temperatures in 1936 and 1937.

(3) Relative humidity.- The methods used for the temperature data were followed in the calculation of daily, weekly and monthly humidities.

The hygrograph was checked by two different methods in 1936 and 1937. During the former year a sling psychrometer was used to check the instrument twice daily. This method was unsatisfactory because of the inherent lag on the hygrograph so it was discontinued during the next season. In 1937 the check prescribed by the manufacturer was used at the beginning of each week. By this method the hairs of the hygrograph were saturated with distilled water and set to register 95 percent humidity, the deviation from 95 percent was then the amount of error for which

the instrument had to be adjusted. During the season of 1937 the instrument ran within plus and minus 5 percent which, we believe, is the limit of accuracy of these instruments in the field.

(4) Precipitation.-- The rainfall was measured in the morning and evening and later the weekly and monthly totals compiled.

(5) Evaporation.-- The evaporation tank was not installed until May 7, 1937 and was only operated until October 10.

The height of water in the evaporation tank was recorded each morning and evening and the evaporation for the preceding period computed. When the water level fell about 4 inches below the rim of the tank it was refilled to within 2 inches of the rim. Dust, insects and algae fouled the tank throughout the summer and it was necessary to clean it several times. The weekly and monthly totals for 1937 were tabulated and are found in Appendix III.

(6) Hours of sunshine.-- The daily records of the hours of sunshine were taken from June 4 until September 29, 1936 and from April 20 to October 31, 1937. The number of hours the sun burned the graph were estimated daily, and later the weekly and monthly totals were calculated.

(7) Wind.-- The anemometer was installed September 1, 1936 and operated until October 31. During the following season records were secured for the period May 1 to October 31.

The wind mileage was read every morning and evening, and the average hourly velocity of the preceding period was ascertained (Appendix III). Only in 1937 were there sufficient data for calculating weekly and monthly velocities. The weekly and monthly velocities are not averages of the daily wind velocities but are averages for the whole period. That is to say, the weekly and monthly mileages were divided by the number of hours intervening to give an average hourly velocity for the whole period.

A detailed tabulation of the weather data secured in 1936 and 1937 is found in Appendix III.

4. A Discussion of Weather Conditions of the Lyleton District from 1934-1937

(1) The drought period of 1934.- From 1929 to 1934, inclusive, moisture conditions were below normal in southwestern Manitoba. The precipitation for the previous fall and growing season of each year were calculated by Ellis (1936) for five stations in southwestern Manitoba and the records showed that precipitation fell below the forty-nine year mean of 13.49 inches. Severe drought in 1933 and 1934 culminated the period of low precipitation, high winds and high temperatures. Heavy torrid winds in 1934 raised the parched soil in clouds and many areas were severely eroded; drift soil covered fences and other stationary objects. The abundant rains of 1935 flooded areas blown out during the preceding year and favored a heavy vegetation of ruderal weeds and especially false ragweed.

(2) The weather conditions of 1936 and 1937.- The hythergraphs, figures 10, 11, and 12, plate X, summarize the weather features of both seasons and compare the seasons with a 32-year average for Pierson, the closest meteorological station. The monthly rainfall was decidedly low in 1936 (figure 10) and fell below the long-time monthly average of Pierson. In that year it was noted that reserve moisture and the spring rains were sufficient to carry vegetational growth until mid-June. From then until mid-August, precipitation was sparse and there was little growth until light rains of late August again revived the vegetation.

Figure 10 shows that the rain occurred mostly in June of the 1936 season which the hythergraph of Pierson (figure 12) indicates is more usual than a heavy July precipitation such as occurred in 1937.

Peak temperatures normally occur in July so in this respect the season of 1936 was closer to normal.

In both seasons May was warmer and drier than the normal for Pierson.

Plates XI to XII indicate other minor differences in the weather of the 1936 and 1937 seasons.

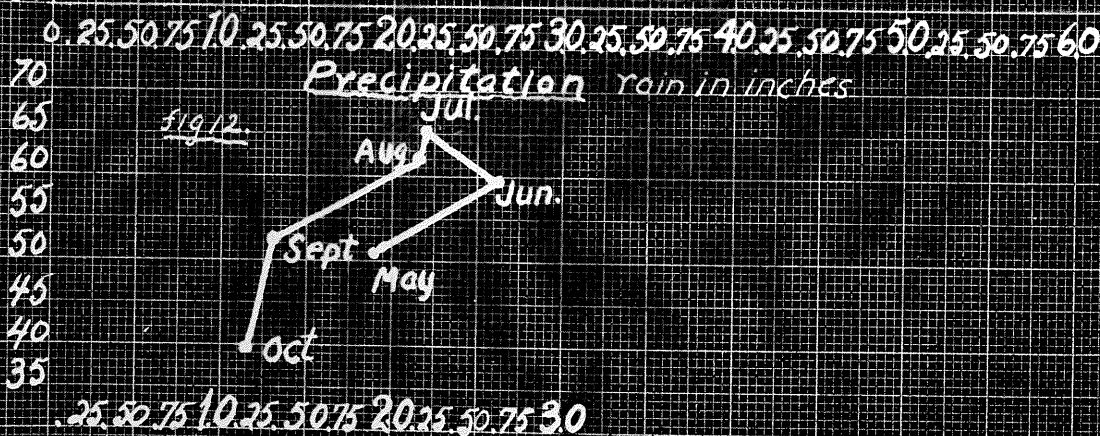
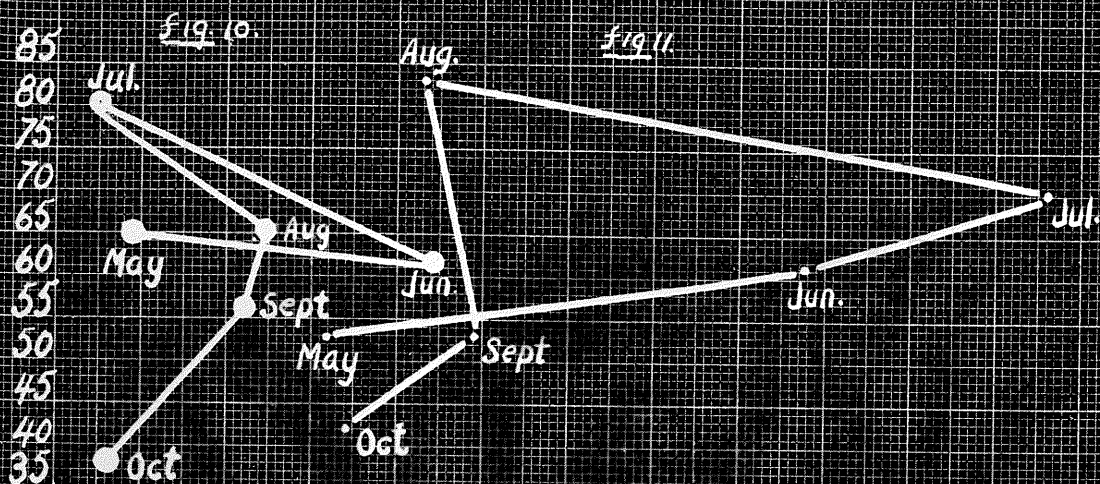


PLATE X

Fig. 10. A hythergraph of the monthly mean temperatures and precipitation occurring at Lyleton in 1936.

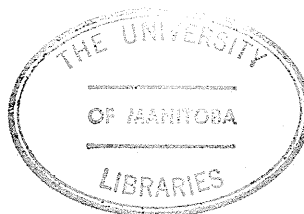
Fig. 11. A hythergraph of the monthly mean temperatures and precipitation occurring at Lyleton in 1937.

Fig. 12. A hythergraph of the monthly mean temperatures and precipitation occurring at Pierson from 1904 to 1936. (Records obtained from the 1936 reports of the Meteorological Service of Canada).

PLATE XI

Weekly Mean Temperatures

The weekly mean temperatures for the seasons 1936 and 1937 have been plotted and correspond closely except for two intervals in 1936 when the weekly temperature was considerably higher. These intervals occurred during the week of May 24 to 30 and from July 11 to August 1.



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WEEKLY MEAN TEMPERATURES

1936
1937

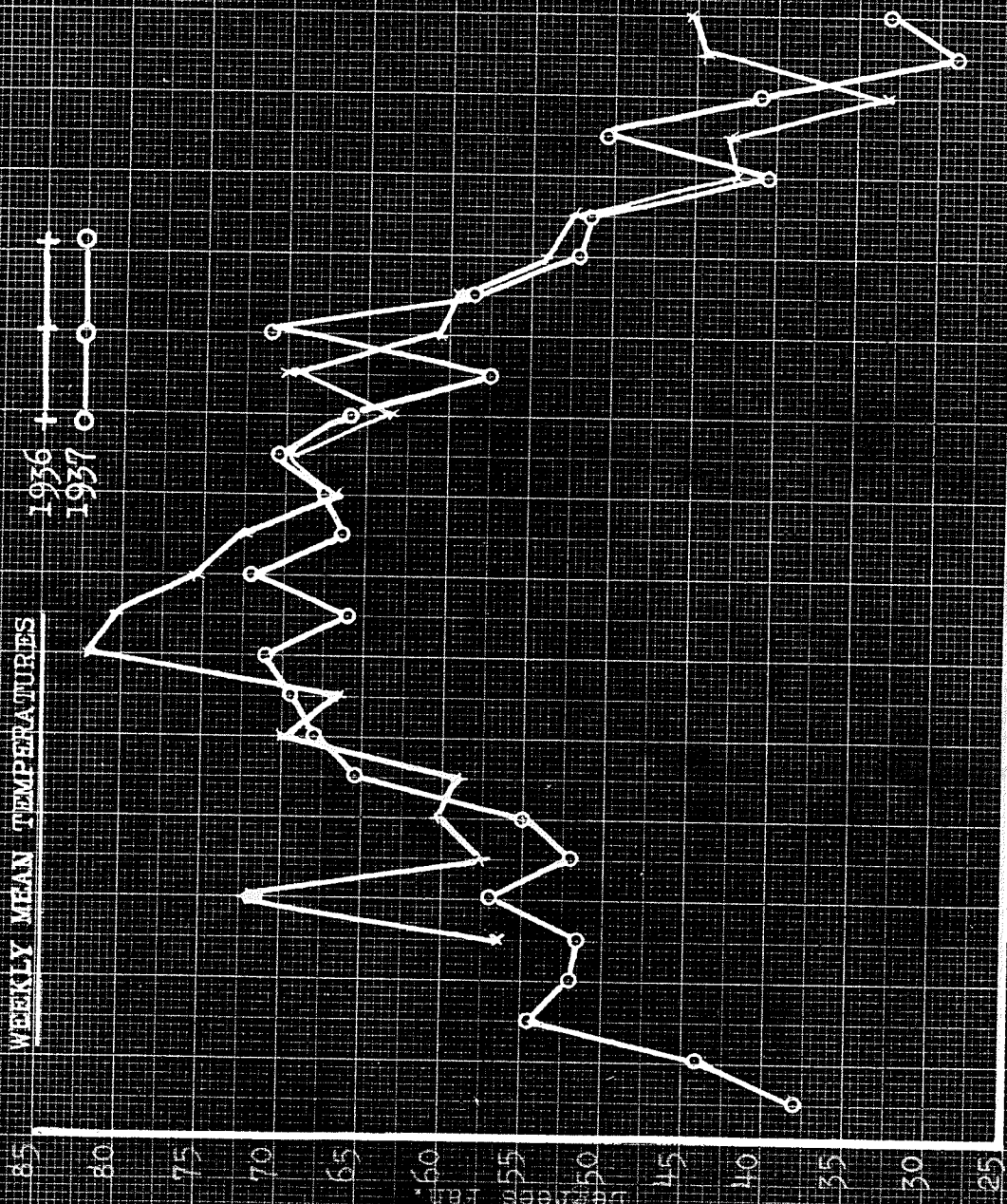


PLATE XII

Monthly Mean Humidities

The monthly mean humidities for 1936 and 1937 have been plotted. The months of May and July of 1936 were much below the same months of 1937. The hythergraph (figures 10 and 11, plate X) indicates the months were warmer and drier in 1936 which would account for these differences in mean humidity.

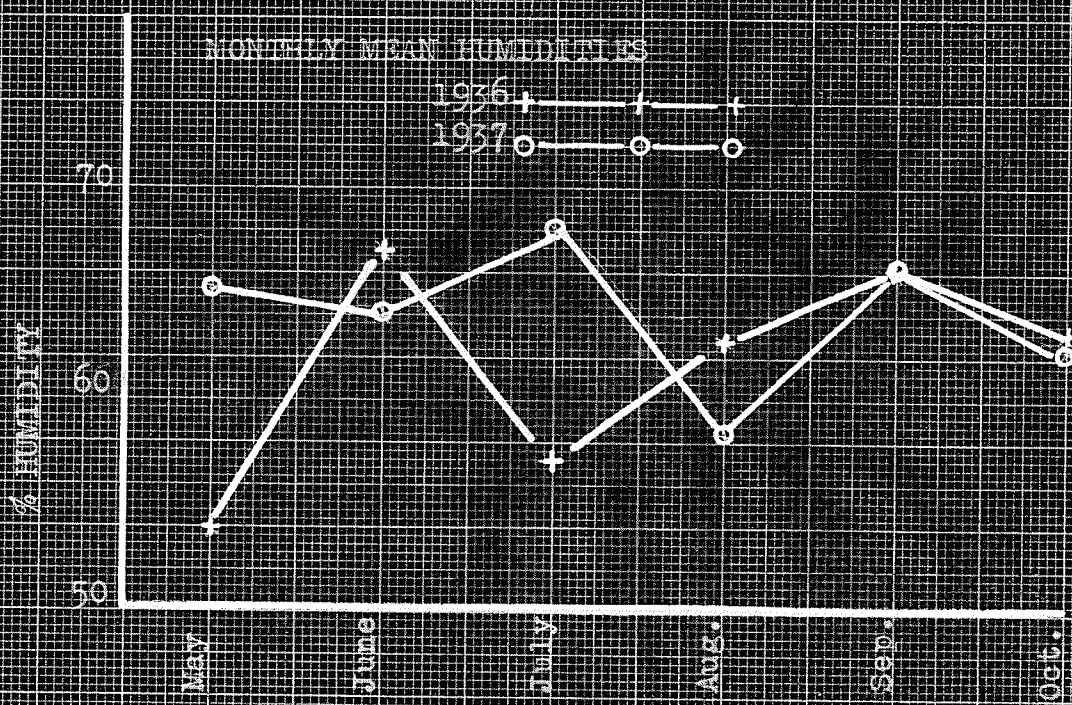


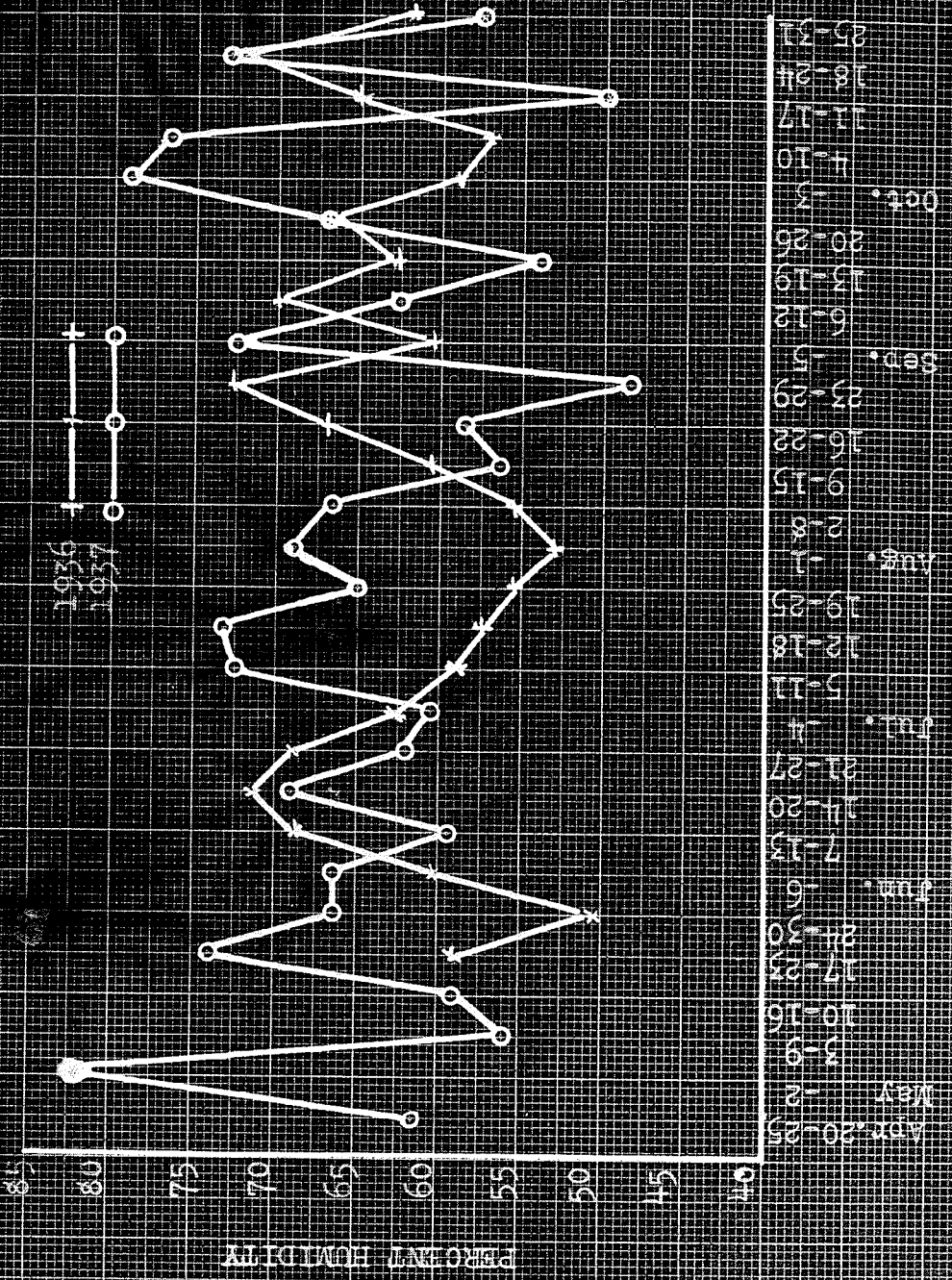
PLATE XIII

Weekly Mean Humidities

The weekly mean humidities for 1936 and 1937 have been plotted. The humidities vary erratically but the lower humidities of the end of May and July, 1936, are the most conspicuous departures. The hythergraph (figures 10 and 11, plate X) indicates the months were warmer and drier in 1936 which would account for these differences in mean humidity.

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WEEKLY MEAN HUMIDITIES



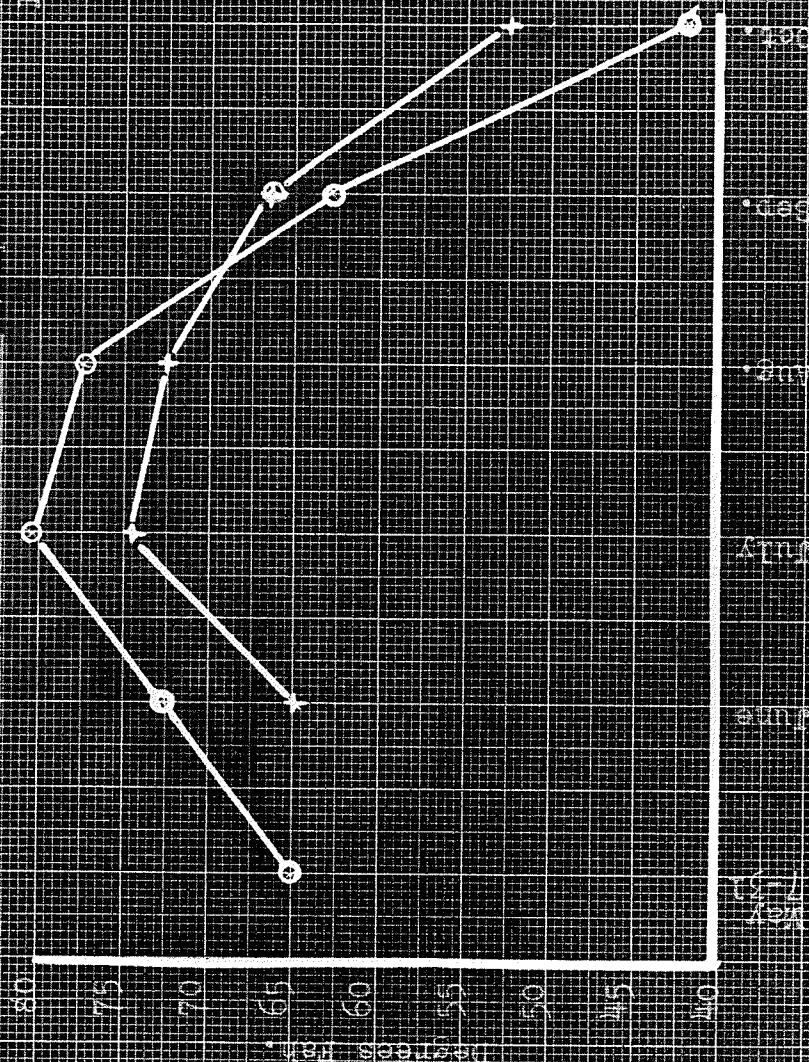
Monthly Mean Soil Temperatures

The monthly mean soil temperatures for both seasons were plotted. The temperatures of June, July and August appear higher in 1937 but the fact that only the 26th and 23rd day were recorded in June and July, 1936, may be responsible to some extent for the wide difference. The soil temperature, it will be noted, dropped off earlier in 1937.

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

MONTHLY SOIL TEMPERATURES (Depth 1m)

1936 + - - - -
1937 o - - - -



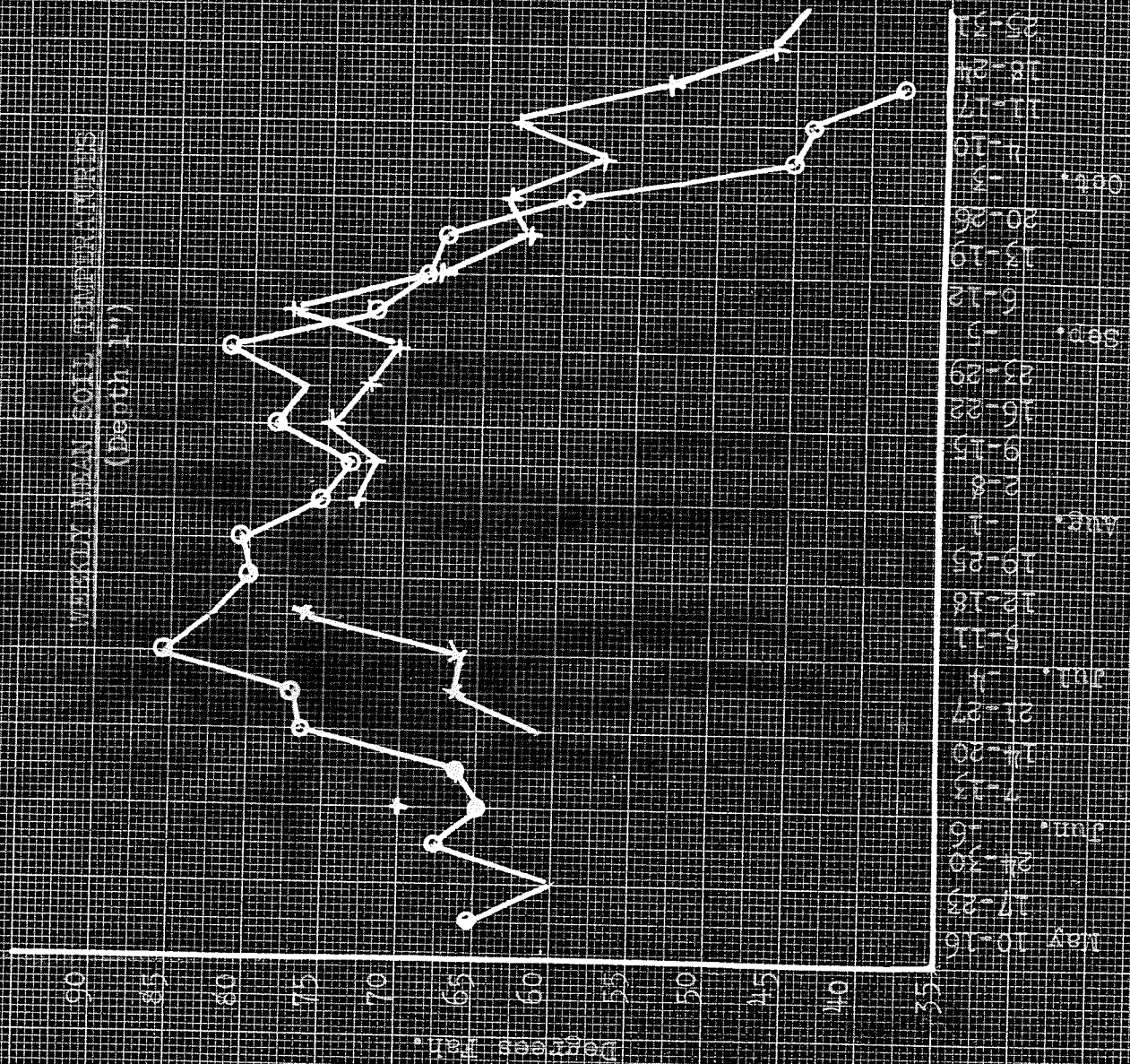
1936
June - 26 days
July - 23 days
Oct. - 30 days

PLATE IV

Weekly Mean Soil Temperatures

The weekly mean temperatures for both seasons were plotted and show essentially the same trend as the monthly mean soil temperatures (plate III).

WEEKLY MEAN SOIL TEMPERATURES (Depth 1")



1936
1937

V. RELATIVE ABUNDANCE OF GRASSHOPPER POPULATION

1. Methods of Studying Yearly Abundance

Estimates of the population were made by egg, nymphal and adult surveys.

(1) Egg survey.-- The egg survey was begun about mid-September and was continued until the end of the month or mid-October. In the following spring additional samples were made to further complete the survey. Approximately 2,000 samples were taken in each survey.

(a) Sampling.-- Two methods of soil sampling were employed.

Sifting.-- A circular sieve, about one foot in diameter, fitted with an 8-inch mesh was used. An area, approximately one foot square, was marked out and the soil to a depth of 2 inches was passed through the sieve. All the egg pods and predators contained in the sample were then revealed. This method was found to be most useful when the soil was loose and dry.

Scraping.-- A mason's trowel was used to scrape off layers of soil until the egg pods and predators were exposed. The scraping was continued until the excavation was 2 inches deep. This method was employed when the soil was too wet for sifting. It was also the quickest method when a firm level location was selected.

(b) System of sampling.-- The preliminary spring survey in 1936 was hastily completed in the spring when the study centre was opened. In the later surveys a system was devised to cover the area as well as possible with the number of samples which could be taken. For this reason transects of 5 samples spaced at intervals of one, 3, 15, 25 and 50 yards were taken into the fields from the border. The original idea was to run a transect into each quarter every 8 miles but time did not permit this detail. In order not to entirely neglect the central

area of the sections strips of samples were banded across the quarter sections. Plates XIX and XXII show the arrangement adopted. It will be obvious also that where possible the transects were run in the same location each year. The Experimental Farm sub-station, section 28, was surveyed in greater detail because records of their management practices are readily available. Roadallowances and drift ridges were sampled so that there would be 5 samples per eighth mile. In the case of roadsides, both sides of the road were sampled, thus 10 samples per 8th mile were taken.

(c) Records.-- As each sample was made its location, the number of egg pods of the known species, the number and kinds of predators, the dominant vegetation, soil type, and slope of ground were recorded. The egg population was plotted on the survey map, suitable symbols being used to designate each species.

(2) Nymphal and adult surveys.-- The nymphal survey was made when the hatch was complete and the adult survey when over 75 percent were adult.

(a) Estimating.-- The population was measured by a visual estimate and recorded as so many nymphs or adults per square yard. This method is the one adopted by Canadian and United States Government surveyors who after considerable experimentation found it the most rapid and accurate method.

(b) System of estimation.-- The study area was surveyed systematically. Transects were run in from the crop edge. This was accomplished by averaging estimates made while proceeding in approximately 100 yards from the border of the field. An attempt was made to take the estimates in the same locations each year. Estimates were made across the strips on strip farms to gain an idea of the uniformity of population. On roadallowances and drift ridges the estimate was made for each eighth mile (plates XVIII, XX, XXI).

(c) Records.-- The estimates were plotted on maps. A system of dots was used to represent the estimates with the idea of showing the main concentrations by the density of dots. Notes were made on

the location of the samples, vegetation, slope of ground, etc.

2. Rating the Egg, Nymphal and Adult Surveys

The allocation of factors for gauging grasshopper infestation established by Shotwell (1938) was used to measure the population. For the Lytleton area the rating given for small field conditions was used in the following manner. The egg counts or estimates of population were averaged for each quarter section, and it was then rated normal, light, etc. If the quarter section rated light or higher it was colored as the following table indicates. The allocation of factors (Shotwell 1938) under nymphal concentration was used to rate the nymphal population. The factors for adult spread and egg pods per square foot were used for the adult and egg surveys respectively. The factors for fields were mostly used but road allowances and drift ridges required use of the factors under the head of margins. The table of allocation of factors appears on the following page.

3. Discussion of Spring Egg Survey 1936

The data from the spring egg survey of 1936 are shown on plate XVI. There were very few places indeed which rated light and these were mainly on drift ridges.

4. Discussion of Nymphal Survey 1936

The nymphal survey following in mid-May showed the grasshopper population was very low (plate XVII). Concentrations were found along the fence lines at that time. The fields were not systematically surveyed but it was known that most fields contained few grasshoppers.

5. Discussion of Adult Survey 1936 (Plate XVIII)

Section 32

Northwest quarter. - No rating.

Table 2.
Allocation of Factors for Small Field Conditions
(Taken from Shotwell 1938)

Rating	Nymphal		Adult		Egg pods		Color on survey map
	Field Margin	concentration	Field Margin	spread	Field Margin	/sq. ft.	
Normal	7	10	4	5	0.5	1	green
	11	17	6	7	0.75	2	
Light	15	25	6	10	1.00	3	yellow
	23	32	11	13	1.50	4.5	
Moderate	30	50	15	20	2.00	6	blue
	45	75	22	30	3.00	9	
Severe	60	100	30	40	4.00	12	red
	90	150	45	60	6.00	18	
Very severe	120	200	60	80	8.00	24	red

PLATE XVI

Spring egg survey 1936.

Lyleton Study Centre

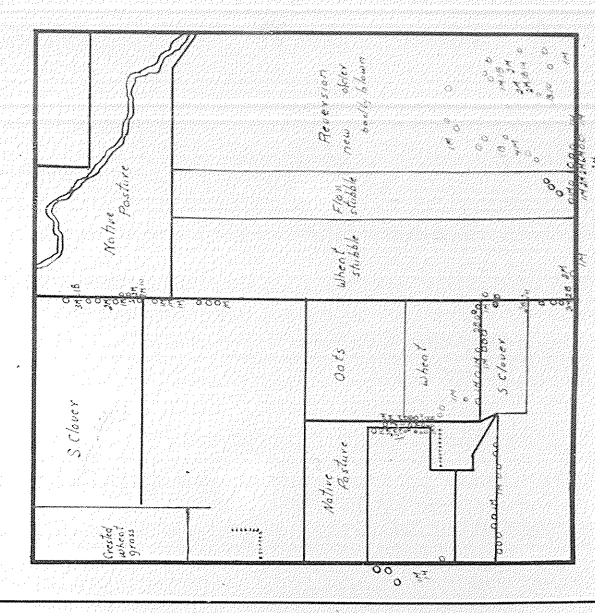
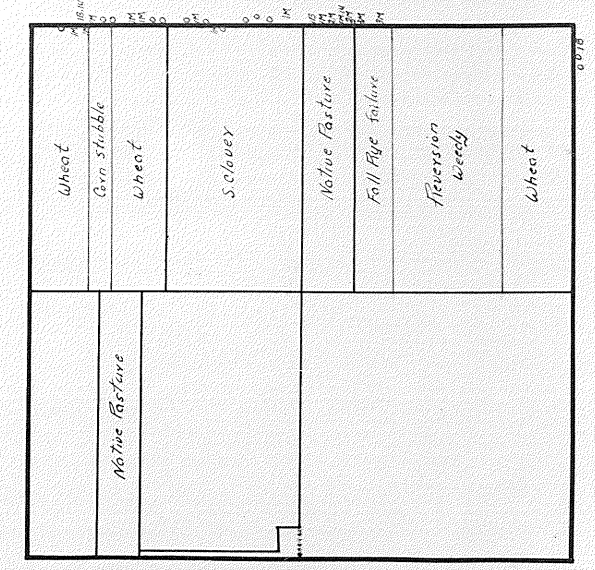
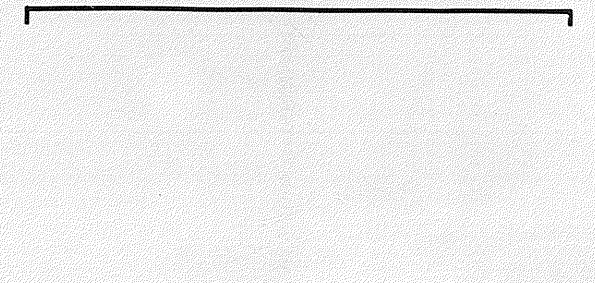
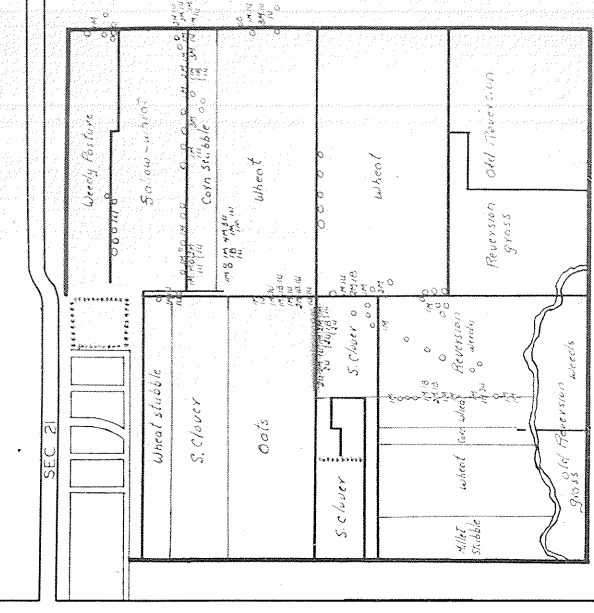
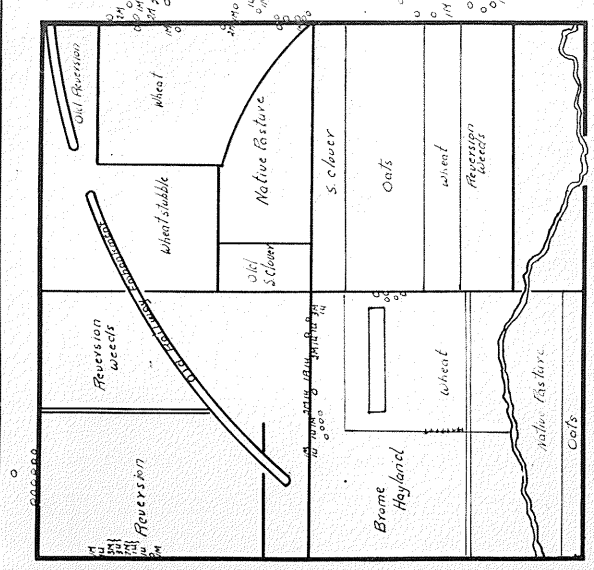
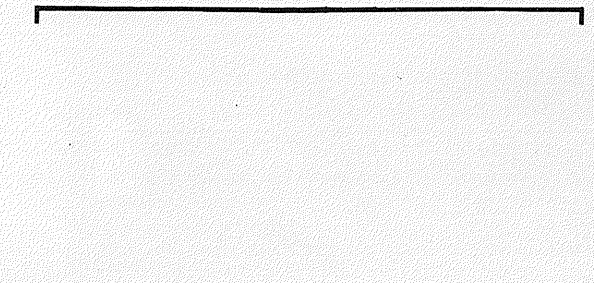
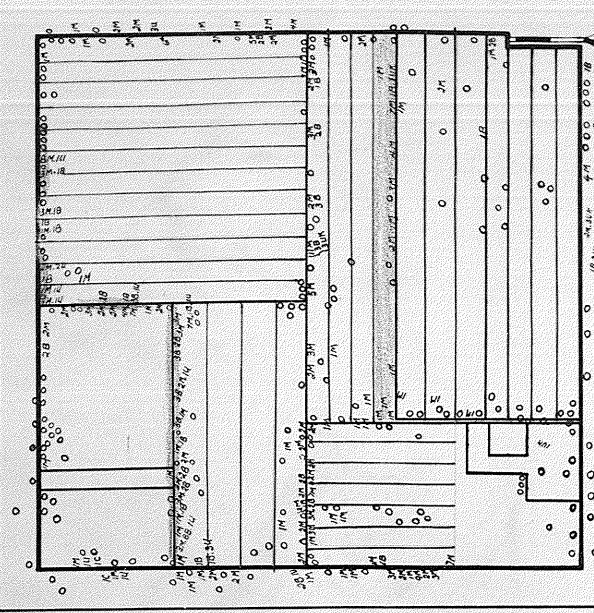
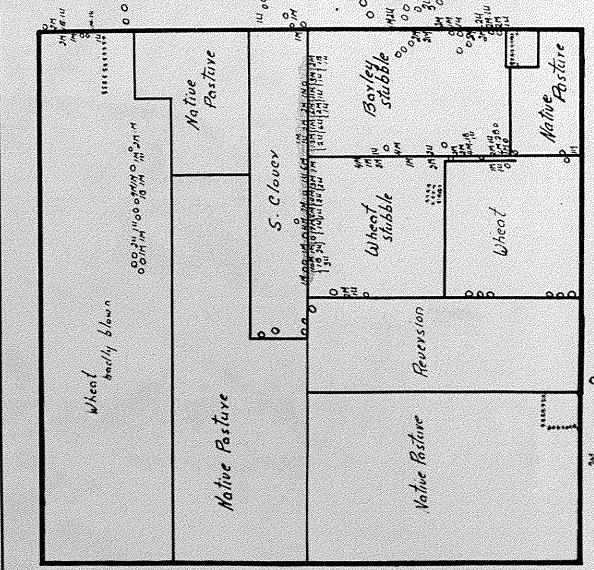
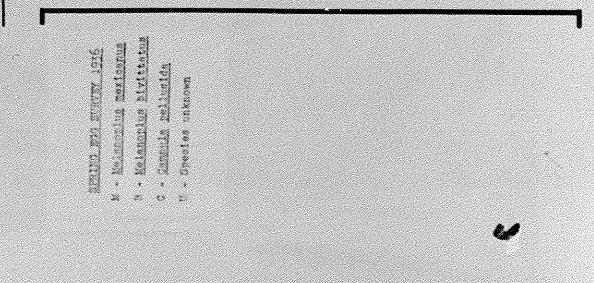
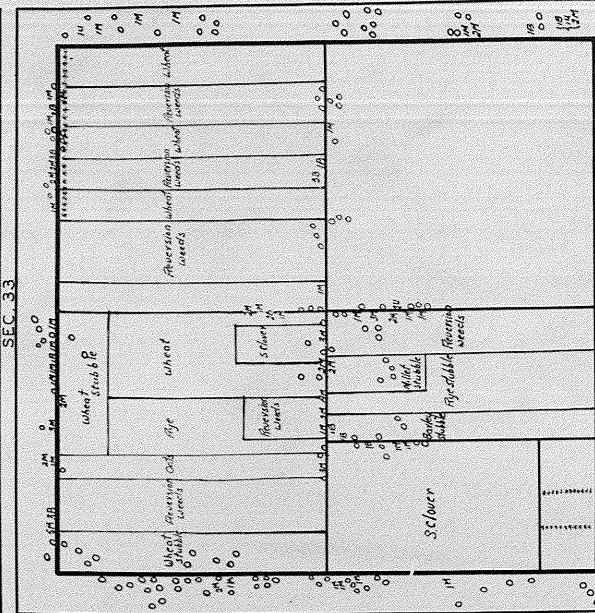
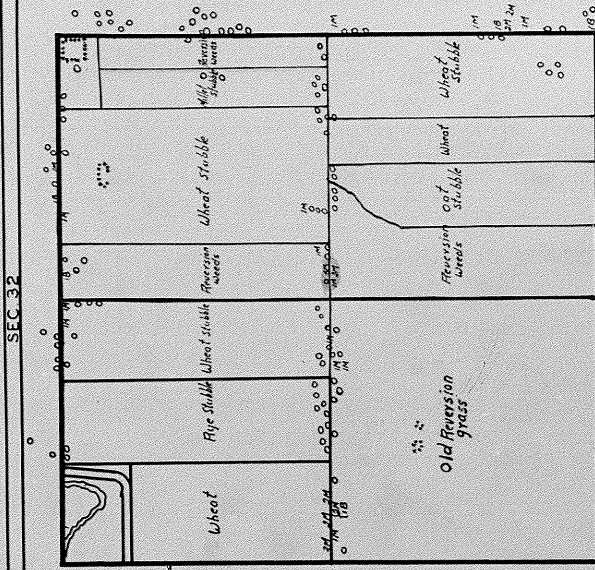
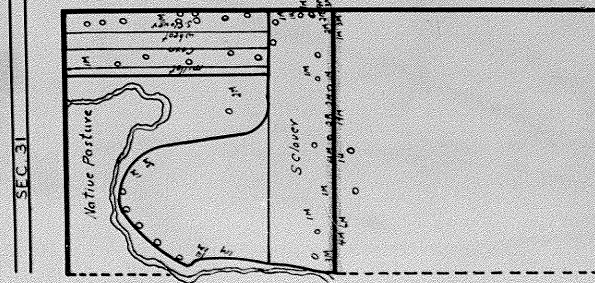
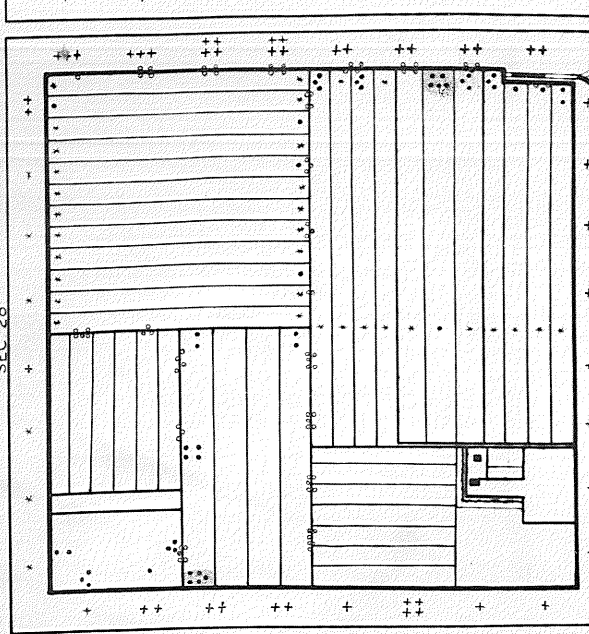
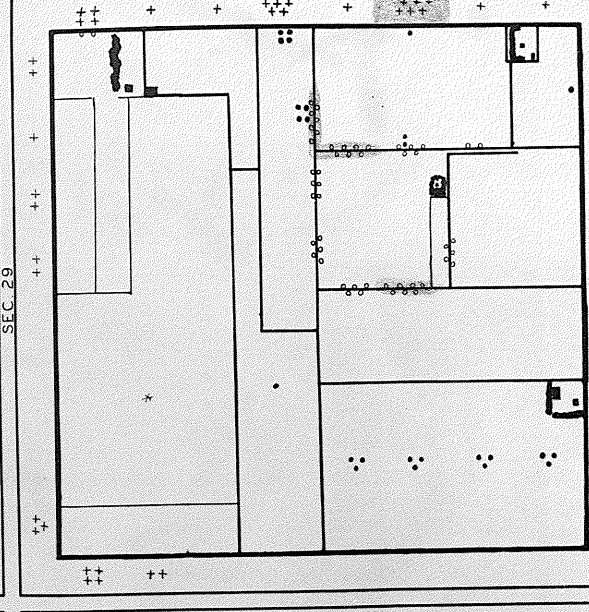
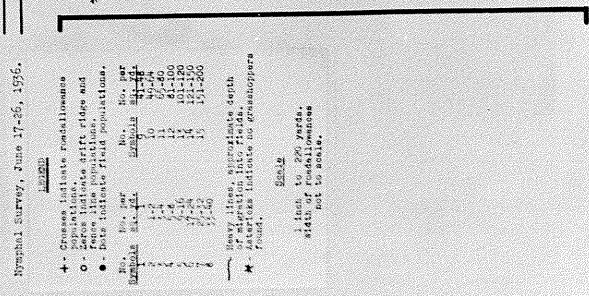
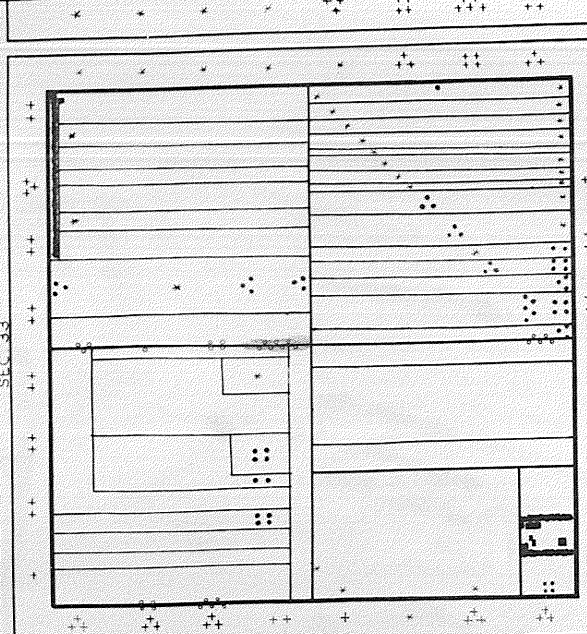
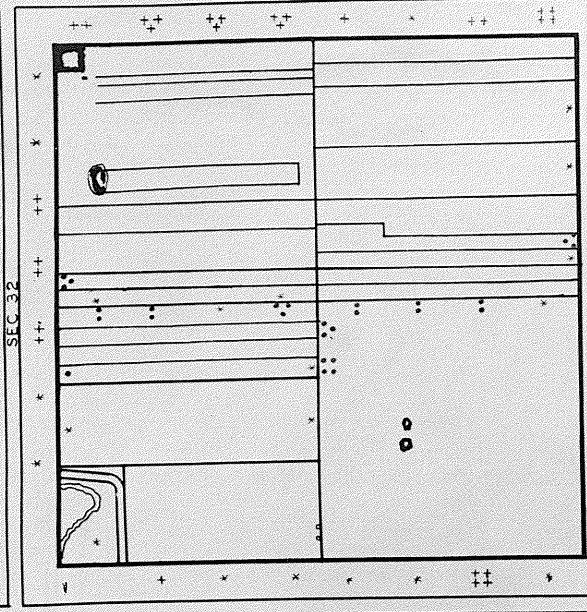
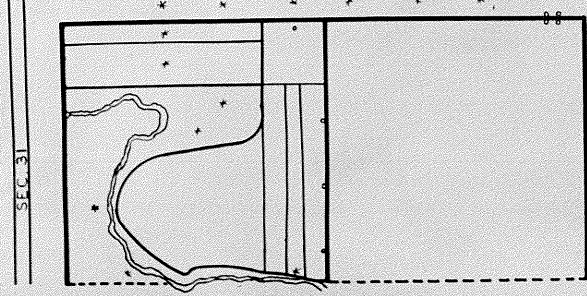


PLATE XVII

Nymphal survey 1936.

Lyleton Study Centre



Nymphal Survey, June 17-26, 1956.

123201

4+ - Section indicates population
 0 - Section indicates drift ridge and
 1 - Section indicates field population.

Pop.	No. per	No. per
1-2	10	40-50
3-4	10	40-50
5-6	10	40-50
7-8	10	40-50
9-10	10	40-50
11-12	10	40-50
13-14	10	40-50
15-16	10	40-50
17-18	10	40-50
19-20	10	40-50
21-22	10	40-50
23-24	10	40-50
25-26	10	40-50
27-28	10	40-50
29-30	10	40-50
31-32	10	40-50
33-34	10	40-50
35-36	10	40-50
37-38	10	40-50
39-40	10	40-50
41-42	10	40-50
43-44	10	40-50
45-46	10	40-50
47-48	10	40-50
49-50	10	40-50
51-52	10	40-50
53-54	10	40-50
55-56	10	40-50
57-58	10	40-50
59-60	10	40-50
61-62	10	40-50
63-64	10	40-50
65-66	10	40-50
67-68	10	40-50
69-70	10	40-50
71-72	10	40-50
73-74	10	40-50
75-76	10	40-50
77-78	10	40-50
79-80	10	40-50
81-82	10	40-50
83-84	10	40-50
85-86	10	40-50
87-88	10	40-50
89-90	10	40-50
91-92	10	40-50
93-94	10	40-50
95-96	10	40-50
97-98	10	40-50
99-100	10	40-50

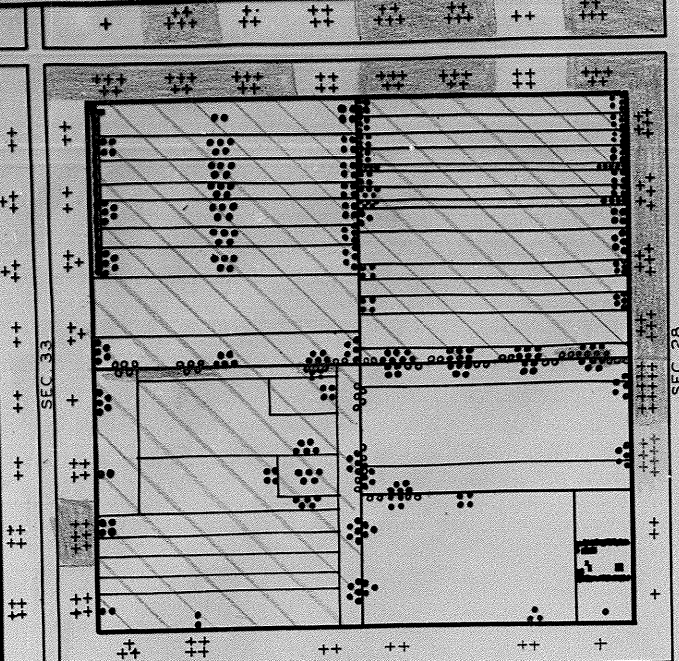
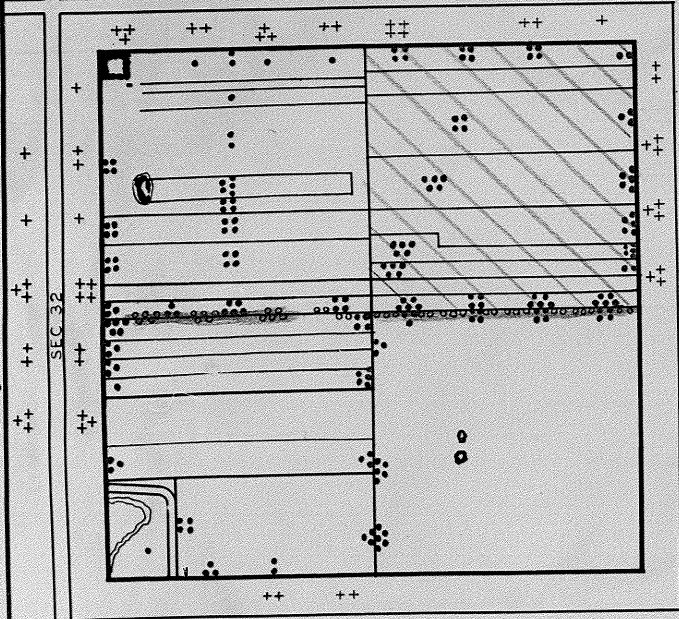
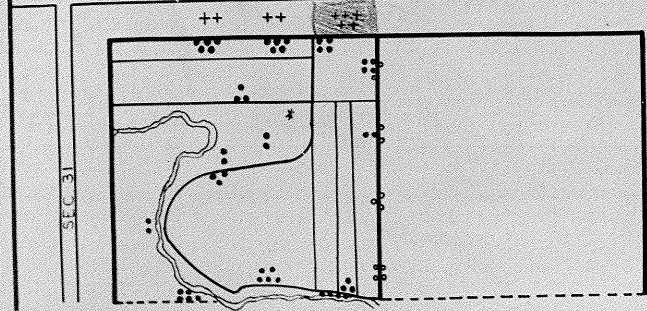
Map: Area, 1000 ft. by 1000 ft.
 of migration into field.
 Asterisks indicate in grasshopper
 field.

Scale
 1 inch = 1000 feet
 1/4 inch = 250 feet
 1/8 inch = 125 feet
 1/16 inch = 62.5 feet
 1/32 inch = 31.25 feet
 1/64 inch = 15.625 feet
 1/128 inch = 7.8125 feet
 1/256 inch = 3.90625 feet
 1/512 inch = 1.953125 feet
 1/1024 inch = 0.9765625 feet
 1/2048 inch = 0.48828125 feet
 1/4096 inch = 0.244140625 feet
 1/8192 inch = 0.1220703125 feet
 1/16384 inch = 0.06103515625 feet
 1/32768 inch = 0.030517578125 feet
 1/65536 inch = 0.0152587890625 feet
 1/131072 inch = 0.00762939453125 feet
 1/262144 inch = 0.003814697265625 feet
 1/524288 inch = 0.0019073486328125 feet
 1/1048576 inch = 0.00095367431640625 feet
 1/2097152 inch = 0.000476837158203125 feet
 1/4194304 inch = 0.0002384185791015625 feet
 1/8388608 inch = 0.00011920928955078125 feet
 1/16777216 inch = 5.960464477539062e-05 feet
 1/33554432 inch = 2.980232238769531e-05 feet
 1/67108864 inch = 1.490116119384766e-05 feet
 1/134217728 inch = 7.450580596923828e-06 feet
 1/268435456 inch = 3.725290298461914e-06 feet
 1/536870912 inch = 1.862645149230957e-06 feet
 1/1073741824 inch = 9.313225746154784e-07 feet
 1/2147483648 inch = 4.656612873077392e-07 feet
 1/4294967296 inch = 2.328306436538696e-07 feet
 1/8589934592 inch = 1.164153218269348e-07 feet
 1/17179869184 inch = 5.82076609134674e-08 feet
 1/34359738368 inch = 2.91038304567337e-08 feet
 1/68719476736 inch = 1.455191522836685e-08 feet
 1/137438953472 inch = 7.275957614183425e-09 feet
 1/274877906944 inch = 3.637978807091712e-09 feet
 1/549755813888 inch = 1.818989403545856e-09 feet
 1/1099511627776 inch = 9.09494701772928e-10 feet
 1/2199023255552 inch = 4.54747350886464e-10 feet
 1/4398046511104 inch = 2.27373675443232e-10 feet
 1/8796093022208 inch = 1.13686837721616e-10 feet
 1/17592186044416 inch = 5.6843418860808e-11 feet
 1/35184372088832 inch = 2.8421709430404e-11 feet
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PLATE XVIII

Adult survey 1936.

Lyleton Study Centre



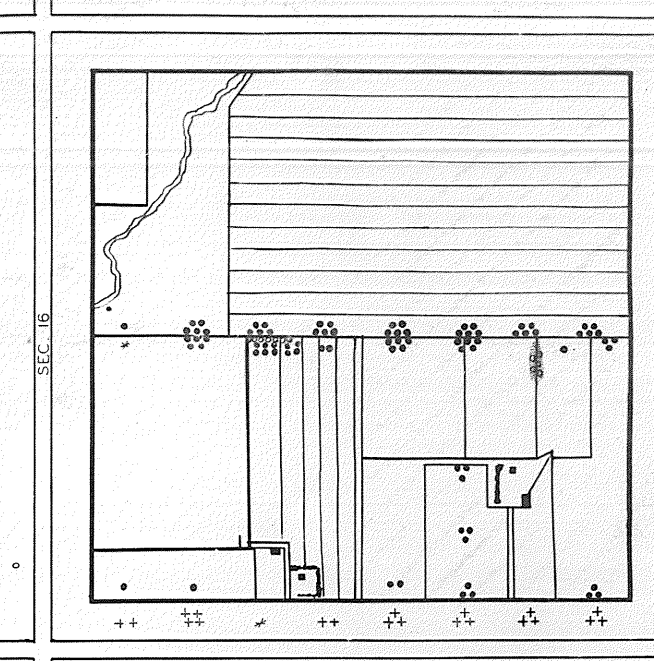
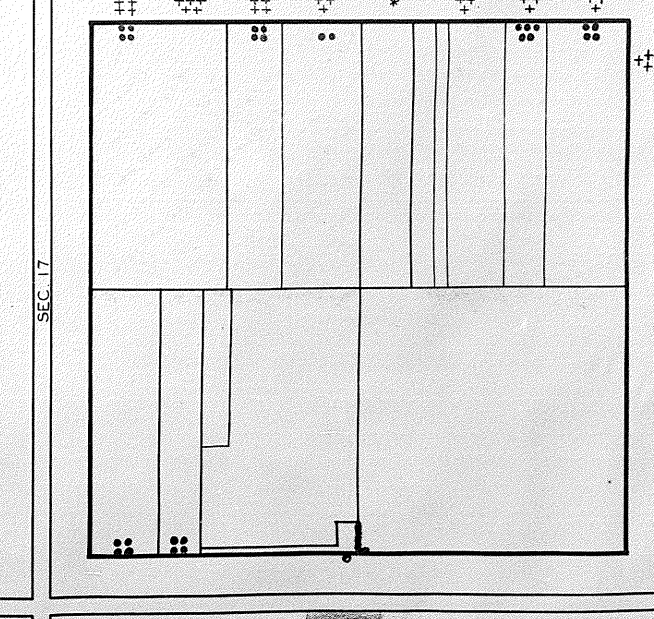
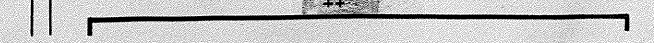
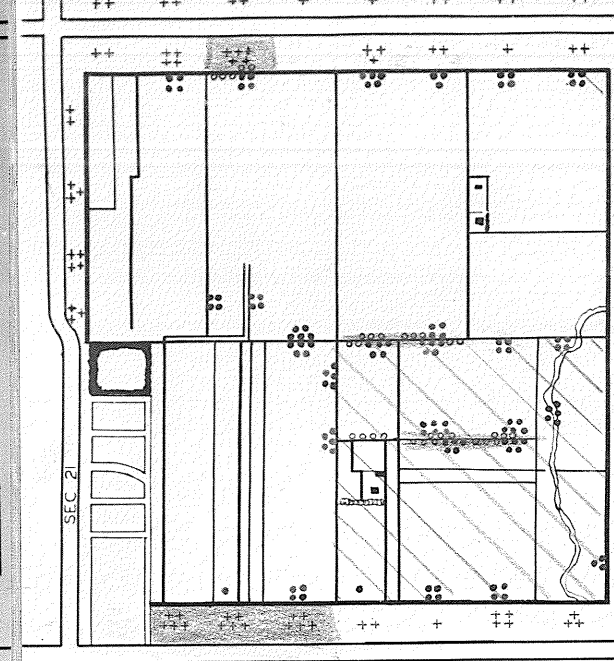
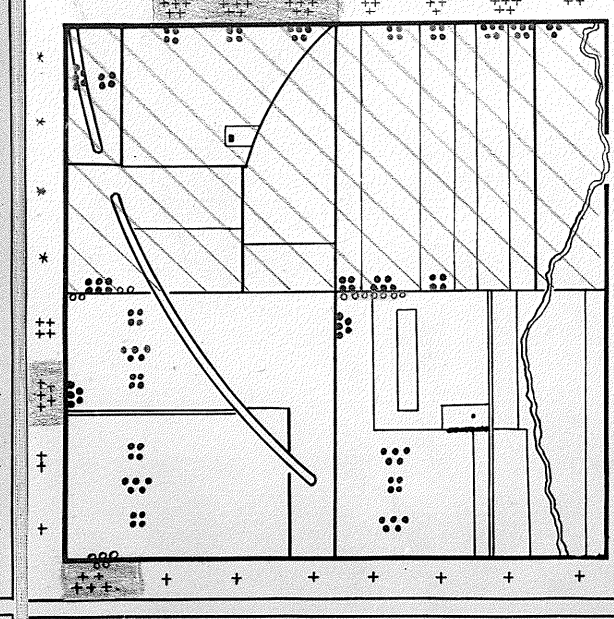
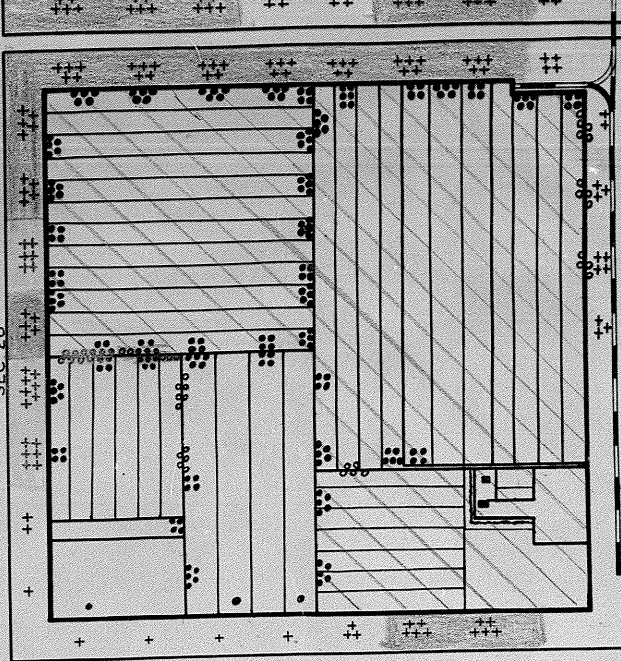
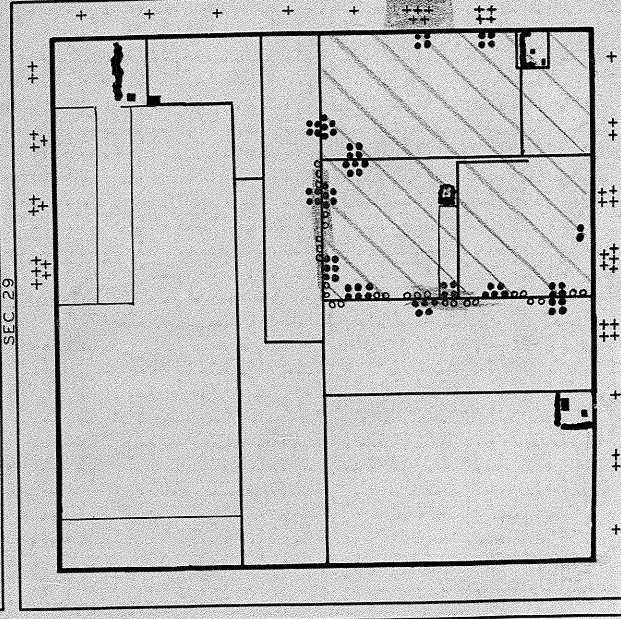
Adult Survey, August 3-10, 1956

Legend

+ - Green indicates fossiliferous
populations
o - Green indicates drift ridge and
fossil line populations
* - Green indicates fossil populations

Section	No. of sites	No. per site	Total
31	1	1	1
32	11	10-40	110
33	15	10-120	150
34	15	10-120	150
35	15	10-120	150
36	15	10-120	150
37	15	10-120	150
38	15	10-120	150
39	15	10-120	150
40	15	10-120	150
41	15	10-120	150
42	15	10-120	150
43	15	10-120	150
44	15	10-120	150
45	15	10-120	150
46	15	10-120	150
47	15	10-120	150
48	15	10-120	150
49	15	10-120	150
50	15	10-120	150
51	15	10-120	150
52	15	10-120	150
53	15	10-120	150
54	15	10-120	150
55	15	10-120	150
56	15	10-120	150
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58	15	10-120	150
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72	15	10-120	150
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87	15	10-120	150
88	15	10-120	150
89	15	10-120	150
90	15	10-120	150
91	15	10-120	150
92	15	10-120	150
93	15	10-120	150
94	15	10-120	150
95	15	10-120	150
96	15	10-120	150
97	15	10-120	150
98	15	10-120	150
99	15	10-120	150
100	15	10-120	150

Heavy lines, elevations 200
American Indians, elevations 200
Found.



Northeast quarter.-- No rating.

Southwest quarter.-- No rating.

Southeast quarter.-- Rated "light". The west side was a little heavier than the east.

Section 33

Northwest quarter.-- Rated "light", probably because of a small block of reversion where the population ran around 15 to the square yard.

Northeast quarter.-- Rated. Population here was general.

Southwest quarter.-- Did not rate.

Southeast quarter.-- Rated "light". A barley crop next to the half mile line was particularly heavy, running from 15 to 30 per square yard.

Section 29

Northwest quarter.-- No rating.

Northeast quarter.-- No rating.

Southwest quarter.-- No rating. These three quarters of the section were not surveyed at this time but on July 17 and 23 a few hoppers were found.

Southeast quarter.-- The north 40 acres grew a crop of oats. From the north and east fence lines bordering it a large number of nymphs hatched late in the spring and entered the crop which was badly damaged. This quarter rated "light". The population was general.

Section 28

Northwest quarter.-- Did not rate.

Northeast quarter.-- Rated "light" but only one wheat strip (No. 5) carried 15 grasshoppers per square yard.

Southwest quarter.-- Rated "light" but few

estimates were made there.

Southeast quarter.- Rated "light". A concentration of approximately 25 per square yard was found in a small block of oats and millet at the east end of strip 10.

Section 21

Northwest, northeast and southeast quarters.- Did not rate.

Southwest quarter.- Rated "light" because a block of reversion ran from 10 to 15 per square yard.

Section 20

Northwest and southwest quarters.- No rating.

Northeast quarter.- Rated "light" because a crop of oats in the northeast corner had a concentration of 30 per square yard along its edge.

Southeast quarter.- Rated "light". Population was general.

Sections 17 and 16.- Did not rate.

Drift Ridges

The drift ridges (colored green on the map) showed where there were high enough concentrations to rate "light". These were found principally on sections 32, 33, 26, 29 and 21.

Road allowances

East of sections 33 and 26 rated "light". The mile between sections 33 and 26 ran from "light" to "severe", the heavier pockets being found close to the drift ridges.

(1) Comparison of nymphal and adult surveys 1936.- The grasshopper population appeared at adult survey time in early August much increased. None of

the area in the spring rated "light" but the adult survey showed that the southeast quarter of section 32, three quarters of section 33, one quarter of section 29, three quarters of section 28, the southwest quarter of section 21, and half of section 20 rated "light". The roadallowance east of sections 33 and 28 rated "light" to "normal" as plate XVIII indicates.

In that year hatching, especially from the drift ridges, was much prolonged. After the end of June concentrations were present along the edges of many fields. Intense heat caused them to spread into the crops around July 5. From then onward until the crops were cut and general migrations began they continued to disperse widely. Flights began on July 13 but the first heavy migratory flight occurred on July 22. A much heavier flight from the northwest occurred on July 27 and crop cutting followed a few days later. Therefore, the population present during the adult survey came from the many border concentrations which fused and the additions to population caused by flights.

The roadallowance between sections 33 and 28 had an interesting concentration. The eastern three quarters of a mile south of the road and a quarter of a mile north of the road immediately west of the half line were ploughed in the spring. The farmer attempted to get a catch of brome. Wheat and fall rye were used as nurse crops. Grasshoppers began to gather on the roadallowance about the end of June. Soon they crossed to the road to the succulent mat of young brome and remained with it until the end of August. By July 15 the grass was badly scorched by high mid-summer temperatures but the grasshoppers stayed to feed on the base of the culms which remained succulent.

6. Discussion of Fall Egg Survey 1936 (Plate XIX)

Section 31. - No rating.

Section 32

Northwest quarter. - No rating. Average number of eggs per sample was 0.9. The second strip east of the quarter mile line growing fall rye rated "light".

Northeast quarter.-- No rating. Average number of eggs per sample was 0.64.

Southwest quarter.-- No rating. Average number of eggs per sample was 0.66.

Southeast quarter.-- Average number of eggs per sample was 0.56. A strip of reversion, fourth east of the half mile line, rated "light".

Section 33

Northwest quarter.-- No rating. Average number of eggs per sample was 0.53. Only a reversion strip east of the road and the reverted block rated "light".

Northeast quarter.-- No rating. The average number of eggs per samples was 0.65.

Southwest quarter.-- No rating. Average number of eggs per sample was 0.53. The wheat field in the west eighth section rated "light".

Southeast quarter.-- Rated "light". Average number of eggs per sample was 1.1. The barley strip beside the half mile line rated "moderate" as did a large reversion strip in the centre while the rest of the crop, exclusive of summer-fallows, rated "light".

Section 29

Northwest quarter.-- No rating. Average number of eggs per sample was 0.5.

Northeast quarter.-- No rating. Average number of eggs per sample was 0.5.

Southwest quarter.-- Rated "light". Average number of eggs per sample was 1.7. The east reversion field was a little heavier than the rest.

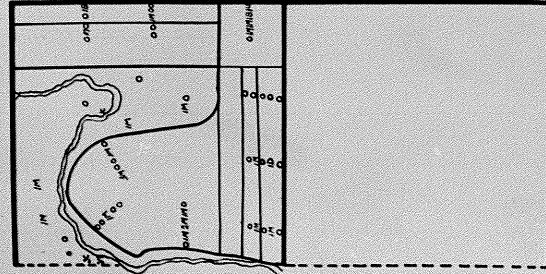
Southeast quarter.-- No rating. Average number of eggs per sample was 0.7. The south 40-acre field in wheat rated "light" with an average of 1.2.

PLATE XIX

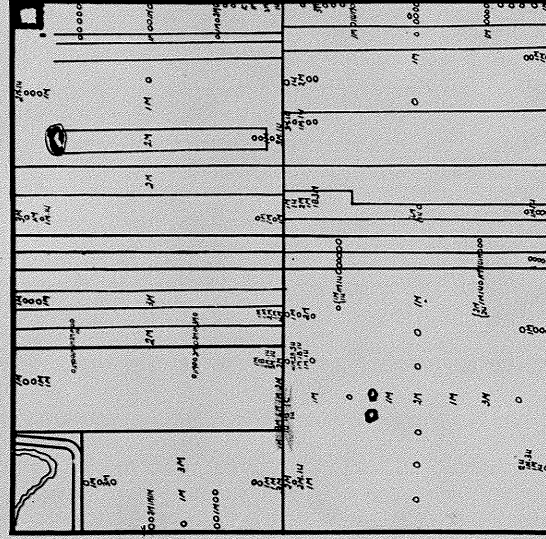
Egg survey 1936.

Lyleton Study Centre

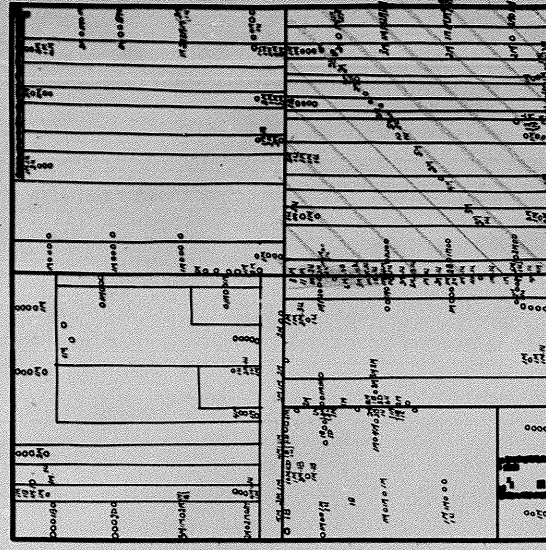
SEC. 31



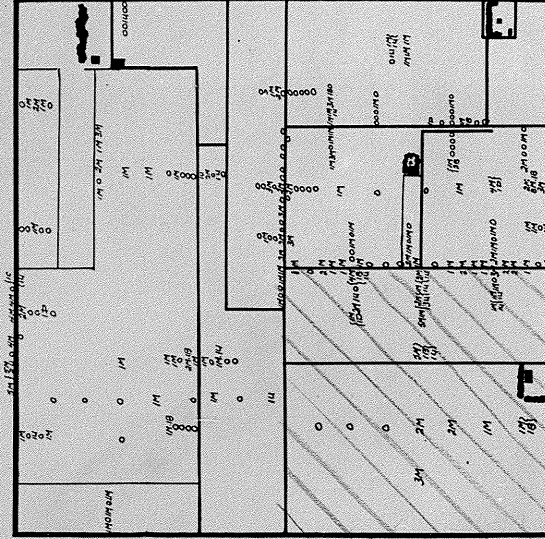
SEC. 32



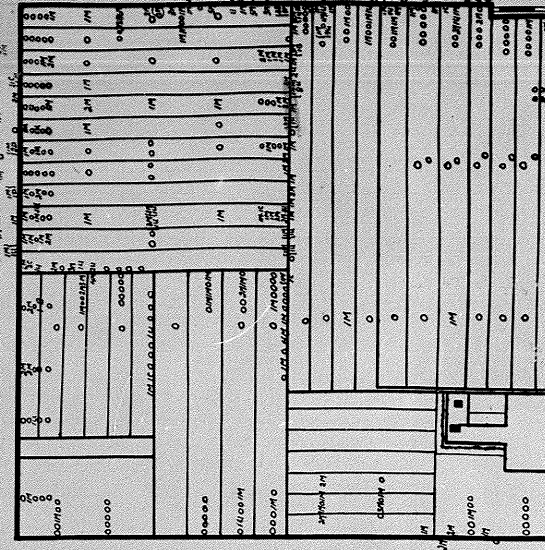
SEC. 33



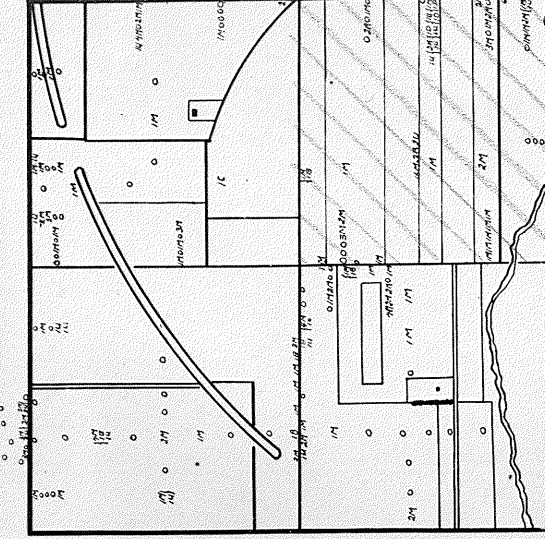
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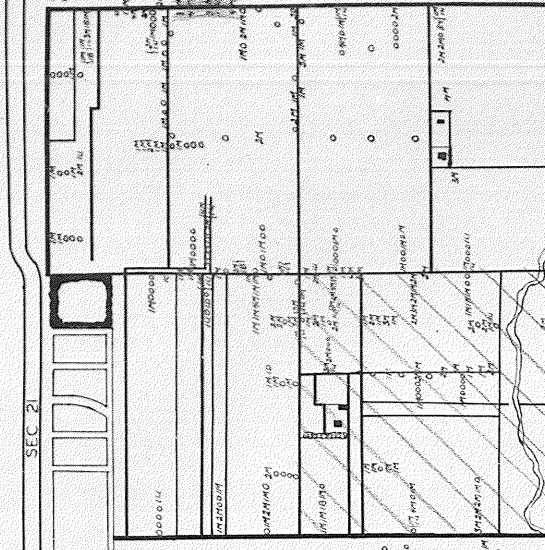
SEC. 28



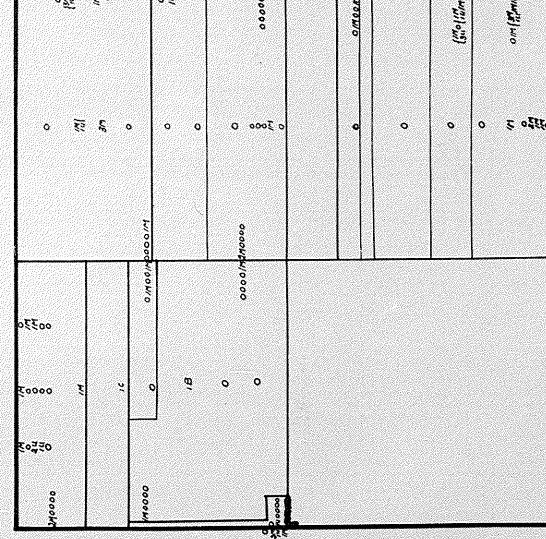
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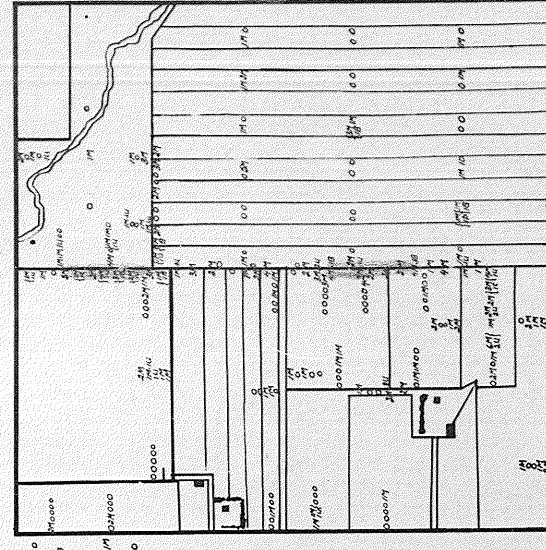
SEC. 21



SEC. 17



SEC. 16



FALL AND SPRING 1971
 SUMMER 1972 AND 1973
 M - *Malurus mexicanus*
 B - *Malurus bairdii*
 C - *Campestris nelsoni*
 D - *Pluricinctus carolinensis*
 U - Species unknown

Section 28

Northwest quarter.-- No rating. Very low, average number of eggs per sample being 0.34.

Northeast quarter.-- No rating. Average number of eggs per sample was 0.77. Strip 10 growing fall rye rated "light" and strip one in wheat was also "light".

Southeast quarter.-- No rating. Very low, the average number of eggs per sample being 0.14.

Section 21

Northwest quarter.-- No rating. Average number of eggs per sample was 0.66.

Northeast quarter.-- No rating. Average number of eggs per sample was 0.65.

Southwest quarter.-- Rated "light". Average number of eggs per sample was 1.1. A reverted block in clover along the east side averaged 1.3, being much higher than the wheat land which only averaged 0.8.

Southeast quarter.-- No rating. Average number of eggs per sample was 0.8. Only a small piece of old reversion near the buildings, about 10 acres, rated "moderate".

Section 20

Northwest quarter.-- No rating. Average number of eggs per sample was 0.54.

Northeast quarter.-- No rating. Average number of eggs per sample was 0.66.

Southwest quarter.-- No rating. Average number of eggs per sample was 0.77.

Southeast quarter.-- Rated "light". Average number of eggs per sample was 1.3. Here a high count in the centre of the section caused this rating.

Section 17

Northwest quarter.-- No rating. Very low. Average number of eggs per sample was 0.28.

Northeast quarter.-- No rating. Average number of eggs per sample was 0.3.

Southeast quarter.-- No rating. Average number of eggs per sample was 0.6.

Section 16

Northwest quarter.-- No rating. Average number of eggs per sample was 0.42.

Northeast quarter.-- No rating. Average number of eggs per sample was 0.69.

Southwest quarter.-- No rating. Average number of eggs per sample was 0.76. A small clover field near the southeast corner rated "moderate".

Southeast quarter.-- No rating. Average number of eggs per sample was 0.56.

Drift Ridges

Only spots of drift ridge on sections 32, 33, 28, 21, and 16, shown in plate XIX, rated "light".

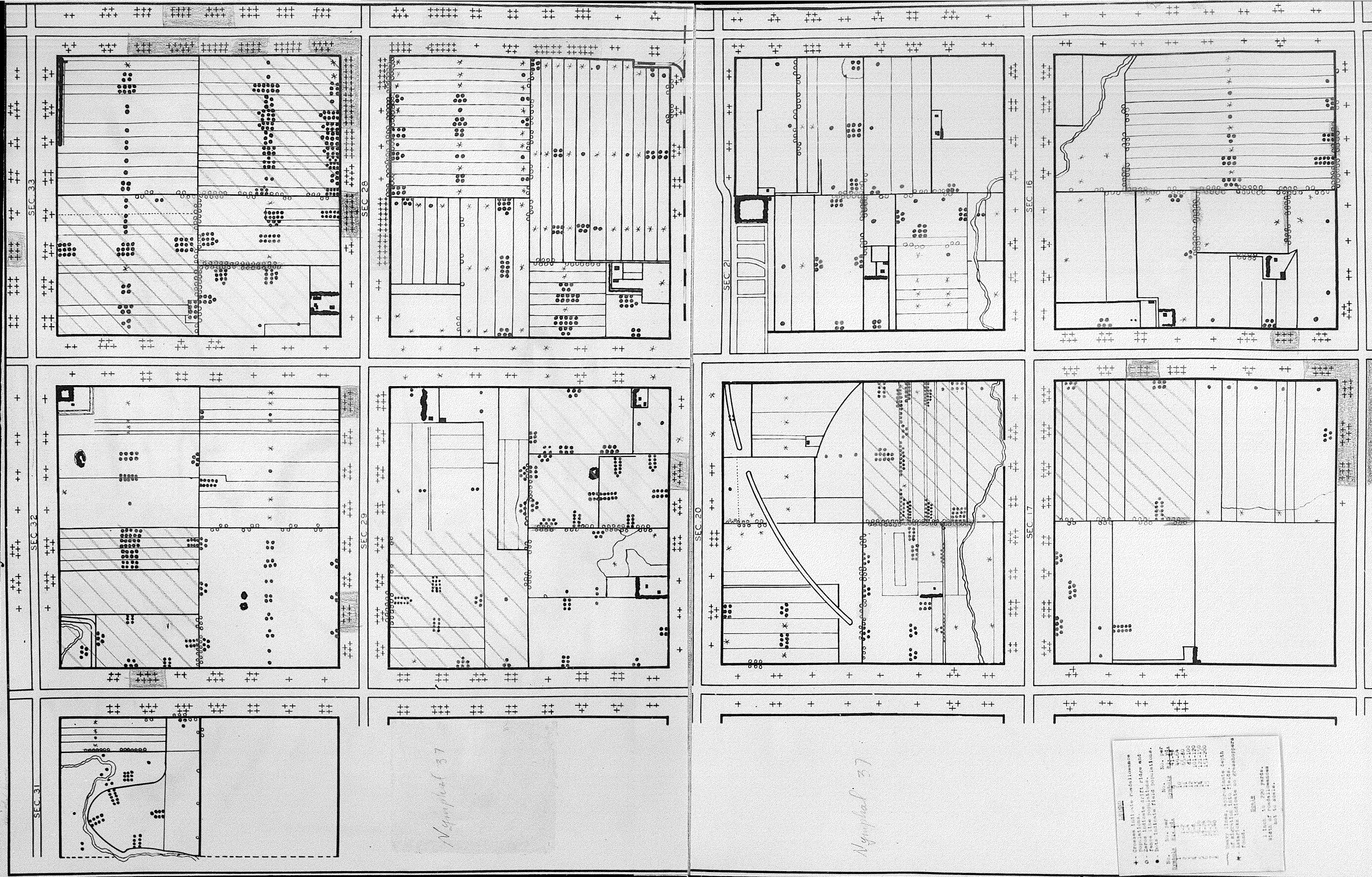
Roadallowances

Only the roadallowances where eggs were expected in sufficient number for surveying were completed. Only 3 eighth mile blocks north and east of section 28 rated. The "moderate" patch at the northeast corner of section 28 rated "moderate" because a small pocket of Cannula was found there. This was the only patch of Cannula found during this survey.

(1) Comparison of adult and fall egg surveys 1936.-- The fall egg survey when compared with the adult survey shows a much lower infestation. Only three quarter sections rated "light" in both the adult and

PLATE XX

Nymphal survey 1937.



Nymphal 37

Nymphal 37

Legend

+ Contour lines, road, railroad
 O - Wells indicate drift, river and
 - - - - - Fences indicate field boundaries
 * - - - - - Bush indicate field boundaries

Sec.	No. of Acres	No. of Acres	No. of Acres	No. of Acres	No. of Acres	No. of Acres	No. of Acres	No. of Acres	No. of Acres
15	10	10	10	10	10	10	10	10	10
16	10	10	10	10	10	10	10	10	10
17	10	10	10	10	10	10	10	10	10
20	10	10	10	10	10	10	10	10	10
21	10	10	10	10	10	10	10	10	10
28	10	10	10	10	10	10	10	10	10
29	10	10	10	10	10	10	10	10	10
32	10	10	10	10	10	10	10	10	10
33	10	10	10	10	10	10	10	10	10

Heavy lines, indicate with
 light lines, indicate with
 * - - - - - indicate no grasshoppers
 road.

Scale
 1 inch = 20 feet.
 1/2 inch = 10 feet.
 1/4 inch = 5 feet.

egg surveys, southeast of section 33, southeast of 20, and southwest of 21. On the other hand, only one quarter section, southwest in section 29, rated above the adult survey, possibly because a few estimates were made there at that time. The southeast quarter of section 33 rated "light" mainly because a barley strip which had 25 to 35 hoppers per square yard in the adult survey rated a "moderate" egg infestation. Also, one of the reverted strips rated "light". The southeast quarter of section 20 rated "light" because of a heavier egg deposit in the southern fields, one in clover, the other a weedy reversion. The southwest quarter of section 21 rated "light". Here a small piece of clover and a piece of reversion favored egg deposition.

Of the roadallowances surveyed it is interesting to find that the heavy concentration between sections 33 and 28 rated in only two eighth miles (see plate XIX). It is appropriate to mention here that the nymphal survey of 1937 revealed the egg deposit must have been higher than the egg survey indicated.

7. Discussion of Nymphal Survey 1937 (Plate XX)

Section 31

No rating. The field on the point rated "moderate". Also a small pocket of Camnula, averaging 100 per square yard, was found in the creek flat just off the east side of the point.

Section 32

Northwest quarter.- Rated "light". Rye crops stubbled in and rye stubbles for summer-fallow on the east side of the quarter section caused the rating.

Northeast quarter.- Did not rate. On the cropped land a very few hoppers were found. On the centre field a stubble left for a surface cultivated fallow was "moderately" infested.

Southwest and southeast quarters.- No rating. There were very few hoppers.

Section 13

Northwest quarter.- Rated "light" because the centre rye stubble was not completely ploughed nor was the small block of reversion at its south end. From this strip 80 to 100 hoppers per yard hatched to invade a crop land which then harbored very few nymphs.

Northeast quarter.- Did not rate. Only a wheat stubble on the east side had 40 nymphs per yard while most of the remaining land had been prepared for crop and was free of nymphs.

Southwest quarter.- Rated "moderate". The east eighth section was in stubble except for a small strip of surface cultivated land which carried few hoppers. However, it may be noted that the east border of the west eighth section (in wheat) carried 50 to 60 per square yard into a depth of 100 yards, suggesting that they moved as the stubble on the east was cultivated. Later considerable foliage trimming occurred here and an application of bait was made.

Southeast quarter.- Rated "light". This quarter section was worked slovenly. Several small stubble strips were left for summer-fallow which this farmer usually cannot manage to do until the time of fall ploughing. The stubble had populations ranging from 10 to 80 nymphs per yard while the strips worked for crop ran from less than one to 20 per square yard, reaching a maximum of 30 to 60 per square yard in some places where nymphs were entering the crop strips. Trimming was noticeable at this time along the edges of some of the strips. Of 20 acres of millet crop on the east side approximately 8 were completely destroyed by nymphs.

Section 20

Northwest quarter.- Rated "light" but when the estimates were averaged a "moderate" rating was indicated. However, the estimates were made mostly in the central reversion part and it was felt that a "light" rating was sufficiently high.

Northeast quarter.-- No rating.

Southwest quarter.-- No rating. The pasture was uniformly infested.

Southeast quarter.-- Rated "moderate", especially the west eighth.

Section 28

Northwest quarter.-- No rating but a rye strip that was stubbled in had a population of from 50 to 60 per square yard.

Northeast quarter.-- No rating.

Southwest quarter.-- No rating. Here, only a rye strip and one wheat strip sown to corn in 1936 had populations of 60 and 30 per square yard respectively.

Southeast quarter.-- No rating. Population light. Only one wheat strip had from 5 to 20 nymphs per square yard.

Section 21

Northwest quarter.-- No rating.

Northeast quarter.-- No rating. Only one strip of stubble had from 20 to 40 per square yard.

Southwest quarter.-- No rating. The only population found was on the reversion at the east side.

Southeast quarter.-- No rating.

Section 20

Northwest and northeast quarters.-- No rating.

Southwest quarter.-- No rating. The wheat stubble left on the east side hatched 40 nymphs per square yard.

Southeast quarter.- Was poorly farmed. Several small lands of weeds were left among the wheat crop. At the north 20 acres of wheat stubble were left unploughed. Large numbers of nymphs emerged from this unworked land and entered the edges of the crop. An especially heavy concentration of 300 per square yard was present along the edge of the north wheat crop. Ten yards were stripped bare and later this crop was a total loss. At the same time concentrations of 80 to 90 per yard were trimming considerably the borders of adjacent strips but there were very few nymphs in the centre of any of these strips. In the fall of 1936 a heavy deposit of eggs was found in drift sand on a nearby reverted strip which had been blown up when an oat crop blew badly in the spring of 1936. Otherwise, the survey did not accurately measure the infestation.

Section 17

Northwest quarter.- Was not rated. From an average of estimates it rated "light" but it was so patchy that it is doubtful if the rating was deserved.

Northeast quarter.- Rated "light" because there were 40 acres of clover stubble with a population of 30 to 80 per square yard.

Southeast quarter.- Did not rate.

Section 16

Northwest, northeast and southwest quarters.- No rating.

Southeast quarter.- No rating. Two of the western strips hatched from 20 to 50 grasshoppers per square yard.

Roadallowances (See survey map 5)

The roadallowance east of section 32 rated from "light" to "moderate" and the road east of section 25 rated "moderate". Between sections 33 and 26 the

infestation was patchy, ranging from "light" to "severe".

(1) Comparison of fall egg survey 1936 and nymphal survey 1937.— Of the four quarter sections rated "light" by the 1936 egg survey, southeast in section 33, southeast in section 20, southwest in section 29 and southwest in section 21, only the first two rated in the nymphal survey of 1937. The first quarter section mentioned rated "light" as prognosticated but the southeast quarter of section 20 rated "severe". Seeking the reason for this discrepancy we find the farmer left about 20 acres of wheat stubble standing in the north part of this quarter section. Also, small unploughed lands were left between each of the crops as plate XX indicates. The egg survey method, however, did not indicate the worst possible conditions. Large numbers of nymphs emerged from the unworked land to enter the crops. The concentration of dots across one of the wheat strips shown on plate XX indicates where a concentration of 300 per square yard occurred. Later the crop here was uncut, thus being a total loss. The borders of the adjacent wheat strips contained concentrations of 80 to 90 per square yard which caused considerable trimming. However, in the centre of all these strips a few nymphs were present showing that few escaped the plough here and that those present came from the unploughed land. Again on section 33 work was badly done. Small strips of stubble were left for summer-fallow. The wonder is that the quarter only rated "light" but as half the land was worked a much heavier infestation was likely reduced. There were other quarter sections which rated from "light" to "moderate" in the spring of 1937 which were not rated by the egg survey of 1936. Looking for the causes we find that on the east side of the northwest quarter of section 32 a rye crop was stubbled in and alternated with stubbles of 1936 rye (see plate IX). Also, a wheat stubble on the west side was left standing. Again on the northwest quarter of section 32 a rye stubble was responsible for a "light" rating. Unploughed land on the east side of the southwest quarter of section 33 allowed a rating of "moderate". Here 60 to 80 grasshoppers per yard were found in patches over the wheat and rye stubble on May 21. A piece of year-old reversion on the northwest quarter of section 29 hatched a large

population. The land on the southeast quarter of section 29 was not worked until mid-summer and here again a "moderate" infestation occurred. The "light" rating of the northeast quarter of section 17 is accounted for by 40 acres of sweet clover growing there.

Plate XX shows how the roadallowances rated in the spring of 1937. The road east of section 33 did not rate in the fall but a "light" to "moderate" infestation of nymphs was present in the spring. Many of these likely came off the stubble land west of the road which was ploughed early. East of section 28 some of the nymphs may have come off the adjoining stubble strip ploughed between May 26 and June 8 but it is likely that many of the nymphs hatched from this roadallowance. The ratings indicate a large concentration on the road between sections 28 and 33 and the egg survey did not indicate the possible population. Brome had been drilled into part of this mile (one quarter mile immediately west of the half line north and south of the road). By May 21 concentrations of 80 to 100 nymphs per yard were isolated in small patches of Russian thistle but the surrounding sown area carried few nymphs at that time. As the wheat nurse crop came along the population increased at this point and it is suspected that most of the nymphs hatched right there. The infestation was "severe" enough that the nurse crop and much of the young brome were badly destroyed by nymphal survey time (see section on damage to cultivated crops).

(2) Comparison of adult survey 1936 and nymphal survey 1937. - Comparing the nymphal survey of 1937 with the adults present in 1936 we find that the northwest quarter on section 32, the southwest on section 33, the northwest on section 29, and the northeast on section 17 were normal in 1936 but rated the following spring. All these sections rated "light" with the exception of the southwest quarter of section 33 and it rated "moderate". The reason for these higher ratings was that sufficient ploughing was not done to reduce the population.

The northwest quarter of section 33, the southeast on section 33, the southeast on section 29, and the southeast on section 20 rated at both times,

the first two rated light, the latter two being one or two categories higher. Here again, not enough land was worked.

A reduction of population was found on the northeast quarter of section 33, northeast, southeast and southwest quarters of section 28, and the northeast quarter of section 20. A drop from "light" to "normal" infestation occurred. On section 28 the reduction showed the effect of timely work done on the experimental sub-station. Ploughing was also sufficient on the other quarters named, while on the northeast quarter of section 20 there was little excuse for it rating "light" in 1936.

In the nymphal survey of 1937 the roadallowances east of section 33 rated somewhat higher than in mid-summer 1936. The road east of section 28 rated nearly a category higher. The roadallowance between sections 33 and 28 was also considerably higher (see plates XVII to XX). The east roadallowances apparently received nymphs from ploughing adjacent stubbles, but this factor was less important in the infestation rise found between the two sections.

6. Discussion of Adult Survey 1937 (Plate XXI)

Section 31

Rated "moderate". The whole section was uniformly infested.

Section 32

Northwest quarter.-- Rated "moderate". The rye strips mentioned in the nymphal survey still remained particularly high.

Northeast quarter.-- Rated "light", although when the average estimates were calculated "moderate" infestation was indicated. However, the population was very small on the surface-cultivated summer-fallow which covered about 40 acres of the quarter section. For this reason it was rated "light".

Southwest quarter.-- Rated "severe".

Southeast quarter.- Rated "moderate". Uniformly infested.

Section 33

Northwest quarter.- Rated "moderate". Two oat fields on each side of the quarter had high populations causing a "moderate" rating.

Northeast quarter.- Rated "moderate". Uniformly infested. A weedy corn field had the highest population of 35 per square yard.

Southwest quarter.- Rated "severe" because the clover left for pasture and the strip of weeds left uncultivated attracted the grasshoppers.

Southeast quarter.- Rated "moderate". The west half where wheat lay between reverted strips or stubbles (not fallowed) was heavily infested. The hoppers seemed to come back to the reversion after the crop was cut. The rest of the quarter in millet and fallow was "light".

Section 29

Northwest quarter.- Rated "moderate". The pasture and reversion were fairly heavily populated.

Northeast quarter.- Rated "moderate".

Southwest quarter.- Rated "moderate". The population was uniform although there was very little crop.

Southeast quarter.- Rated "light" because 90 acres of it were in summer-fallow.

Section 21

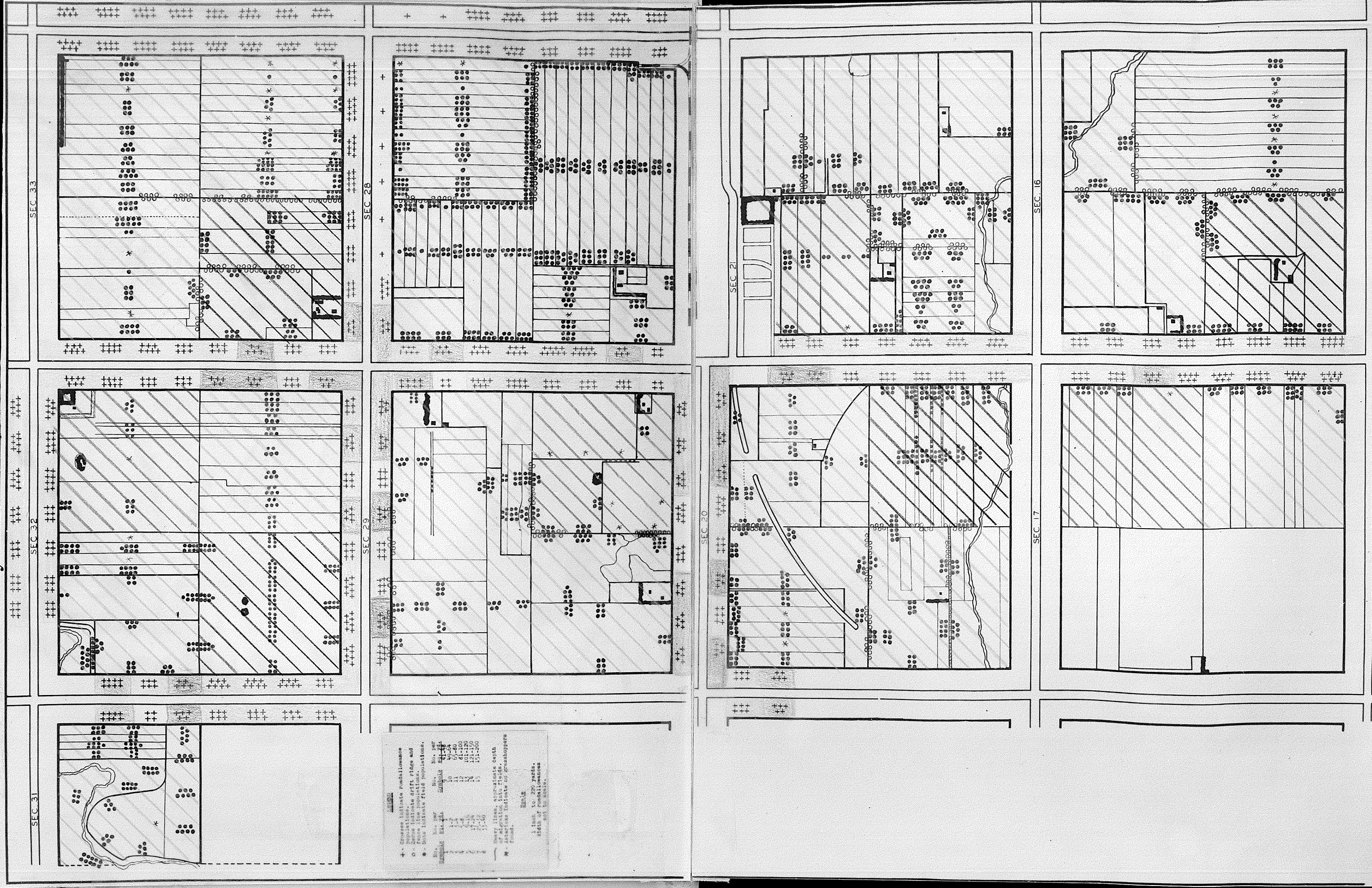
Northwest quarter.- Rated "light" because it was mostly in fallow.

Northeast quarter.- Rated "moderate". Population uniform.

Southwest quarter.- Rated "moderate". Oats

PLATE XXI

Adult survey 1937.



Legend

* - Chance locations of human remains
 O - Stone masonry drift, ridges and
 * - Stone masonry drift, ridges and
 * - Stone masonry drift, ridges and

Site	No. per	No. per	No. per
	100 yds	100 yds	100 yds
1-2	1-2	1-2	1-2
3-4	3-4	3-4	3-4
5-6	5-6	5-6	5-6
7-8	7-8	7-8	7-8
9-10	9-10	9-10	9-10
11-12	11-12	11-12	11-12
13-14	13-14	13-14	13-14
15-16	15-16	15-16	15-16
17-18	17-18	17-18	17-18
19-20	19-20	19-20	19-20
21-22	21-22	21-22	21-22
23-24	23-24	23-24	23-24
25-26	25-26	25-26	25-26
27-28	27-28	27-28	27-28
29-30	29-30	29-30	29-30
31-32	31-32	31-32	31-32
33-34	33-34	33-34	33-34
35-36	35-36	35-36	35-36
37-38	37-38	37-38	37-38
39-40	39-40	39-40	39-40
41-42	41-42	41-42	41-42
43-44	43-44	43-44	43-44
45-46	45-46	45-46	45-46
47-48	47-48	47-48	47-48
49-50	49-50	49-50	49-50
51-52	51-52	51-52	51-52
53-54	53-54	53-54	53-54
55-56	55-56	55-56	55-56
57-58	57-58	57-58	57-58
59-60	59-60	59-60	59-60
61-62	61-62	61-62	61-62
63-64	63-64	63-64	63-64
65-66	65-66	65-66	65-66
67-68	67-68	67-68	67-68
69-70	69-70	69-70	69-70
71-72	71-72	71-72	71-72
73-74	73-74	73-74	73-74
75-76	75-76	75-76	75-76
77-78	77-78	77-78	77-78
79-80	79-80	79-80	79-80
81-82	81-82	81-82	81-82
83-84	83-84	83-84	83-84
85-86	85-86	85-86	85-86
87-88	87-88	87-88	87-88
89-90	89-90	89-90	89-90
91-92	91-92	91-92	91-92
93-94	93-94	93-94	93-94
95-96	95-96	95-96	95-96
97-98	97-98	97-98	97-98
99-100	99-100	99-100	99-100

* - Heavy lines, approximate center
 of alignment, this field.
 * - Found.

* - Limit to 200 yards.
 * - Limit to 50 yards.

and reversion on the west were particularly heavy.

Southeast quarter.-- Rated "moderate". The population was uniform.

Section 20

Northwest quarter.-- Rated "moderate". Population was fairly uniform. The east oat field was lighter while the summer-fallow strips on the west side had a high population in small patches of Agropyron repens.

Southwest quarter.-- Rated "moderate". Bromo hayland and crops were uniformly infested.

Southeast quarter.-- As in the nymphal survey the infestation was heavy, being particularly so in small unploughed lands.

Section 17

Northwest quarter.-- Not surveyed.

Northeast quarter.-- Rated "light". The few counts made indicated a "moderate" rating but because they were few and half of it was summer-fallow (one-way disced) it was rated "light".

Southeast quarter.-- Rated "moderate".

Section 16

Northwest quarter.-- Rated "moderate". However, an oat field in the centre was very severely infested and numerically the quarter should have rated "severe".

Northeast quarter.-- Rated "moderate". Numerically it should have rated "severe" but estimates were only made in the north pasture.

Southwest quarter.-- Rated "severe". The population was generally heavy in this quarter, particularly a barley crop at the northeast corner.

Southeast quarter.- Did not rate.

Roadallowances

In the adult survey in 1937 (see survey map 6) most of the roadallowances in the area rated "moderate". There was a considerable area rating "light" and a couple of spots rated "severe".

(1) Comparison of adult survey 1937 and nymphal survey 1937.- The study area had a greatly increased adult population at adult survey time (see plate XXI). At the time of nymphal survey localized concentrations were found which coincided with land unworked in the spring or previous fall and also a few drift ridge concentrations. Local flights began to occur July 12 and from then onwards concentrations spread. Heavy migratory flights from the southeast on July 21 and 26 augmented the population which began to dehead wheat. During August the area was blanketed by a uniformly heavy population which began to subside by the end of the month. Most quarter sections increased from one to two categories in infestation. Only the southeast quarter of section 20 and northeast quarter of section 17 had ratings smaller than the nymphal survey. On the former quarter the population spread widely but enough adults remained to allow it a "severe" rating. The northeast quarter of section 17 was lower than the surrounding area because 40 acres had been one-way disced.

9. Discussion of Fall Egg Survey 1937 (Plate XXII)

Section 31

No rating. The average number of eggs per sample was 0.5. Osmia eggs were found about twice as frequently as in 1936.

Section 32

Northwest quarter.- No rating. Average number of eggs per sample was 0.86. Only the rye strips could rate "light".

Northeast quarter.-- No rating. A large wheat strip on the west side was the only part that could rate "light".

Southwest quarter.-- No rating. Average number of eggs per sample was 0.5.

Southeast quarter.-- Nearly rated "light" but there was only an average of 0.92 eggs per sample. The third strip east of the half line (reversion) rated "moderate".

Section 22

Northwest quarter.-- No rating. Average number of eggs per sample was only 0.54.

Northeast quarter.-- No rating. Average number of eggs per sample was 0.83. The first two strips east of the half line, reversion and wheat strip, rated "light".

Southwest quarter.-- No rating.

Southeast quarter.-- No rating. Average number of eggs per sample was 0.76. The third strip of stubble east of the half line rated "light" as did a millet strip four strips from the east side.

Section 29

Northwest quarter.-- No rating. Average number of eggs per sample 0.9.

Northeast quarter.-- No rating. Average number of eggs per sample 0.00.

Southwest quarter.-- Rated "light". Average number of eggs per sample 1.0.

Southeast quarter.-- No rating. A weedy oat crop, the only portion of the section not in fallow, rated "light".

Section 26

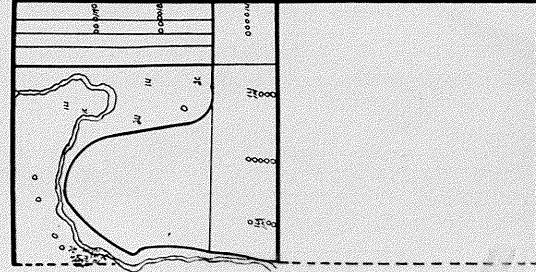
Northwest quarter.-- Rated "light". Average

PLATE XXII

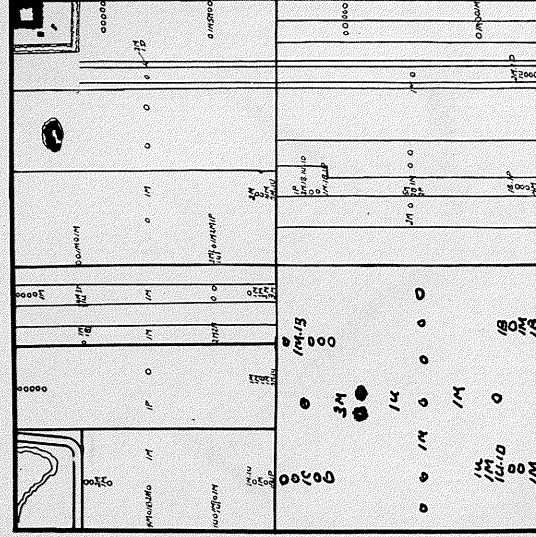
Egg survey of 1937.

Lyleton Study Centre

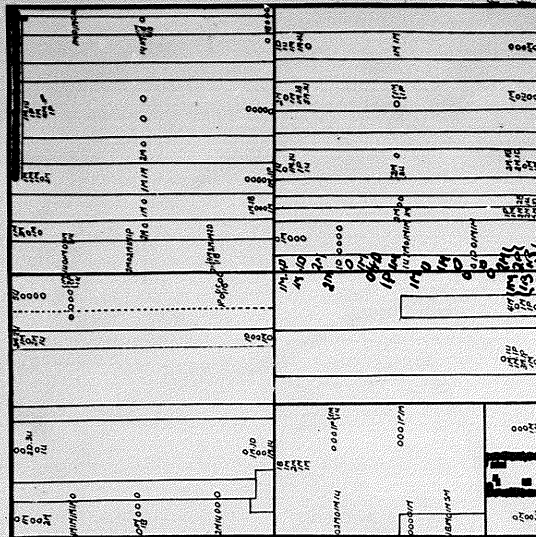
SEC. 31



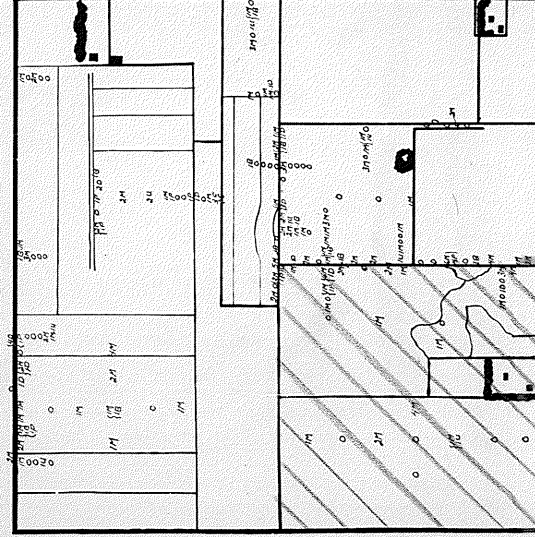
SEC. 32



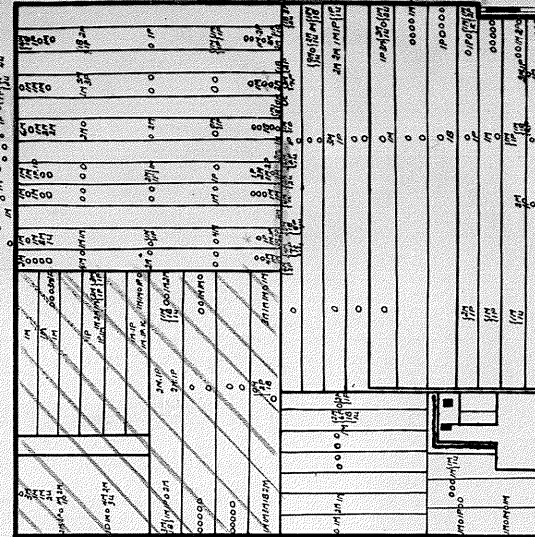
SEC. 33



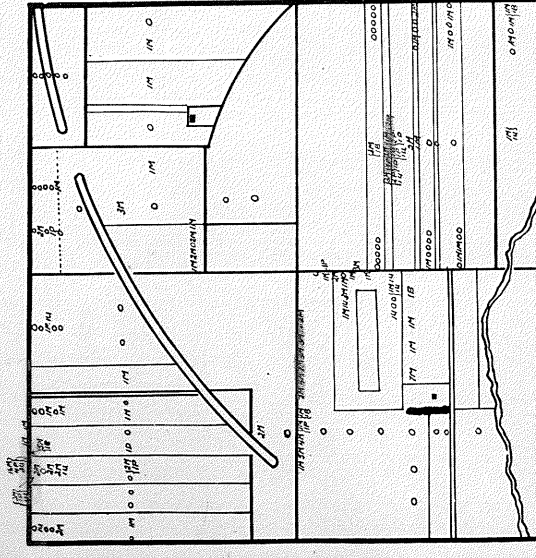
SEC. 29



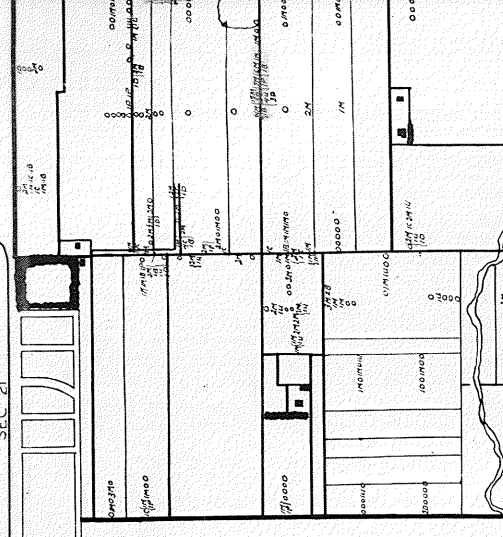
SEC. 28



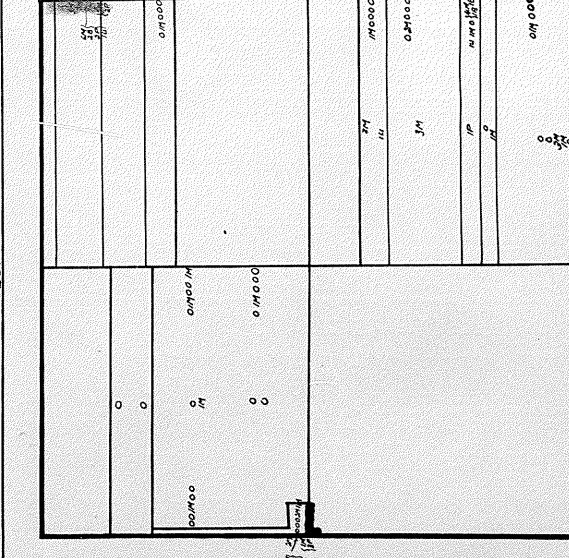
SEC. 20



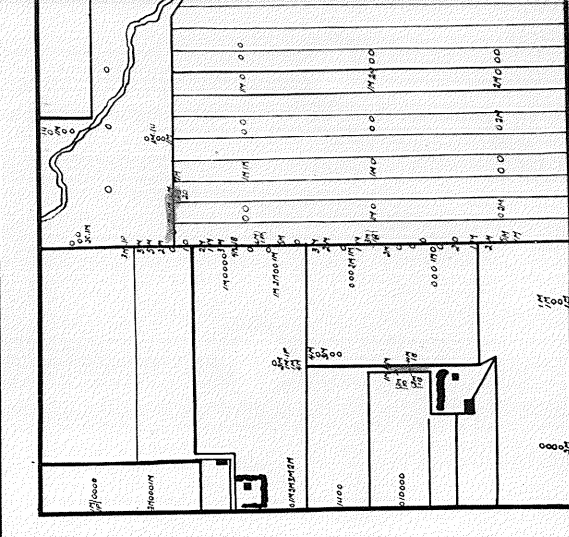
SEC. 21



SEC. 17



SEC. 16



1111 100 1111 100
 A - Mainland section
 B - Mainland section
 C - Mainland section
 D - Mainland section

number of eggs per sample was 1.5. The old broom pasture rated "light". Strips 13 and 15, first-year clover and oats, rated. Strips C6 and C4 (wheat and clover) rated "light" and "moderate" respectively.

Northeast quarter.- No rating. Average number of eggs per sample was 0.64. Strips 2, 6 and 12 rated "light".

Southwest quarter.- No rating. Average number of eggs per sample was 0.67.

Southeast quarter.- No rating. Average number of eggs per sample was 0.6. Strip 2 (wheat and clover), strip 4 (oats), strip 7 (barley), strip 9 (wheat) and strip 10 (seedy fallow) rated "light" on the east side.

Section 21

Northwest quarter.- No rating. Average number of eggs per sample 0.6.

Northeast quarter.- No rating. Average number of eggs per sample 0.57. The north pasture rated "light".

Southwest quarter.- No rating. Average number of eggs per sample 0.5. A small piece of oats in the northeast corner rated "light".

Southeast quarter.- No rating. Average number of eggs per sample 0.48.

Section 20

Northwest quarter.- No rating. Average number of eggs per sample was 0.54.

Northeast quarter.- No rating. Average number of eggs per sample 0.64.

Southwest quarter.- No rating. Average number of eggs per sample 0.69. The crop area, wheat stubble, rated "light".

Southeast quarter.-- No rating. Average number of eggs per sample 0.43. Only a small strip of drift soil rated "light".

Section 17

Northwest quarter.-- No rating. Average number of eggs per sample 0.5.

Northeast quarter.-- No rating. Few samples were taken because the land was one-way disced.

Southeast quarter.-- No rating. Average number of eggs per sample was 0.74.

Section 16

Northwest quarter.-- No rating. Average number of eggs per sample was 0.90. The south field of wheat rated "light".

Northeast quarter.-- No rating. Average number of eggs per sample was 0.3.

Southwest quarter.-- No rating. Average number of eggs per sample was 0.90.

Roadallowances

Only a little of the roadallowances was surveyed. Parts of it rated "light" as in 1936.

(1) Comparison of adult and fall egg surveys 1937.-- A very large drop in population was indicated by the egg survey, plate XIII. The nymphal survey map for 1938 (not yet completed) will show a somewhat smaller drop in population so it seems the vast differences in infestation were not entirely due to the faults of the egg survey.

10. Discussion of Yearly Populations

One of the main objects of this study is to follow the trend of grasshopper populations from year to year. A graphic summary of these data is

PLATE XXIII

Yearly Populations

The upper portion of the plate concerns the population of 1936 while the lower portion pertains to that of 1937. The three annual surveys (nymphal, adult and egg) are separately graphed from left to right. The quarter sections are marked off along abscissa and the population standards (ratings) are plotted along the ordinate.

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

COMPARISON OF POPULATIONS

S.

M.

L.

N.

Nymphs

Adults

Legs

31 32 33 29 28 21 20 16 17 31 32 33 29 28 21 20 16 17 31 32 33 29 28 21 20 16 17

Section

Section

Population 1936

S.

M.

L.

N.

31 32 33 29 28 21 20 16 17 31 32 33 29 28 21 20 16 17 31 32 33 29 28 21 20 16 17

Section

Section

Population 1937

shown in plate XXXIII and was previously considered in the section concerning the three yearly surveys.

These graphs show the population of 1937 was considerably higher than 1936. The migration of 1936 and the lack of efficient cultivation were responsible for this increase. The 1937 adult population rated one to two categories higher than that of the previous year. For this there were two reasons. Firstly, there was a higher initial nymphal population, and secondly, migration was heavy. The last named factor was the most important in this increase.

The egg infestation of both years was very similar but there was a marked difference between the adult and egg infestation of both years. This was particularly true in 1937. The reasons for this discrepancy are not now obvious, but one of the following may explain it. (1) A seasonal reproductive deficit among the grasshoppers. At survey time the impression was gained that there were not sufficient egg pods found for the high adult population, but observations in the spring of 1937 on unworked land where nymphal populations were heavy somewhat dispelled this idea. (2) The survey method may be imperfect for gauging the extent of the infestation on such a small area. From plate XXXIII it appears obvious that the egg survey did not forecast the heaviest population possible as it is intended to do. (3) The ratings applied may not have been high enough. Were this true one should expect the error to be only one of degree which does not appear to be the case.

It should be pointed out that by analyzing our methods we only attempt to realize their limitations with a view to improving them. Such knowledge and more data may enable us to point out why the egg depositions of 1936 and 1937 were low, if such proves to be the case. (The study is being continued as a long term project by the Entomological Laboratory, Brandon, and the methods will be further tested.)

11. Relation of Population to Plant Associations

(1) Abundance of nymphs in plant communities.- The main concentrations of nymphs were found where fields were unworked, stubble fields, on drift ridges and road allowances covered with drift soil. The presence of plants, such as Russian thistle, false ragweed, horse weed, bind weed and Artemisia biennis, were coincidental but they must be credited with the ability of providing sufficient spring food for the nymphs and holding them in concentrations until the later instars were reached.

(2) Abundance of adults in plant communities.- When the grasshoppers began to fly, about mid-July, they spread widely and found sufficient food available everywhere, but when the cultivated crops and native vegetation began to mature in late July they again became more localized. Then, concentrations are found in late crops of wheat, oats, or barley. Somewhat later, stubbles of oats which often remain green, weedy wheat stubbles, corn crops and weedy clover fields or first-year clover, were selected. Russian thistle is a plant favored by the adults because it matures late and irregularly and provides succulent food until early September. In fact, by the time it has fully matured the population has greatly waned. For this reason stubbles with a good growth of Russian thistle in general supported a heavier late season population.

Lactiferous plants, such as blue lettuce (Lactuca pulchella), Chamaejasme (Euphorbia glyptosperma) and also skeleton weed (Lycodesmia juncea) were important grasshopper food plants in weedy stubbles and reversions in August. These plants are more fully dealt with in the section on adult behavior

(p. 104).

Grass reversions were noted to be well populated during mid-summer and they retained their populations with a natural reduction until fall. These areas began with low nymphal populations but were flooded by general population spread and migrations as the season advanced. They are designated on the crop plan (plate VII) as Acropyron

reversions and the fact that they are characterized by a dominant growth of A. repens, makes them favorable to adult grasshoppers because: (1) M. mexicanus found A. repens a favorable feeding ground when the intense drought of July, 1936, desiccated the other vegetation. Grasshoppers were found concentrated in pure stands of A. repens early in July, 1936, and the populations were observed until September. The month of July and the first half of August were exceedingly dry and A. repens remained more succulent than other grass vegetation until about the end of July. The desiccation of this grass then caused a drop of grasshopper population. (2) In 1937 when moister conditions prevailed vegetation did not mature as early and the late maturing Agropyron repens was not resorted to until later in the season. The first retreat to A. repens was not noted until mid-July in 1937 and was most pronounced in the middle of August. (3) The fact that A. repens lost population as the drought of 1936 became more intense and gained it again when the drought was broken supports the supposition that this plant is favored by M. mexicanus because of its succulence.

One small area of pure Agropyron repens was followed very closely during 1936 and the grasshopper population trend was as follows:

Date	Population per square yard
July 2	50
9	30
19	30
23	20
August 4	10
12	5
21	25
September 4	20

From the meteorological records we find only 0.3 inches of rain fell from July 1 to August 18 and on the latter date 0.67 inches fell to break the drought. Therefore, as better moisture conditions prevailed the population rebounded to the level of late July. This rebound of population indicated by the above estimates was noted at other points where Agropyron repens was studied but

only these figures, which are the most complete, are included in this discussion.

By the end of July and mid-August in 1936 and 1937 respectively the broms hayland in the southwest quarter of section 20, in common with other grass vegetation, carried a fairly heavy population. In the first season it was noted in August that the grasshoppers were concentrated in a slight depression in the field where the vegetation remained more succulent. Concentrations of adults were observed in August of both years among broms on the roadallowance where cutting had favored a fall growth. In both years there was a noticeable movement to the roadallowances towards the end of August, because the grass vegetation then provided better food.

Dense patches of Symphoricarpos occidentalis grow along the creek on section 31. In both years it was noted that the grasshoppers retreated to it and the grassy slopes bordering the creek as the upland vegetation matured. The grasshoppers fed upon Symphoricarpos but did not accomplish the damage one would expect from the population present. Dr. E. E. Clarke, while conducting a plant survey of the area in 1935, pointed out a definite plant association which provides a late season habitat. Among the Symphoricarpos grasses as Agropyron Smithii and A. repens grow more lush, and Poa pratensis, Agropyron pauciflorum, and Poa palustris, which require more humid conditions are found. His belief was that the Symphoricarpos held more of the winter's snow, allowing better soil moisture. The shelter provided for the grasses by Symphoricarpos also would provide a cooler and moister habitat. Therefore, it seems quite possible that the grass vegetation among the Symphoricarpos was also an important feeding ground.

12. Relation of Population to Natural and Physical Environment

(1) Soil type.-- At present the only information on the relationship of grasshoppers to soil differences on the study area is in connection with drift soil. The nymphal survey of 1937 discussed on page 65 and mapped on plate XX shows a large

nymphal concentration occurred on the roadallowance between sections 20 and 33. The presence of this concentration on drift soil was due to the fact that such habitats provide favored oviposition sites. Drift ridge concentrations found in the spring are present for the same reason. However, the fact that the vegetation and temperature conditions are very favorable to young nymphs should not be depreciated. In fact, the higher spring temperatures of these habitats establish nymphal populations earlier in the spring and the vegetation provides abundant food.

(2) Slope.-- No noticeable relationship was observed between grasshopper abundance and large slopes. Any observations of this nature were confined to small drift ridges where slope is considered as a factor in the selection of oviposition site. (See section VIII).

(3) Density of vegetation.-- The density of vegetation in relation to grasshopper abundance was studied very little.

13. Relation of Population to Artificial Changes in Physical Environment

(1) Effect of cultivation methods.--

(a) Ploughing.-- The ploughing of the land either in the fall or spring was found very effective in reducing the grasshopper population. The nymphal survey of 1937 (plate XX) well illustrates this fact, because at that time all the major concentrations on the area were present as the plough had not been used. Observations made on the southeast quarter of section 20 showed a very large population hatched from the unploughed land and advanced into the crop. At the same time practically no nymphs were found in the centre of the crop strips.

The plough, when used for the final fall or spring preparation, tends to reduce weeds, particularly Russian thistle which is an important food plant of nymphal and adult grasshoppers. This agronomic feature is seldom considered but any reduction

of the weed is for this reason highly desirable.

(b) Discing.-- The one-way disc was used almost exclusively on the Experimental Farm substation on section 28. Our adult survey of 1936 and nymphal survey of 1937 show a significant population reduction occurred on the section between these surveys. Because in the adult survey three quarters of the section rated light and none rated in the following spring. The rye strip of the section rated moderate to severe showed a high potential population was present which must have been subdued by the cultural practices employed.

(c) Cultivating.-- The duck-foot cultivator when used for preparing summer-fallows reduces the grasshopper population. The one-way disc, when used, accomplishes the same end. The advantage of these implements lies in the fact that larger areas can be quickly worked and freed of grasshoppers. Any population which may remain or later appears will be proportional to the amount of weed growth present. Two large fields on the area (northeast in section 32 and northeast in section 16) were cultivated early in the summer of 1937. Few adults were present at adult survey time and of course few nymphs hatched from the areas in the following spring.

Spring work with a cultivator should be accompanied by poisoning because nymphs will be forced from the stubble to the neighboring crop. Plate XX shows how this occurred on the southwest quarter of section 33.

Spring cultivation of corn crops and summer work on summer-fallows, which are good farming practices, are very desirable because weeds which favor grasshoppers are greatly reduced.

(2) Damage to cultivated crops.--

(a) Damage in 1936.-- In the fall of 1935 a strip of fall rye was badly trimmed on section 28 and a second seeding was required. Figure 13, plate XXIV shows the difference of growth between the seedings as the crop was heading in 1936. Figure

14 of the same plate shows a 30-acre field of late oats which was practically destroyed by grasshoppers. Another total loss occurred on the northwest quarter of section 16 where the grasshoppers coming from a clover crop which was cut in mid-July concentrated in barley and made short work of the crop. About the end of August two 13-acre strips on the northeast quarter of section 28 were sown to wheat for a cover crop. The grasshoppers devoured the seedlings as they appeared above ground so that in less than a week it was hard to find any evidence that the crops had been sown. These three losses represent the only extensive crop damage done in 1936. Otherwise, only marginal trimming and damage to grass seedlings were recorded. One farmer was foiled in his attempt to get a catch of brome on part of the road-allowance between sections 28 and 33. Sown with a nurse crop of fall rye and wheat the brome grass came on well until the grasshoppers began to concentrate early in July. About the same time a period of intense heat occurred and the vegetation was scathed. The grasshoppers, however, remained to complete the destruction by feeding of the succulent culms left under the dry mat of vegetation.

(b) Damage in 1937.— In this year another attempt was made at securing a catch of brome on the same roadallowance (between sections 28 and 33). Figure 15, plate XXV shows how the grasshoppers completely destroyed the nurse crop of wheat. Needless to say, the young brome seedlings did not survive the onslaught. Thirty acres of millet were damaged to the extent of 32 percent in the young seedling stage on section 33. The advance made into one side of one of the millet strips is shown in figure 16, plate XXV. The other border and the borders of the other strip grown were similarly damaged. Extensive damage occurred on the southeast quarter of section 20. Plate XX indicates the high population present (see page 60). By the end of June a population of 250 per square yard had ~~been~~ 10 yards in from the margin. Later more ground was bared and defoliation and deheading were so severe that the crop (10 acres) was not cut. Other crops on the same quarter were trimmed along the edge and considerable defoliation was effected. During the month of July no extensive

PLATE XXIV

Fig. 13. Damage to fall rye.

Fig. 14. Damage to late oats. A view north
on study plot II.



PLATE XXV

Fig. 15. Complete deheading and defoliation of wheat used as a nurse crop for brome grass.

Fig. 16. Damage to millet.



damage was observed on the area but marginal trimming and defoliation were fairly general throughout the area. At the end of July, as the wheat was ripening, the grasshoppers began to cut off the heads. Flights had brought the population close to its maximum for the year and the struggle between the grasshopper and the farmers to see who would get the crop cut first began. The grasshoppers accounted for a loss of thousands of bushels of wheat in the district. A study to ascertain the extent of the loss was completed on the northwest quarter of section 28. The fallen heads per square yard were counted at 6 points on each of the crop strips. The average number of heads down per square yard was 49 and one count of 145 heads was recorded. The average loss for the quarter section was calculated to be 5 bushels per acre. It was not possible to compute the total loss on the study area but observation suggested that in general 1.5 to 3 bushels per acre were lost.

14. Summary

In the first part of this section the survey map and the discussion of the surveys are found. From these data and additional field notes the sections which follow and which are summarized here were derived.

(1) Discussion of the yearly populations.-

(a) The nymphal population of 1937 was higher because of the migration of 1936 and the lack of efficient cultivation.

(b) The adult population of 1937 was higher because of the increased nymphal population and exceedingly heavy migration.

(c) There was a significant drop between the adult infestation and egg infestation as measured in both seasons which was not fully understood.

(2) Relation of population to plant associations.-

(a) The main concentrations of nymphs occurred where land was unworked. Food plants were coincidentally

abundant in such locations.

(b) Grasshoppers spread widely when they began to fly in mid-July but later become localized where the vegetation remained more succulent.

(c) Lactiferous plants were relished by grasshoppers in August and Agropyron repens was a much favored late summer grass.

(d) Gymphoricarpus occidentalis clumps provided a definite habitat of lush grass favored in late summer by Melanoplus mexicanus.

(3) Relation of population to natural and physical environment.-

(a) A drift soil type was correlative with nymphal abundance because such habitats were favored for oviposition.

(b) Ground slope was not noticeably related to grasshopper population.

(4) Relation of population to artificial changes in physical environment.-

(a) Ploughing either in the autumn or spring was very effective in reducing grasshopper population.

(b) The one-way disc also caused a great reduction of grasshopper population.

(c) Surface-cultivated summer-fallows, eliminating weed growth, are not favored by grasshoppers and egg-laying does not occur there. Thus few nymphs are present in the following spring.

(5) Damage to cultivated crops.-

(a) In 1936 the damage was summed as the loss of:

- (i) 30 acres of oats.
- (ii) 10 acres of barley.
- (iii) 26 acres of wheat cover crop.
- (iv) a brome seeding on a roadallowance.

- (b) In 1937 the loss was as follows:
 - (i) 10 acres of wheat.
 - (ii) 30 acres of millet (32 percent damaged).
 - (iii) Fairly general marginal trimming and defoliation.
 - (iv) An average loss in the district when the crop was nearly mature of 1.5 to 3 bushels per acre by deheading by grasshoppers, estimated roughly as and \$6,000.00 loss.

VI. WEEKLY AND BIMONTHLY CHANGES IN POPULATION

1. Method of Study

The weekly and bimonthly changes of population were studied by means of study plots which are described in Appendix IV. The population per square yard estimated at intervals throughout each season on two study plots appears in table 3.

2. Discussion of Results

The estimates in table 3 show the population was higher throughout 1937. The population was higher at the end of May and remained so until the maximum population was reached in August.

(1) Nymphal peak.— Two seasonal population peaks are particularly noticeable on plot I in 1937. The first nymphal peak occurred about mid-June when 60 percent of the nymphs were in the third and fourth instar. It may be taken to represent the total nymphal population hatched from the plot. On plot I the greatest population was found on strip 16, a rye stubble, which was summer-fallowed a little later and on the drift ridges which represented the best hatching locations on the study plot. On plot II the increase was general since most of the plot was uncultivated.

In 1936 a nymphal peak was only indicated on plot II but did not occur until July 6 to 18. At the time 70 percent of the nymphs were in the third

Table 3.

Populations on Study Plots

1936			1937		
Date	Plot I	Plot II	Date	Plot I	Plot II
May 25	1		May 21	9.3	
June 2		2.2	June 1	5.5	
11	2.3	2.5	2		6
26		7.8	9	11.6]	
July 4	2.3		12	16.6]	9.6]
6		10.2	24		18.5]
18			26	11.4	
20	7.0		July 6	13.8	
26		7.2	7		14.7
Aug. 3	6.8		13		19.0
8		7.0	17	13.4	
11	6.7		24	12.7	
14		6.3	27		16.7
16	6.2		Aug. 5	17.2	
24	6.8	12.7	7		17.5
Sep. 1	7.4		20	27.8]	15.7
7	8.2		26	21.2]	12.0
8		9.5	Sep. 3	14.3	12.6
			10	10.0	
			13		5.2
			21	6.1	3.2
			26	7.1	2.4

and fourth instars. The increase was general but was most conspicuous in the oat crop which was being invaded.

(2) The adult peak.— The adult peak was most conspicuous on plot I in 1937 between August 20 and 25 and is accounted for by the fact that grasshoppers (increased in number by flights) were finding the alfalfa on strip 12, the clover on strip 13, and the corn on strip 13 (southeast quarter) provided a succulent late season food supply. Plot II did not show

this adult peak because the above mentioned crops were not present. The adult peak was not as apparent on either plots in 1936, possibly because there was not as heavy a migration to the area. Plot II showed a peak which was due to a general population increase on the plot.

(3) Changes due to cultural practices.- Observations on the study plots yielded other information most of which was also shown by the general surveys.

(a) Stubble in fall rye crops hatch large nymphal populations.

(b) The grasshoppers must move into adjoining crop strips when a strip is summer-fallowed.

(c) The adult population peak on the study plot occurs after the crops have been cut and the grasshoppers are widely spread and begin to become localized in crops succulent late in the season.

(d) Practically no nymphs or adults are found on summer-fallows but the population will rise when a fallow becomes weedy towards fall.

VII. BEHAVIOR

1. Hatching

(1) Methods of study.- In the study of air and soil temperatures at hatching time undertaken on study plot I (elsewhere described) records of 47 hatching pods were obtained. 25 of these were hatching from a small drift ridge approximately one foot high and 2 to 3 feet wide. This small ridge had a southward incline quite favorable for egg-laying in the autumn. From an adjacent rye crop 7 of the records were gained. The remaining observations were made at various points throughout the area. M. mexicanus being predominant, it was believed most of the eggs were of that species.

Soil surface temperatures, as in all the behavior studies here discussed, were taken by placing

PLATE XXVI

Graph 1. Soil surface temperatures and soil temperatures at which egg pods of Melanoplus mexicanus were observed hatching.

Graph 1.

Hatching temperatures
(*Melanoplus mexicanus*)

Figures show number of observations
ABC-areas outlined

Soil Surface Temperature

122
120
118
116
114
112
110
108
106
104
102
100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
64
62
60

52 54 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98

Soil Temperature (depth 1")

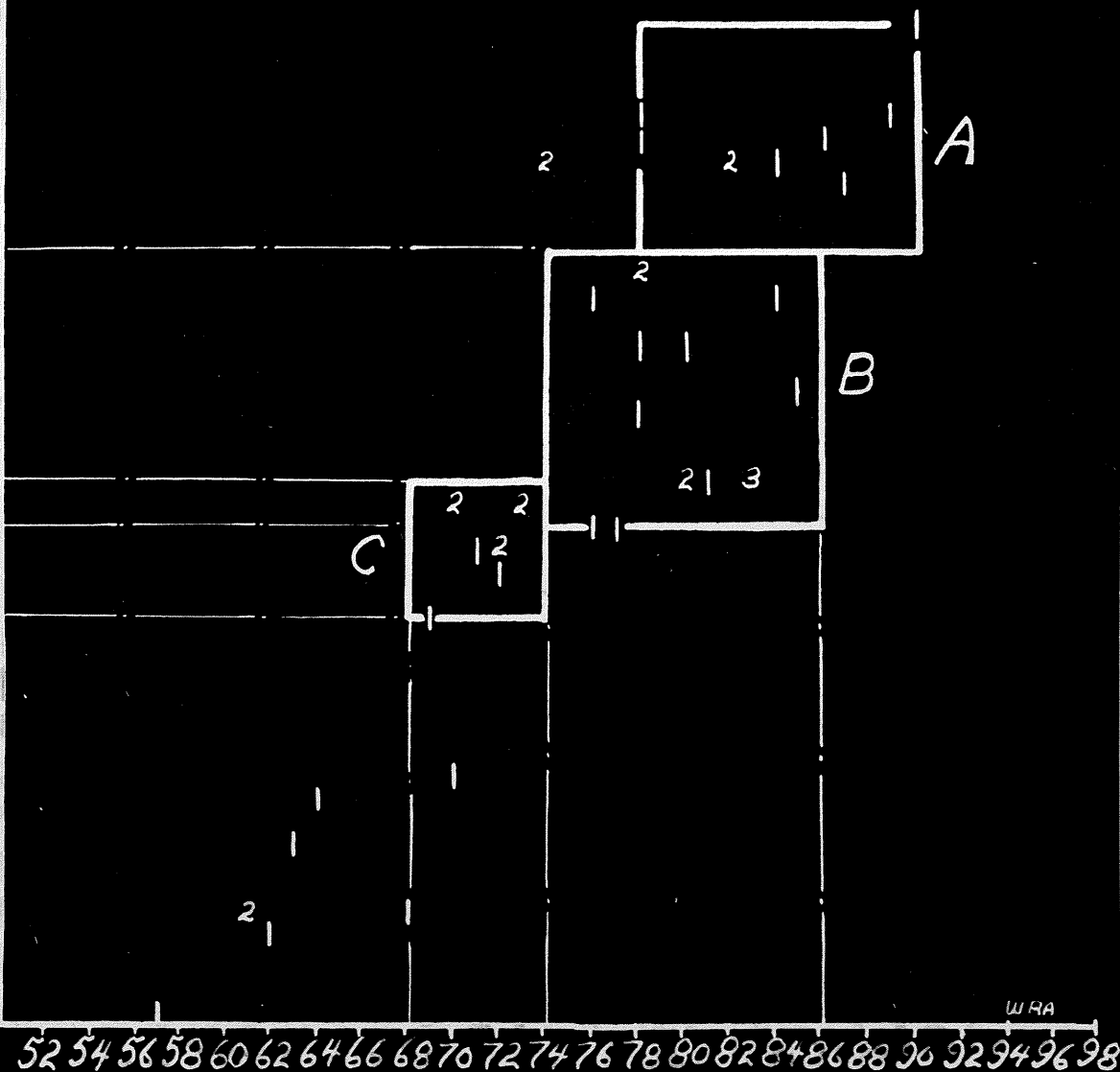
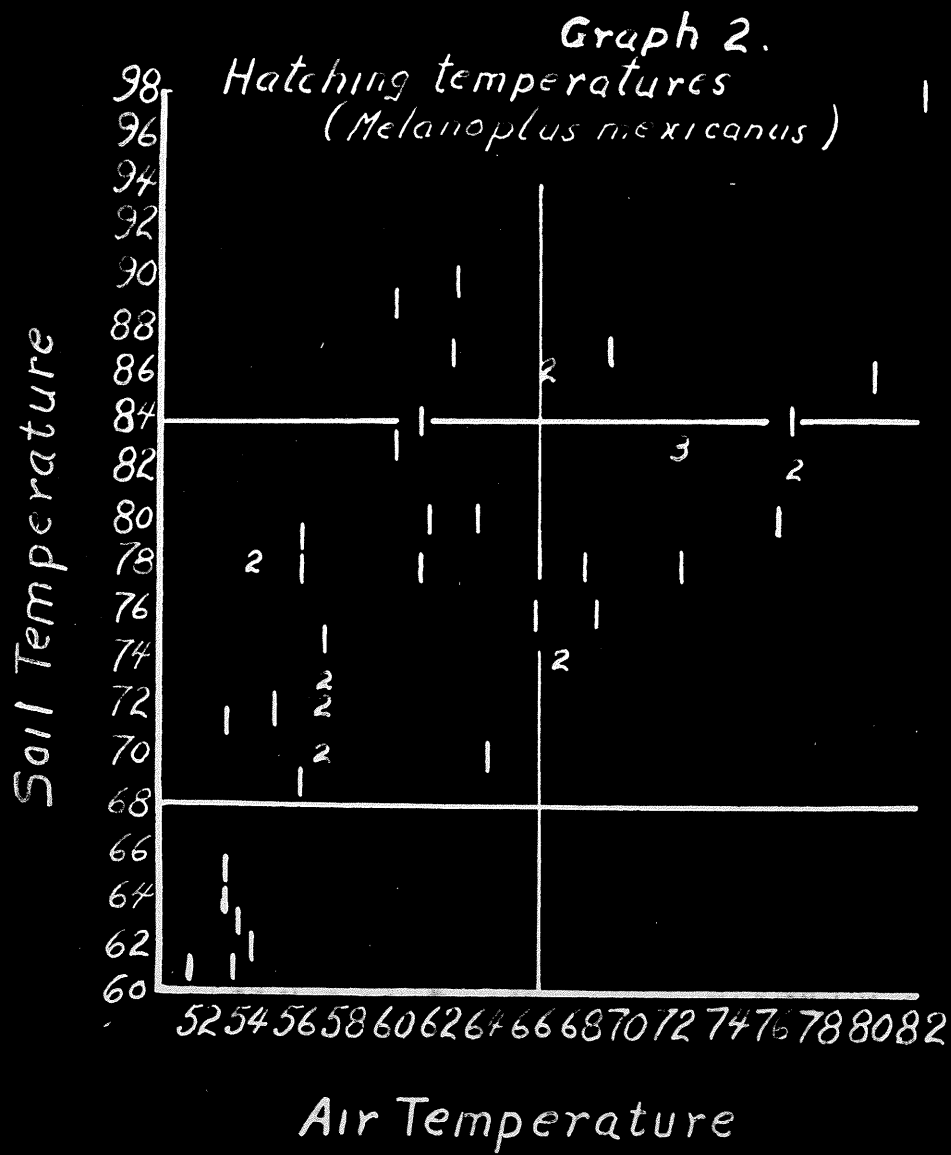


PLATE XXVII

Graph 2. Soil temperatures and air temperatures
at which egg pods of Malanoplus mexi-
canus were observed hatching.



66 to 64° F. A similar percentage (69 percent) showed an air temperature between 50 and 66.5° F. prevalent. This range of air temperature seems low. However, in the first place it must be remembered that they were shade temperatures. Furthermore, from graph 2 it may be seen there is little positive correlation between soil and air temperature while graph 1 shows quite well the positive correlation which one would expect between soil surface and soil temperatures.

In general, the temperature ranges established in this study agree reasonably well with the temperatures Parker (1930) set forth for general hatching of M. mexicanus and C. pellucida under Montana conditions. He says, in part, "general hatching . . . takes place during the first warm period in the spring when the maximum air temperatures are 75.2° F. or above for 3 to 5 successive days". "Soil surface temperatures at time of hatching are generally 80.6° F. or above, and soil temperatures at 2 inches 73.4° F. or above."

2. Nymphal

(1) Methods of study.— Intensive studies on the beginning of various activities were made principally on study plots where population was sufficiently large for observation. When continuous observations of various activities were made temperature records were taken every quarter hour. Pocket thermometers were used. Temperatures of the soil surface in the sun and shade were recorded while the other temperatures were those registered at the height of vegetation. The thermograph record obtained at the weather station was taken as the air temperature and is, therefore, the shade temperature. Many other isolated observations were made in different parts of the area when nymphal behavior arrested the observer's attention. In these instances temperatures were taken in similar positions or those of them that were considered more important. Unassembled data are found under nymphal behavior (Appendix V).

The following discussion of nymphal behavior attempts to bring forth the salient features of the

data gathered. Consequently the only temperatures given are those believed most concerned with the activity as it was observed.

The study of nymphal development is based upon population sweeps made on the study plots. In some cases attention was paid to rough estimates made at bimonthly intervals and duly reported. In this way the sweeps which were notoriously inaccurate were brought into line with the impressions of the observer.

(2) Discussion of results.

(a) Seasonal history.— Below are found two tables summarizing as far as is possible the rate of nymphal development for both years of study. The data seem to show mainly that June, 1937, was more conducive to development than June in the previous year because when the percentages in each instar are grouped to include roughly 70 to 80 percent of the individuals (table 5), further advanced nymphs formed more of the bulk at corresponding times.

Comparing the weather data of the two seasons the greatest difference is found in the amount of June rainfall which was 3.25 inches above the long-time average for Pierson, 2.57 inches. The increased precipitation did not cause long periods of cool weather which might have caused slower growth.

Table 4 shows the approximate period each instar was present.

Table 4.

Instar	1936	1937
1st	May 14 - June 30	May 10 - June 30
2nd	June 1 - July 15	June 1 - 30
3rd	1 - 20	1 - Aug. 5
4th	1 - Aug. 8	1 - 28
5th	10 - 8	10 - Sep. 21
Average days per stage	56	65

Table 5.

Date	1936					1937				
	1st	2nd	3rd	4th	5th adult	1st	2nd	3rd	4th	5th adult
June 1						13	140	74%		13
" 10	18	57	34	17.5	3.5					
" 12						8	9	146	80%	34
" 15	10	140	40	13	2					
" 30	2	6	130	40	20	*	3	21	72.5%	3.5
July 15		*	15	15	120			2	18	150
" 20			15	15	119.3					
" 27										
Aug. 5										
" 20										
" 26										
Sept. 21										

* - Instars taken

Summary of Table 5.

June 10, 1936	- 79% - 1st, 2nd and 3rd instars	
12, 1937	- 80% - 3rd and 4th	"
30, 1936	- 70% - " " "	"
, 1937	- 72.5% - 4th and 5th	"
July 13, 1936	- 70% - 5th and adult	"
, 1937	- 80% - " " "	"
Aug. 5, 1936	- 100% - adult	
8, 1937	- 100% - "	

(b) Temperature reactions.-

(i) Activity on hatching.- Normally nymphs upon hatching remain congregated close to where they issue forth. They rest on the soil, on diminutive vegetation or should it be windy in some sheltered place. Their main activity while they color up is sunning in some such location. But at a time when low temperature is accompanied by wind and rain their first reactions are somewhat different. Such an instance was observed in May, 1937. The air temperature at the time was just 60° F. and the soil temperature was 3° lower. After the initial moult was accomplished the nymphs remained exposed for a few minutes to a light wind and rain. When they crawled or jumped they were aided by a 19-mile an hour wind which at the time was driving a light shower of rain. Nymphs that crawled or jumped into small holes that provided shelter were quite content to remain there. Others not so fortunate moved further until they had found shelter. In this manner half of the nymphs were completely sheltered half an hour after hatching. The remainder were in places affording at least partial protection.

(ii) Beginning of activity.- Nymphs were observed beginning activity late in June, 1936, when the air temperature had reached 55° F. and when the temperature just above the vegetation had attained 60° F. where the observations were made a pure stand of 6 to 10-inch false ragweed seedlings existed. Beginning of activity was marked by the appearance of small clusters of nymphs upon ragweed leaves. The population was largely M. mexicanus, their first activity of the day being to seek the warmth of the

sun. Four to 8 nymphs clustered together on suitable leaves, all engaged in the same pursuit.

(iii) Normal activity.- Normal activity may be considered started when these basking clusters break. At an air temperature of 60° F. or when the temperature close to the basking nymphs reaches about 70° F., nymphs become excited and restless. A few forceful kicks by a fellow nymph cause several to leave his company or being restless they may leave of their own accord. By the time the air temperature is 70° F. and the immediate temperature is close to 80° F. all clusters will be broken. The breaking of clusters was further observed early in June, 1937. The air temperature was 73° F. when nymphs left the leaves to continue their activity among the vegetation and debris. Here they may sun in partially shady places or can find a situation more shaded and 5 to 10° cooler. Feeding becomes more active for they may interrupt their sunning for a nibble at different plants or feed on one for a slightly longer time.

(iv) Reaction to hot soil.- Usually about this time of day (9.30 a.m.) the surface temperature of bare soil in the sun may have reached 116° F. Nymphs cannot tolerate this or higher temperatures. When crossing patches of bare soil of their own accord they move rapidly till they reach a plant debris or a shady spot. Should they be forced unwillingly onto patches of bare soil they quickly retreat. The efficiency of guard strips, in all likelihood, depends to a large extent upon this inability of nymphs to stand hot soil. It may also be a strong force driving hatching nymphs from hatching ground with sparse vegetation during drought years to cultivated or other vegetation that would assure them protection. Nymphs may then sun themselves in the morning, resting upon plant leaves or bare ground but later in the day they must confine themselves between these strata. The strata of vegetation then provides them with a habitat, forming patterns of temperature and shade in which to sun and feed.

(v) Reaction of seeking warmth.- On cool cloudy days nymphs are less active and behave differently. On a day in late June, 1936, air temperature

did not exceed 68° F. and the wind was very light. Just nymphs were found resting on bare soil in groups of 12 to 20. Soil surface temperature registered 74° F. which in all other locations tested was 8 to 10° lower. These other temperatures were taken under, vegetation, above it and among the plants present. Similarly, on this type of day nymphs are often observed clustering on rocks warmed by a few hours of sunshine. The rocks rose to 75° F. and 65° F. respectively.

(vi) Climbing to escape heat.— Nymphs may climb to escape heat if it is possible. A record of this activity was secured when the sun temperature registered 92° F. 6 inches above the soil and was for one to two degrees higher one foot above ground. In mid-afternoon several nymphs were up old ragweed stalks 2 feet above ground while others had used masses of old Russian thistle for the same purpose. As the sun begins to decline nymphs, and more particularly adults, may seek a position in the upper strata of vegetation for quite another purpose because then this strata provides warmth from the last rays of sunlight. on study plots and field observations.

(vii) Seeking protection from wind.— Wind drives nymphs to protection. On June 19, 1936, a very strong wind blew. Observation showed pockets of nymphs were congregated in small weedy patches among a 2 1/2 to 3 foot stand of sweet clover. These small openings provided nooks where they could sun and feed without being disturbed by the wind. The same day the leeward side of a small drift ridge was also found a favorable spot. Early in May, 1937, young nymphs were found protected in a dead furrow to the leeward of a fence clogged with Russian thistle. On the windward side wind velocity along the ground measured 10.2 miles per hour. The old Russian thistle debris only reduced the velocity 0.8 to 1.0 miles per hour while in the dead furrow there was not sufficient air movement to record. By July 30 in 1936 70 percent of the grasshoppers were estimated adult.

(viii) Feeding activities.— Study of feeding behavior of nymphal grasshoppers is difficult because even when a population of 100 or more per yard is present nymphs do not begin to feed and continue gluttonously but feed spasmodically. One in-

(iii) First copulation.-- The following are the first dates copulation was observed:

	<u>1936</u>	<u>1937</u>
<u>Melanoplus mexicanus</u>	July 9	July 12
<u>M. bivittatus</u>	10	7
<u>M. packardii</u>		13

(iv) First flights.-- Flights were first observed July 13, 1936 and on July 12 and 13, 1937.

(v) First and general egg-laying.-- In 1936 egg-laying began about August 15, was most general around August 20, and remained general until the end of August. Few were observed ovipositing after September 7. Egg-laying probably began about the end of July in 1937, but was only believed general between August 15 and 30. This activity was very slow during the first half of September. The last laying of the season was observed on September 26.

(b) Temperature reactions.--

(i) Beginning of activity.-- Grasshopper adults were observed before they had begun their day's activity when the air temperature only varied from 61 to 63° F. and the soil surface temperature between 63 and 66° F. between 5.30 and 6.00 a.m. The adults were inactive and most of them rested upon the lower ragweed leaves or on plant debris. The adults were basking in clusters on the ragweed leaves when the air temperature was 64° F. and the sun temperature nearby was 66° F.

(ii) Normal activity.-- Clusters of basking adults broke at an air temperature of 72° F. when the temperature in the sun near the cluster was 76° F.

(iii) Feeding.-- Feeding was only slight when the immediate temperature was 74° F. and the air temperature registered 69° F. Feeding appeared more general when the air temperature reached 75 to 76° F.

(iv) Local migrations.-- A striking migration into an oat crop was observed while recording behavior on July 8, 1936. Figure 14, plate XXIV shows the location of the observation. When the air temperature

over the border of the false ragweed reached 85° F. a few adults began to fly from it. Half an hour later a general exodus began. Adults flew 3 to 10 feet into the oat crop and nymphs hopped in. After 7 minutes 125 were counted in flight. The temperature was then 5° F. higher. However the sun clouded, a strong wind arose and the migration stopped. On July 4 a movement towards the border of weeds had been noted after 4.00 p.m. Nymphs and adults were then crawling towards the weeds. Some stopped to sun awhile but others crawled or jumped onto the dense vegetation. These observations show the grasshoppers were seeking the dense vegetation for protection at night but preferred the thin crop, possibly as food during the day.

A different type of migration was encountered July 26, 1937. Grasshoppers were taking short flights from a fairly mature wheat crop to a late barley crop 10 yards away. A few were moving the opposite way. Only a population of 10 per square yard remained in the wheat while the population 10 yards into the barley was 150 per square yard and averaged 30 per square yard in 100 yards. The grasshoppers were following the breeze randomly but were staying in the green barley which offered more palatable food.

(v) Reaction to hot soil.-- Before feeding in the morning or during feeding intervals the adults like to sun on the soil. As the soil temperature rises this location is not so favored. When the soil temperature had reached 120° F. July 4 the adults were more numerous 3 inches up the oat plants where the temperature was just 93° F. but others could tolerate the soil. Later in the day it was found 126° F. was too warm for the adults for when they were forced to alight upon the hot soil they repeatedly crawled a few inches or as far as necessary to bring them to a cooler location. Locations shaded by plants, clots of earth, where the temperature was 30 to 35° F. lower, were hastily sought. On another occasion a soil surface temperature of 126° F. forced adults to seek shadier places or climb 6 inches up barley plants.

The same reaction was described under nymphal

behavior, but it is interesting to note that the response does not occur among the adults until the temperature is 20° F. higher.

(vi) Seeking warmth.- Sometimes a population of grasshoppers may be found clustered on the ground or other object, obviously seeking warmth. When the following record was made the sun had clouded and the air temperature was falling. Two feet above ground the thermometer registered 83° F. It registered 4° higher a half a foot lower and was 102° F. on the soil surface where the population was concentrated.

(vii) Mass attacks on succulent food plants.- Several attacks upon succulent plants were observed in August, 1937. Skeleton weed, Lygodesmia juncea, with its green succulent bark and Chamaesyce glyptosperma and blue lettuce, Lactuca pulchella, both lactiferous, were the plants attacked. The species attacking were Melanoplus mexicanus, M. packardii and M. bivittatus. The first two species were the most important in attacks on the first two plant species and M. bivittatus was most numerous in attacks on blue lettuce. In all cases recorded more than half of the individuals were females. Figures 17, 18 and 19, plate XXVIII show an actual attack in progress.

(c) Flights.-

(1) Important flights and their direction in 1936 and 1937.- The flights which occurred in 1936 can now be considered light and of short duration. There were many days when a few grasshoppers were flying but the main flights of the year, on July 22, 27, August 6 and 29, came from the northwest. The last flight was the heaviest of the season which was remarkable because of the lateness of the season. It was the only flight when the grasshoppers within the halo around the sun could be estimated from 50 to inestimable, and this was so for only an hour.

The heavy flights recorded for 1937 were more intense and of longer duration than in the previous year. On good flight days 5 to 10 or more grasshoppers could be estimated in the halo around the sun from about 11.00 a.m. until 3.30 p.m., or

PLATE XXVIII

Figs. 17, 18 and 19. Clusters of grasshoppers
attacking skeleton weed (Cynodactylon juncea).



about four and a half hours. The most intense part of the flight usually occurred between 12.00 noon and 2.30 p.m. when it was usual to record estimates of hundreds or thousands in the halo around the sun. The dates and directions of the main flights are listed below:

July 21	-	southeast
26	-	"
Aug. 8	-	"
9	-	" -south
11	-	"
12	-	northeast (of short duration)
13	-	south

The flight of August 12 was intense only at 1.00 p.m. when the grasshoppers were ascending because the wind was not strong enough to carry them along.

(ii) Wind velocity and flight.— Wind velocity records taken at the weather station indicated these flights occur on days when the average hourly velocity is between 7.0 and 9.0 miles per hour. Hourly velocities above 11.0 miles per hour keep the grasshoppers on the ground and winds with hourly velocities below 5.0 miles do not support flights. These figures, however, are averages based on morning and evening readings and their applicability depends entirely on the constancy of the wind.

(iii) Temperature and flight.— Air temperatures and soil surface temperatures recorded for the important flights of 1937 at the beginning of flight and at the time of heaviest flight are given below:

Date	<u>Beginning of flight</u>		<u>Maximum flight</u>	
	Temperatures		Temperatures	
	Air	Soil Surface	Air	Soil Surface
July 21	86	108	84	140
26	79	100	83	120
Aug. 8			73*	
9	71	94	85	130
11	76	99	83	128
12	76	111	81	128
13	88	104	80	132
Average	79.1	102	86	129.6

* Temperature was above 73° F.

These flights began between 10.00 a.m. and 11.30 when the air temperature reached about 80° F. and the soil surface temperature was around 102° F. The most intense part of the flight always occurred between noon and 2.30 p.m. The average air temperature for the above flights was 86° F. and the average soil temperature about 130° F.

(a) Oviposition.--

(i) Temperature and oviposition.-- The soil temperature at the depth of laying (approximately one and a half inches), the soil surface temperature, and the air temperature recorded when females were found laying in 1936 are listed below:

<u>Species</u>	<u>Soil laying depth</u>	<u>Temperatures</u>	
		<u>Soil surface</u>	<u>Air</u>
<u>Melanoplus mexi-</u> <u>canus</u>	82	100	
	70	72	65
	70	69	
	98	108	64
	98	106	
	76	96	62
	68	77	62
	68	74	61
	66	71	62
	65	66	61
	64	63	61
	65	68	60
	74	85	65
	66	64	
	81	85	
<u>M. packardii</u>	104	112	
	98	108	64
	78	88	62
<u>Spharagemon collare</u>	74	74	65
<u>Dissosteira carolina</u>	104		
	98	114	
Average	92.6	99.2	

The records were secured in a few days during the last half of August, 1936 and most of the females were found laying between 10.00 a.m. and 2.00 p.m. For M. mexi-

canus the soil temperatures at laying depth observed mostly fell within the range of 65 to 70° F. but a temperature of 98° F. was observed. The soil surface temperatures from 64 to 108° F. were observed but most of the observations fell between or close to a range of from 70 to 80° F. The air temperatures were close to the average air temperature of 61.9° F. Parker (1930) found the first egg-laying of the day occurred at an average air temperature of 71.1° F. and soil surface temperature of 99.6° F. (12 observations) and was never observed at air temperatures below 69° F. or soil surface temperatures below 98° F. These temperatures are considerably higher than those observed at Lyleton which were low because most of the records were made during cloudy weather. However, they serve to indicate further the temperature range of egg-laying. It may also be noted from the few available records that the three other species, M. packardii, Spharagemon collare, and Dissosteira carolina, were observed laying at higher temperatures. This would be expected because these species favor oviposition sites of coarse sand.

(ii) Oviposition and the surface soil.- The following observations were made in mid-August, 1936. Adults of the species Melanoplus mexicanus, M. packardii and Dissosteira carolina were running around on a gentle west slope testing laying sites by pushing the valves of their ovipositors against the soil. Only four individuals were then laying. They chose the location where the observer had previously been sitting. In 15 minutes there were 22 adults ovipositing on this piece of ground and with the exception of one M. packardii adult, all were M. mexicanus. The soil had been crusted by rain three days before the observation. Therefore, it was believed the crusted surface soil inhibited oviposition. To find out whether a loose surface soil was preferred several plots, approximately 18 by 9 inches, were set up with one half the area loosened to a depth of about half an inch. The egg pods laid in both plots were later counted. A few more pods were found in the treated plots but the results were not conclusive because egg-laying had been underway for some time and in many cases the eggs in the plots were laid before the experiments were begun.

4. Summary

(1) First hatching was found about mid-May in 1936 and 1937 but was continued spasmodically until the middle of June or slightly later.

(2) Eggs hatched quicker from a drift ridge with a southern exposure than from level land surrounding. Moisture apparently urges on hatching while an insufficiency at that time results in mortality. Hatching proceeds normally during windy weather.

(3) The following temperature ranges were most commonly observed.

	<u>Range</u>	<u>Mid-point</u>
Soil surface temperature	78-84° F.	81° F.
Soil temperature	68-84° F.	76° F.
Air temperature	52-66° F.	59° F.

(4) Nymphal development was apparently quicker in June, 1937, because moisture conditions were better.

(5) Nymphal activity began at an air temperature of 58° F. and normal activity followed when the air temperature reached 70° F.

(6) A soil surface temperature of 116° F. will drive nymphs from the bare soil. They will climb to escape the heat. Nymphs will be attracted to the soil for warmth on cool cloudy days.

(7) A wind drives nymphs to protected locations.

(8) Nymphs feed spasmodically. Feeding became general around an air temperature of 65 to 70° F.

(9) In both seasons Melanoplus mexicanus adults appeared about the same time and copulation began about July 10.

(10) Egg-laying appeared general for about the same length of time in both seasons.

(11) Adults became active when the air temperature reached about 61° F. and when the soil surface

temperature was between 63 and 66° F. Normal activity followed when the air temperature had reached 72° or was 76° in the sun. Feeding was slight at an air temperature of 69° F. and when the air temperature in the sun was 74° but became more general at an air temperature of 75° F.

(12) Local migrations from dense vegetation which the grasshoppers sought in the evening was well observed in 1936. A local random migration to a late barley crop was observed in 1937.

(13) Soil which reaches a temperature of 126° F. is too warm for adults and they will climb plants or move into shady locations to avoid the heat. Conversely, on cool cloudy days adults will cluster on the soil seeking warmth as do nymphs.

(14) Mass attacks by Melanoplus mexicanus, M. packardii, M. bivittatus upon lactiferous plants in August are described.

(15) In 1937 flights were light and of short duration and from the northwest. In 1937 the flights were more intense and longer in duration. Most of them came from the southeast.

(16) The flights began between 10.00 and 11.30 a.m. when the approximate temperatures were:

Air temperature - 80° F.
Soil surface temperature 102° F.

The most intensive part of the flight occurred between noon and 2.30 p.m. when the approximate temperatures were:

Air temperature - 86° F.
Soil surface temperature 130° F.

An average hourly wind velocity of 7 to 9 miles was favorable to flights.

(17) Most of the temperature records of oviposition were secured between 10.00 a.m. and 2.00 p.m. During cloudy weather the air temperature at

egg-laying time was around 61.9. The soil temperature ranged mostly between 65° and 70° F. and soil surface temperatures between 70° and 80° F.

(18) Indications are that a crusted surface soil may not be as favored for egg-laying as a sandy loose one.

VIII. DETAILED STUDY OF EGGS

1. Locations Where Eggs were Found in 1936 and 1937

(1) Methods of study.- During the egg surveys notes were taken on the number and kinds of egg pods in relation to vegetation, slope and soil found at the location of each egg sample. The set-up of the egg surveys, designed to gain a knowledge of egg infestation on the study area, required the taking of as many samples as possible from the whole area. This arrangement was not satisfactory for a study of egg deposition in relation to types of vegetation, etc., because no provision was made for securing a comparable number of samples from similar locations in subsequent years. For example, wheat was grown on most of the cultivated land, so was well sampled. Oats, barley, fall rye, and sweet clover, more variable in acreage, were not adequately sampled. The same was true of other types of vegetation, particularly those on idle land, the area of which decreased greatly after 1936.

The preliminary spring egg survey of 1936 is included in the following tables of comparison, but the data are adequate for such comparisons in only a few cases.

(a) Adequate sampling.- To gain some idea of how many samples gave a reasonably reliable average of the number of M. mexicanus pods per sample, some data from the 1937 survey are tabulated (table 6).

Column I shows the number of samples in lots of approximately 50, 100, 150, etc., of each

series of samples used to calculate the averages in columns II and III.

Column II shows the average number of samples in which no egg pods were found.

Column III shows the average number of M. mexicanus egg pods per sample.

Table 6.

Sampling

Location	No. of samples	Ave. No. of zeros	Ave. No. of max. pods
Wheat	63	0.37	0.90
	100	0.44	0.79
	155	0.50	0.75
	204	0.49	0.73
	300	0.47	0.78
	402	0.51	0.74
	486	0.50	0.75
Oats	56	0.47	0.80
	104	0.58	0.64
	150	0.55	0.67
	191	0.53	0.69
Level ground	49	0.37	0.75
	98	0.33	0.99
	155	0.29	1.16
	207	0.27	1.37
	248	0.27	1.43

From an inspection of table 6 it appears that 50 to 60 samples gave an unreliable average when compared with the averages for 486, 191 and 248 samples. One hundred samples were somewhat more reliable. One hundred and fifty samples seemed adequate for practical purposes.

This information should be kept in mind

when viewing tables 6, 7, 8 and 9 because many of the data in these tables were obtained from fewer than 150 samples.

(b) Classification of results.-- The data were first classified into three general groups, widely different in vegetational and soil conditions. These groups were : (1) road allowances, (2) drift ridges, and (3) fields, each heading indicating where the samples were obtained.

Four general types of vegetation were distinguished: (1) pure, (2) mixed, (3) grass, and (4) cultivated crops. A pure vegetation consisted of a single plant species, as Russian thistle or false ragweed. Mixed vegetations were made up of two or more plants and were named after the dominant plant. The term "grass vegetation" was applied to vegetations such as Agropyron Smithii and Bromus inermis in more or less pure stands.

The components of these general types of vegetation sampled are found in Appendix VI.

The slope of ground where each sample was taken was recorded and the results tabulated (Appendix VI). However, the results of the spring survey in 1936 were tabulated differently than those from the two later surveys. In the first survey all the samples taken were sorted according to slope while in the later surveys only the samples from drift ridges were used.

A detailed tabulation of the three egg surveys forms appendix VI. Tables of yearly comparison are included here to bring forth important points.

(2) Discussion of results.--

(a) The effect of soil on oviposition.--

Table 7 was prepared to show the effect of soil condition on egg-laying.

Table 7.

Soil Condition and Oviposition

Location	No. of samples	Ave. No. of eggs	Ave. No. of Mex. pods
<u>Roadallowances:</u>			
Spring 1936	203	0.63	0.59
Fall " "	272	0.49	0.76
" 1937	147	0.33	1.27
Average of 3 surveys	207	0.48	0.68
<u>Drift ridges:</u>			
Spring 1936	445	0.47	1.11
Fall " "	439	0.33	1.36
" 1937	207	0.22	2.23
Average of 3 surveys	364	0.34	1.56
<u>Fields:</u>			
Spring 1936	198	0.75	0.23
Fall " "	1,613	0.51	0.61
" 1937	1,256	0.53	0.68
Average of 3 surveys	1,001	0.59	0.50

The average figure of 1.56 pods per sample for the three surveys found in column III indicates drift ridges contained more egg pods than the other general groups. Roadallowances with an average of 0.68 pods per sample were second in importance. Fields only had an average of 0.50 pods per sample.

The reason drift ridges are favored by M. mexicanus for egg-laying appears to be due to a soil difference. They are composed largely of coarse to fine sand with silty clay intermixed and present a marked difference from the textural soil type of the area.

Roadallowances appear to be second in importance for egg laying. However, this cannot

be held true for most of the area because only a few roadallowances were surveyed and much of the surveyed portion had deposits of drift soil. Consequently, most of the area surveyed was of soil very similar to that of drift ridges.

The fields, the majority of which were cropped and were generally heavier in texture, had the lowest egg deposit.

(b) The effect of vegetation on oviposition.--
The average number of M. mexicanus egg pods found in the four general types of vegetation are tabulated in table 6.

Table 6.

Vegetation and Oviposition

Vegetation	No. of samples	Ave. No. of eggs	max. pods
<u>Pure vegetation:</u>			
Spring 1936	404	0.50	0.94
Fall " "	471	0.42	0.97
" 1937	227	0.32	1.65
Average of 3 surveys	367	0.41	1.18
<u>Mixed vegetation:</u>			
Spring 1936	162	0.45	1.20
Fall " "	451	0.34	1.23
" 1937	242	0.32	1.47
Average of 3 surveys	291	0.37	1.30
<u>Grass vegetation:</u>			
Spring 1936	97	0.67	0.23
Fall " "	290	0.57	0.50
" 1937	172	0.42	0.77
Average of 3 surveys	147	0.55	0.50
<u>Crop:</u>			
Spring 1936	173	0.82	0.20
Fall " "	1,112	0.55	0.64
" 1937	864	0.52	0.73
Average of 3 surveys	716	0.63	0.52

Comparing the average figure for the three surveys we find mixed vegetation (average 1.30) contained more egg pods per sample than pure vegetation (average 1.18). Grass vegetation (average 0.50) and cropped land (average 0.32) contained considerably fewer egg pods.

The vegetation types mixed and pure both indicate disturbance of the normal vegetation by wind erosion. The mixed vegetations were composed of a conglomeration of ruderal weeds, such as Russian thistle, false ragweed, lamb's quarter and bind weed. A pure vegetation was distinguished as a pure stand of either Russian thistle or false ragweed (the only two pure vegetations sufficiently sampled) which likewise are ruderal weeds. Both types of vegetation were found on road allowances, on drift ridges on drift soil so would be expected to have similar egg deposits.

Grass vegetation and crops, on the other hand, were not subjected to the disruption mentioned above. Thus, it seems fair to say that M. mexicanus favored the ruderal vegetations which were present because of the drift soil deposits. The soil condition then appears to have more influence on oviposition than vegetation differences.

(c) The effect of cultivated crops on oviposition.— The cultivated crops are compared in table 9. The three egg surveys are tabulated but only the results of the two latter are discussed because too few samples were taken in the preliminary survey of 1936.

Table 9.

Cultivated Crops and Oviposition

Crops	No. of samples	Ave. No. of	
		zeros	max. pods
Wheat:			
Spring 1936	60	0.70	0.25
Fall "	499	0.54	0.71
" 1937	486	0.50	0.75

Table 9. (con'd.)

Cultivated Crops and Oviposition

Crops	No. of samples	Ave. No. of eggs	Ave. No. of max. pods
<u>Oats:</u>			
Spring 1936	19	0.72	0.26
Fall "	265	0.59	0.56
" 1937	191	0.53	0.69
<u>Barley:</u>			
Spring 1936	13	0.91	0.15
Fall "	72	0.54	0.66
" 1937	50	0.54	0.62
<u>Rye:</u>			
Spring 1936	23	0.86	0.12
Fall "	49	0.43	0.86
" 1937	29	0.38	1.03
<u>Millet:</u>			
Spring 1936	11	1.0	--
Fall "	54	0.72	0.36
" 1937	62	0.68	0.38
<u>Corn:</u>			
Spring 1936	8	0.84	0.60
Fall "	53	0.72	0.38
" 1937	38	0.61	0.76
<u>Sweet clover:</u>			
Spring 1936	35	0.85	0.54
Fall "	100	0.48	0.71
" 1937	8	--	--
<u>Cultivated stubble:</u>			
Spring 1936			
Fall "	42	0.83	0.14
" 1937	32	0.81	0.19
<u>Ploughed fallow:</u>			
Spring 1936			
Fall "	51	0.90	0.21
" 1937	60	0.87	0.10

Considering the few samples taken from rye stubble in the fall surveys of 1936 and 1937 we find the average figures in column III high. Sweet clover where 100 samples were taken in 1936 also seemed rather favorable for egg-laying. However, more samples would be required to establish these crops as better egg-laying sites than wheat.

During the fall surveys of 1936 and 1937, 985 samples from wheat yielded an average of 0.73 pods per sample. Oats and barley with 476 and 122 samples yielded respectively only 0.62 and 0.64 pods per sample. Wheat then appears more favored than oats or barley for egg-laying.

For the same two surveys millet had the low average of 0.37 pods per sample and every 7 out of 10 samples did not contain egg pods. Thus it appears to be the crop least favored for oviposition.

The corn stubble during the same surveys had averages of 0.38 and 0.76, for 53 and 38 samples respectively, so appears quite variable. The state of cultivation which will later be discussed may account for this difference.

Cultivated stubble or land summerfallowed with the one-way disc (two-year average 0.16) and ploughed fallows (two-year average 0.15) both contained few M. mexicanus egg pods.

(d) Effect of ground slope on oviposition.--
Data on the occurrence of M. mexicanus egg pods in relation to ground slope is recorded in table 10.

Table 10.

Slope of Ground and Oviposition

Slopes	No. of samples	Ave. No. of zeros	Ave. No. of mex. pods
Level:			
Spring 1936	419	0.70	0.35
Fall " "	424	0.47	0.82
" 1937	248	0.37	1.43

Table 10. (con't.)

Slope of Ground and Oviposition

Slopes	No. of samples	Ave. No. of eggs	Ave. No. of eggs
Average of 3 surveys	370	0.48	0.86
South:			
Spring 1936	69	0.27	1.83
Fall " "	64	0.19	2.08
" 1937	40	0.02	3.33
Average of 3 surveys	58	0.16	2.42
East:			
Spring 1936	105	0.53	0.64
Fall " "	55	0.28	1.38
" 1937	35	0.14	1.65
Average of 3 surveys	65	0.31	1.29
West:			
Spring 1936	62	0.48	0.85
Fall " "	108	0.33	1.24
" 1937	33	0.26	1.64
Average of 3 surveys	68	0.35	1.26
North:			
Spring 1936	47	0.53	1.04
Fall " "	60	0.65	0.55
" 1937	21	0.29	1.29
Average of 3 surveys	42	0.49	0.96

From table 10. it may be observed that the number of samples from each slope and for each year varies considerably. However, from the three survey averages it appears a southern slope (average 2.42) is most favored for egg laying. The eastern and western slopes with averages of 1.29 and 1.26 respectively are somewhat less favored and are of

about the same importance. A northern slope, average 0.96, is scarcely better than level ground with an average of 0.86.

(3) Summarized discussion.--

(a) Drift soil with a vegetation of ruderal weeds is very favorable egg-laying site.-- The condition of the soil appears to be the important factor in making drift ridges suitable to egg-laying by M. mexicanus. The same vegetation of mixed weeds found in reverted fields may not contain as many egg pods as a drift ridge. Similar reversions, however, on road allowances if covered with deposits of drift soil may be nearly as favorable for oviposition as drift ridges. Therefore, the drift soil is chosen as an egg-laying site when the vegetation consists of ruderal weeds.

(b) Crops sown and cut early are preferred for oviposition to late sown crops.-- This study is not conclusive because sampling was inadequate but the points brought forth supplemented with field observations are of some value.

Fall rye and sweet clover stubbles seem more select for oviposition than wheat stubbles. The early cutting of these crops leaves a sunnier habitat for prolonged egg-laying. Also, cutting of the dense foliage allows adults to spread over the stubble. The clover stubble and fall rye stubble (be it weedy) provide abundant food.

Wheat is definitely better for oviposition than either oats or barley and millet is least favored.

The observer believes there are two reasons why millet stubble is not used for egg-laying. Firstly, the soil is not sufficiently firm, being similar in nature to a newly formed drift ridge or loose gopher mounds which are known to be unsuited for egg-laying by M. mexicanus. Secondly, the dense foliage of millet before cutting harbors a low adult population which does not increase appreciably after cutting, because the stubble of a dense stand is usually free of weeds.

Similarly, corn land which has been well cultivated early in the season, has loose soil and is clean so is not favored.

Oats and barley are cut earlier than wheat but are usually sown later, consequently the soil does not settle as firmly which may account for the heavier egg deposition in wheat.

Ploughed summer-fallow and one-way disced land is unfavorable to egg-laying. Here again, firmness of soil is one of the main factors concerned.

(c) Southern exposures are most preferred for egg-laying while western and eastern slopes are more preferred than north slopes or level ground. Griddle (1933) believed that early in the egg-laying season level ground or an eastern slope is chosen for oviposition while southern or western slopes are preferred by late laying species as M. mexicanus. Our observations substantiate the preference of M. mexicanus for southern exposures but also indicate that western slopes are not as favorable as southern slopes. Further, we find that eastern slopes are as preferred as western slopes. Northern slopes are least favored for oviposition.

2. Sex Ratios and the Number of Eggs per Pod for the Years 1936 and 1937

The sex ratio among 1,973 adults examined in 1936 was 0.54, and the ratio in 1937 was only 0.46 among 1,503 adults.

In the first year of the study the average number of eggs per pod was 16.1. The average was slightly higher in the second year when 17.6 eggs per pod were recorded. In both years only a few pods were counted, 87 in 1936 and 63 in the following year.

3. Egg Viability

A study of egg viability was made in the spring of 1937. One thousand eggs of Melanoplus mexicanus were collected on the study area and taken to Brandon for rearing in the laboratory. The rearing was done by Mr. Seyward Smith who reported a 59 percent hatch which was 70 percent complete by the end

of May and complete before the end of June. No parasites emerged. Concerning some of the unhatched eggs examined Mr. Smith said "the majority contained the dried-up or partly gummy yolk material with no evidence of any development. A few contained dried-up grasshopper embryos, and some were merely shrivelled shells, the interior being filled with the same mould that in many cases had eventually covered the eggs in the time. This mould may have been a factor in preventing the hatching of some eggs. It was difficult to combat, wiping it off usually resulted in damaging the egg."

4. Summary

(1) Drift soil with a ruderal vegetation was found the best egg-laying habitat.

(2) Early sown crops which are cut early are preferred for oviposition to late sown crops, especially if the late sown crops are also cut late as in the case of millet.

(3) Southern exposures are most preferred for egg-laying while western and eastern slopes are preferred to northern slopes or level ground.

(4) The sex ratio was 0.54 in 1936 and 0.46 the next year. However, this difference does not seem strikingly significant.

(5) By the examination of a small number of egg pods in both seasons, 16.1 eggs per pod were recorded in 1936 as compared with 17.6 eggs per pod in the following year.

(6) The egg viability was found to be only 59 percent in the spring of 1937. No parasites were found to account for the eggs which were non-viable.

IX. RELATION OF INSECT ASSOCIATION

1. Parasites of the Adults

(1) Species recorded.—Dipterous pupae secured from grasshoppers in cage studies were brought

into the laboratory late in 1937. Sarcophaga atlanis Hld. and S. hunteri Hough were reared. The determinations were made by Mr. C. E. Shewell of the Systematic Division, Ottawa. In 1938 living grasshoppers (1,400 M. mexicanus and 373 Camnula pellucida) were sent to Mr. Chester W. Smith of the Belleville Parasite Laboratory who found parasites belonging to the three families Sarcophagidae, Tachinidae and Nemestrinidae. The following species were recorded: Sarcophaga hunteri Hough, Sarcophaga sp., Hemithrixion sp., Brachymeria sp., and Sarcophaga atlanis Hld.

(2) Abundance of adult parasites.— Throughout the seasons of 1936 and 1937 two methods were used to gauge the relative abundance of dipterous parasites: (1) Dissections of Melanoplus mexicanus adults were made about every two weeks. (2) Several cages were set up throughout the summer. Small cages, approximately one foot square and a foot high, were used. One inch to an inch and a half of sifted soil was placed on the bottom of the cage and the grasshoppers were then put in the cages. No food was provided. When the grasshoppers had died the dipterous larvae or pupae among the soil were counted.

(a) Discussion of results.— The following tables show the results of the dissections and cage studies made in both season.

Table 11.

Dipterous Parasites Dissected from
Melanoplus mexicanus adults 1936

Date	No. dissected	No. of dipterous larvae	% parasitism
July 16	100	8	8
19	50	0	0
Aug. 1-15	545	0	0
15-31	542	12	2.2
Sep. 1-15	745	22	2.9

Table 12.

Dipterous Parasites Obtained by Caging
Melanoplus mexicanus Adults 1936

Date	No. caged	No. of dipterous parasites	% parasitism
July 16	210	0	0
27	181	0	0
Aug. 4	58	0	0
25	201	10	5
Sep. 18	102	3	3

Table 13.

Dipterous Parasites Dissected from
Melanoplus mexicanus Adults 1937

Date	No. dissected	No. of dipterous larvae	% parasitism
July 13	51	0	0
17	64	1	1
24	80	0	0
27	64	4	4.7
Aug. 1-15	202	1	0.49
15-21	401	9	2.2
Sep. 1-15	435	20	4.5
15-30	89	4	4.4

Table 14.

Dipterous Parasites Obtained by Caging
Melanoplus mexicanus Adults 1937

Date	No. caged	No. of dipterous parasites	% parasitism
July 17	106 (75% max.)	0	0
Aug. 15	192	1	0.52
Sep. 8	130 (70% max.)	7	5.3

From the foregoing tables it may be concluded that the parasitism was around 3 percent from mid-August until mid-September in 1936. The results for the following season indicate the parasitism was slightly higher, possibly 4 to 5 percent, for a similar period.

Comparing the two methods of measuring parasitism it may be said that the dissection method is more accurate because the number of larvae present per grasshopper is found and the percent parasitism can be figured on the basis of only one larva per grasshopper. The cage method, on the other hand, is quicker but less accurate because some of the adults containing small larvae may perish before they have grown enough to emerge and one cannot tell how many parasites issue from one host. However, the results above based on only a few figures seem to reveal the trend of parasitism.

(3) Cephaline gregarines.— In 1937 cephaline gregarines which, according to most authorities, are not injurious to grasshoppers and cockroaches were found to be quite abundant in a few Melanoplus mexicanus individuals. The extent of infestation was not ascertained. In some of the individuals examined, there were several hundred gregarines in the ventriculus. They were abundant enough to be easily discernible through the wall of the ventriculus.

2. Parasites of the Eggs

The only egg parasite which was reared from Melanoplus mexicanus eggs was a species of Acelio. These were only found occasionally so at present do not appear to be important parasites.

3. Predators of the Eggs

(1) Species recorded.— The following species were recorded:

Blister beetle larvae

- a. Macrobasis subulabre Fall.
- b. M. murina Lec.

- c. Lytta sphaericollis Say
- d. Epicauta maculata Say

Carabid beetle larvae

- a. Perocoma obesa Say

Beetle larvae

- a. Eystoechus vulgaris Loew.

Red mite

- a. Possibly Eutrombidium locustarum
(Walsh)

The first three blister beetles listed above have been reared from grasshopper egg pods from south-western Manitoba. The rearing was done by the Brandon laboratory in 1935 and at that time Macrobasis subglabra was the most important species. In 1937 M. murina, which was only rarely observed in the previous year, became an equally important species. In fact, it was the most abundant species on the caragena field shelter belt which was planted in the spring of 1937. The damage to the shelter belts by July 15 was estimated by Mr. D. I. Crossley, Dominion Forest Nursery Station, Indian Head, Saskatchewan, to be 50 percent of the year's normal growth, while about 5 percent of the shelter belt was completely defoliated.

Lytta sphaericollis was found mostly on Symphoricarpos occidentalis, and only occasionally abundant on ash and lilac. Epicauta maculata was only taken occasionally on the area.

The other two egg predators, Perocoma obesa and Eystoechus vulgaris, are the only species of Carabidae and Bombyliidae yet known to be predatory upon grasshopper eggs in southwestern Manitoba.

(2) Abundance of egg predators.— Table 15 was prepared from egg survey data and indicates the relative abundance of egg predators for both seasons.

Table 15.

Ratio of Predators to M. mexicanus Egg Pods
(Egg pods per predator)

Predator	1936	1937
Carabid larvae	11.6	15.1
Blister beetle larvae	21.9	7.6
Beefly larvae	5.8	2.8
Red mites	29.4	17.2

Comparing the ratios in table 15 it appears that the predators in order of importance were beefly larvae, carabid larvae, and blister beetle larvae in 1936 and that the order changed in 1937 when blister beetle larvae increased and carabid larvae decreased. It may also be noted from the table that beefly larvae and red mites had apparently increased in 1937.

X. RELATION TO DISEASE

Throughout southwestern Manitoba in the early summer of 1935 an extensive epidemic of the grasshopper disease Empusa grylli Fr. occurred, principally among Cannula pellucida. According to the observations of Dr. H. B. Bird Melanoplus mexicanus escaped attack during the epidemic. During the first two years of this study no extensive outbreak of the disease occurred and only the odd specimens of Cannula pellucida, Dissosteira carolina, and Spharagemon collare were found which had succumbed to the disease.

XI. RELATION TO BIRDS AND MAMMALS

1. Birds

Henderson (1927) reports that Hughey in the first report of the United States Commission believed the only fields in the Great Plains region which escaped depredation by the Rocky mountain locust during the plague of 1873-'76 were those to which birds flocked. The outbreak was too extensive for the birds to control but he was able to show that 202 species were feeding upon the grasshoppers and their eggs. A more recent study by Bryant, according to Henderson, showed grasshoppers constituted the following percentages of the food of the listed birds:

Western kingbird	-	67.5 percent
Brewer's blackbird	-	80 percent
Burrowing owl	-	90 percent
Western meadowlark	-	96 percent

The species of these passerine birds which are present at Lyleton and are important grasshopper predators may be seen from the list under animal life in section II. These birds nesting on the study area likely have more influence upon the grasshopper population than those mentioned below which are more sporadic in their visitations.

Franklin's gull symbolizes the usefulness of birds to agriculture. To it alone stands a monument to commemorate its excellent work in alleviating the scourge of Mormon crickets that beset the early agriculturists of Utah. Franklin's gulls travel in flocks from feeding ground to feeding ground and often large flocks descend to feed on grasshoppers or other insect pests. Bradshaw (1934) records a flock in Saskatchewan one mile in length, averaging sixty birds in width, which descended to exert its usefulness upon grasshoppers. Large colonies of these gulls nest in the marshes at the south end of Lake Manitoba and Lake Winnipeg. Dr. Bird reports that in 1934 large flocks were ranging far from their

nesting colonies to feed upon grasshoppers which were rampant. In the spring of 1937 large flocks were reported working out from Oak Lake during the period of nymphal abundance. Small flocks that appear to commune with the farmer as he ploughs are more common. They follow the turning sod, foraging upon terrestrial insects as they are turned up or snatching up grasshoppers as they jump to safety. The benefit from Franklin's gulls on the study area during the two years under review was from the feeding of these small flocks.

Many coveys of sharp-tail grouse and Hungarian partridge were observed during both years on the study centre and in general the grouse population of southwestern Manitoba was high. Grouse are known to feed on considerable quantities of insects, including of course grasshoppers when they are abundant. In fact, Criddle (1930) believed there is a positive correlation between the numbers of grouse and grasshoppers. The same weather conditions favor the abundance of each and grasshoppers then form an important item in the diet of the grouse. The species of grouse present in southwestern Manitoba are:

Prairie sharp-tailed grouse, Pedioetes phasianellus
campestris Ridgway
 Hungarian partridge, Perdix perdix perdix (Linnaeus)
 Pinnated grouse, Tympanuchus cupido americanus (Reichenbach)

Bird (1934 Brandon Tech. Rept.) listed meadow-larks, Arkansas kingbirds, vesper sparrows, chestnut collared longspurs, Brewer's blackbirds and burrowing owls as the most important birds feeding extensively on grasshoppers.

Two colonies of burrowing owls were located at Lyleton in 1936 and 1937, and grasshopper remains were found in the pellets regurgitated by them.

2. Mammals

Late in the summer of 1936 Dr. Bird and the observer discovered a fox den. The examination of

dried faecal material found outside the den revealed that a great bulk of their food had consisted of grasshoppers. In correspondence with Dr. Bird, Errington expressed the belief that a late season den had been discovered. The late season dens are the last of a series of dens occupied by the fox family as its members become self-sustaining. The preponderance of grasshoppers in the food suggested a late season diet. The food habits of the red fox, according to Errington (1937), are not normal during drought years. In comparing the drought year of 1934 with the normal year 1933 he found them to be more insectivorous in the drier year. From examination of faecal samples he estimated the total amount of insect debris to be about 10 percent of the total bulk of samples examined. The summer of 1936 was exceedingly dry and grasshoppers were easily procurable so that one would expect them to figure prominently in the foxes' diet.

Gophers and jack rabbits are the only competitors of grasshoppers for food. The common gopher, Citellus richardsonii (Sabine), did damage to small areas, 3 to 5 yards in diameter, in the vicinity of their burrows. They were also responsible for more extensive crop damage in a few locations. Fortunately, the extensive damage on the study centre did not exceed 3 to 4 acres of crop. Gophers were as numerous in 1937 but damage was not noticeable because all crops were much denser. Jack rabbits, Lepus townsendii camp-anus Hollister, were suspected to be responsible for the destruction of 3 to 4 acres of a small crop of fall rye in the autumn of 1936.

XII. SUMMARY

1. The glacial history, surface geology and soils present on the area are briefly discussed. A definition of the climatic region of the area in accordance with Thornthwaite's classification of the climates of North America is recorded. The relict native vegetation was studied since the vegetation is a gross expression of the climate and the weather conditions which existed two years prior to the study certainly left their mark upon the veg-

estation. The extent of soil erosion on the area at the inception of the study and the stages of reversion on idle land are also indicated. The description is concluded by considering the cultivated crops which were grown on the area during 1936 and 1937.

2. Since an intimate relationship between weather and grasshopper abundance is acknowledged by all authorities, the collection of weather data must accompany a long term field study as was done at Lyleton. Comparing the season with the normal for Pierson, the 1936 season was noticeably deficient in rainfall, particularly the months of May, July, and October, while in the following season, June, July, September, and October, the rainfall was above normal. May and July were much above normal in temperature the first season and July and August held a similar position the second year.

3. The yearly population of 1937 was above that of the previous year because not enough efficient cultivation was employed in the fall of the year and the influx to the area was greater in the second year of study. The egg infestation did not measure up to the adult infestation in both years. The nymphs were localized on unworked land and the adults spread generally but became more localized later in the season. The use of the plough for cultivation caused the greatest reduction in population but the one-way disc and the surface tillage of summer-fallows were also useful in this respect. Crop damage was not very extensive on the study area in either years. A feature of the damage caused in 1937 was the insidious habit of decapitating wheat as it reached maturity which resulted in a very significant loss in yield.

4. Population trends on study plots seemed to show a nymphal peak, representing the total hatch of the season and an adult peak late in August when the adults had become localized in late season feeding grounds. General points manifested by the study plots were the large nymphal populations which can hatch from stubbled-in fall rye crops and the efficacy of clean fallow in keeping the land free of adults.

5. Hatching* in both seasons continued

* Melanoplus mexicanus (Sauss.) is the species concerned since it formed 80 to 90 percent of the population.

spasmodically from mid-May until mid-June and occurred first on a southern exposure. Moisture apparently urged on hatching while lack of it was a cause of mortality. Hatching proceeded normally during high winds. The mid-points of the temperature ranges most commonly observed at hatching time were:

Soil surface temperature	86° F.
Soil temperature (depth approximately one inch)	76° F.
Air temperature (shade)	59° F.

Nymphal activity began at an air temperature of 58° F. (shade temperature) and normal activity at an air temperature of 70° F. A soil surface temperature of 116° F. drove nymphs from bare soil, making them climb to escape the heat. On the other hand, the heat of the soil surface attracted them on cool cloudy days. Nymphs fed spasmodically but general feeding began around an air temperature of 65 to 70° F.

Adults became active at an air temperature of 61° F. and normal activity began at an air temperature of 72° F. Feeding was only slight at an air temperature of 69° F. but became more general when the air temperature reached 75° F. A soil surface temperature of 128° F. could not be tolerated by the adults (12° F. above temperature for nymphs) which climbed or crawled to shady places to avoid the heat. As in the case of the nymphs, the soil's heat is also sought by the adults on cool, cloudy days.

Peculiar mass attacks by Melanoplus mexicanus, M. packardii and M. bivittatus upon lactiferous plants were observed in August.

Flights from the northwest were light and of short duration in 1936 but those from the southeast in 1937 were heavier and of longer duration. Air temperature at commencement of flight was around 80° F., and around 86° F. during maximum flight. Soil surface temperatures of about 86° F. and 130° F. occurred at the beginning and during maximum flight respectively. A wind with an average hourly velocity of 7 to 9 miles accompanied flights.

Oviposition during cloudy weather occurred near an air temperature of 62° F.

6. In a detailed study of egg-laying sites, sites of drift soil with a ruderal vegetation were found most preferred. Early sown crops cut early were preferred for egg-laying to late sown crops, especially if the late sown crops are also cut late. A southern exposure was the most preferred laying slope. The sex ratio and the number of eggs per pod did not vary significantly in two seasons.

7. Dipterous parasites of the adults recorded to date for the study area are Sarcophaga atlanis Hld., S. hunteri Hough, Sarcophaga sp., Hemithrixon sp., and Brachymeria sp. A three percent parasitism of Melanoplus mexicanus (Gaus.) from August 15 to September 15, 1936, and a four to five percent parasitism during the same period in 1937 was indicated by the study. Cephaline gregarines were found in adults of Melanoplus mexicanus in 1937. A species of Scelio infrequently observed was the only egg parasite of the species. Beely larvae, probably Mytoechus vulgaris Loew., were the most numerous predators but blister beetle larvae of Macrobasis subulabra Fall. and M. murina Lec. and cerabid larvae were important predators. The beely and blister beetle larvae increased in 1937 and the cerabid larvae apparently decreased in number.

8. Disease was not a factor in reducing population in either year.

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