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Bulletin No. 290 - Food Plants as Factors in the Ecology of the Lesser Migratory Grasshopper Melanoplus mexicanus (Sauss.)

University of Wyoming Agricultural Experiment Station

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FOOD PLANTS AS FACTORS IN THE ECOLOGY OF THE LESSER MIGRATORY GRASSHOPPER

Melanoplus mexicanus (Sauss.)
Food Plants as Factors in the Ecology of the Lesser Migratory Grasshopper, *Melanoplus mexicanus* (Sauss.)

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Associate Research Entomologist

**INTRODUCTION**

Vegetation has been shown to control the distribution of grasshoppers both by its influence on the microclimate and by its restriction of the insects' diet. The importance of the latter control has been recognized for some time, but not until recently have critical studies been made on the food habits of grasshoppers. Several good papers have appeared which treat a limited number of species, but for the majority of forms the amount of critical information is small. Little is known about the food habits of the very destructive grasshopper, *Melanoplus mexicanus mexicanus* (Saussure). Several field studies dealing with the distribution of grasshoppers in North America in relation to the vegetation and to physical factors of the environment have included treatments of this species. Investigations of this nature have been made by Vestal (1913), Hubbell (1922), Strohecker (1937), Urquhart (1941), Cantrall (1943), and several others. In general, the conclusion drawn from most of these studies has been that the distribution of grasshoppers is correlated with the different types of vegetation, and further that the controlling factors are entirely physical and are not related in any immediate way to the food preference or food requirements of the grasshoppers.

More direct studies on the role of food-plant in the ecology of *M. mexicanus* have been made. Criddle (1933) through field observations came to the conclusion that the species was a general feeder. R. W. Smith (1939) found that at Dickson, North Dakota certain spring varieties of wheat were injured more than others by grasshoppers (mainly *M. mexicanus*). With some exceptions badly rusted varieties were

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1 A study made in cooperation with the U. S. D. A. Bureau of Entomology and Plant Quarantine, Bozeman, Montana laboratory, J. R. Parker in charge. This paper is part of a dissertation submitted to the faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of doctor of philosophy.

2 I gratefully acknowledge the direction and criticism given me by Dr. A. C. Hodson, University of Minnesota, in pursuing this study. Thanks are also due Dr. L. F. Clarke, University of Wyoming, who read and criticized the manuscript, and Dr. C. L. Porter, University of Wyoming, who identified and verified identifications of plants.
injured considerably more than varieties showing but little rust. In Alberta, Jacobson and Farstad (1941) also observed differential feeding upon wheat varieties.

*M. mexicanus* has been reared on a variety of food-plants, but the early papers gave only slight consideration to the differential effects. Criddle (1924) found wandering Jew particularly suitable for rearing *M. mexicanus*. Parker (1930) used wheat seedlings, corn seedlings, wandering Jew, and dried alfalfa leaves in various experiments, but he made no comparisons of the value of each plant. Faure (1933) in a study of the phases of *M. mexicanus* used mainly young wheat and maize leaves. Drake, Decker, and Tauber (1945) fed *M. mexicanus* a mixed diet of corn, legumes, and several other plants. Upon this diet the females averaged 117 eggs per individual. In a recent paper, Brett (1947) treated the interrelated effects of food, temperature, and humidity on growth. He found that the conditions most favorable for maximum physical development of *M. mexicanus* were kind and succulence of food, high temperatures (about 100° F.), and low humidities (about 35 per cent). Three kinds of food-plants were fed. Lettuce was most favorable, corn less so, and alfalfa was relatively poor.

The present study was undertaken to investigate more fully the role of plants as food in the ecology of *M. mexicanus*. It was desired to find out whether the distribution and abundance of food-plants affected the distribution and abundance of grasshoppers, with the object that such information would serve later for the purpose of predicting population increases and outbreaks. Briefly the following studies were made:

1. The habitat.
2. Observation of feeding in natural habitats.
3. Selection of food-plants under laboratory conditions.
4. Manner in which food-plants are selected.
5. Relation of food-plants to survival and mortality.
6. Relation of food-plants to egg production.
7. Relation of food-plants to growth.

The plants dealt with in the field studies and in the experimental work have been designated by common names throughout the text. As there is still a lack of uniformity in common names the equivalent scientific names are given in an appendix at the end of this paper. Scientific names of cultivated plants, however, have not been included.

**Description of Area**

The field studies were limited chiefly to areas in the short-grass plains of eastern Wyoming. This region lies immediately east of the Rocky Mountains and varies in altitude from about 3500 to 7200 feet. The vegetation is characterized by short-grass dominance. The most important grass is blue grama. Grasses of almost equal consequence are
bluestem, needle-and-thread, buffalo grass, Sandberg bluegrass, mutton grass, and junegrass. Threadleaf sedge is also abundant in this association. There are other species of grasses found within the short-grass plains of eastern Wyoming, but they are usually of less importance. Some, such as Indian ricegrass and prairie sandgrass, are found locally in the sandy areas, while others, such as sand dropseed and desert saltgrass, are characteristic of alkali soils. A few others are found in small numbers under the usual edaphic conditions of the short-grass plains, such as red threeawn, green needlegrass, and slender wheatgrass.

A large number of herbaceous plants occur throughout the region. Chief among these are false mallow, effuse eriogonum, slender scurfpea, curlycup gumweed, and fringed sagebrush. Conspicuous perennials in certain areas are big sagebrush and broom snakeweed. A large number of annual forbs are present. Common species are peppergrass, stickseed, shrubby oreocarya, tansy mustard, tumble mustard, sunflower, goosefoot, pennyroyal, and woolly Indianwheat. In some range areas and in disturbed areas, annual grasses such as downy chess and Japanese chess have risen to importance. Six-weeks fescue, another annual grass, becomes abundant on the range during certain years. Dandelion sometimes grows profusely on low slopes where the soil remains moist from spring to about midsummer.

The composition and density of vegetation at eight stations in eastern Wyoming were obtained in 1945 (Table 1). The data are the means of three ten meter readings secured by the line interception method as described by Parker and Savage (1944). Stations No. 3 to 8 are typical of the grassland of eastern Wyoming in that blue grama makes up a high percentage of the vegetation; however, stations 1, 4, 6, and 7 contain more forbs than is usual. Stations 1 and 2 are rather unusual in that bluestem and species of Poa represent the major part of the vegetation. Station 1 was located on a slope and station 2 was in a flat between two ranges of hills. Both areas appeared to have better than average moisture conditions. In station 1 the high percentage of forbs consisted almost entirely of dandelion.

All of eastern Wyoming does not conform to the description of short-grass plains, for along stream courses flood plain conditions are found and in the northeast section ponderosa pine forests cover the Black Hills. Farming which is carried out on a small scale both on dry land and under irrigation has changed the original grassland conditions in limited areas. Alfalfa, small grains, corn, sugar beets, potatoes, and beans are the chief crops. Many noxious weeds have become a familiar part of ruderal communities. Some weeds such as dandelion and wild lettuce afford favorable food-plants for certain of the economically important crop grasshoppers.

*Waste or weed communities.
### TABLE 1

**PER CENT COMPOSITION AND DENSITY OF VEGETATION AT EIGHT STATIONS IN EASTERN WYOMING**

<table>
<thead>
<tr>
<th>Location</th>
<th>Station Number</th>
<th>Blue grass</th>
<th>Bluestem</th>
<th>Poa spp.</th>
<th>Needle-and-thread</th>
<th>Threadleaf sedge</th>
<th>Carex Electanalis</th>
<th>Junegrass</th>
<th>Six-Weeks reese</th>
<th>Green needlegrass</th>
<th>Other Grasses</th>
<th>Forbs</th>
<th>Total Per cent Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheridan</td>
<td>1</td>
<td>28.3</td>
<td>39.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>43.1</td>
</tr>
<tr>
<td>Manville</td>
<td>2</td>
<td>35.8</td>
<td>11.4</td>
<td>43.2</td>
<td>4.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
<td>1.3</td>
<td>3.7</td>
<td>25.1</td>
</tr>
<tr>
<td>Manville</td>
<td>3</td>
<td>55.3</td>
<td>3.7</td>
<td>9.1</td>
<td>9.3</td>
<td>2.7</td>
<td></td>
<td></td>
<td></td>
<td>1.7</td>
<td>2.4</td>
<td>0.2</td>
<td>11.2</td>
</tr>
<tr>
<td>Lusk</td>
<td>4</td>
<td>48.1</td>
<td>1.0</td>
<td>10.2</td>
<td>6.0</td>
<td>8.0</td>
<td></td>
<td></td>
<td></td>
<td>0.9</td>
<td>6.3</td>
<td>0.1</td>
<td>18.2</td>
</tr>
<tr>
<td>Guernsey</td>
<td>5</td>
<td>53.5</td>
<td>0.7</td>
<td>8.0</td>
<td>4.4</td>
<td>4.2</td>
<td></td>
<td></td>
<td></td>
<td>3.3</td>
<td>17.1</td>
<td>0.5</td>
<td>7.8</td>
</tr>
<tr>
<td>Dwyer</td>
<td>6</td>
<td>53.0</td>
<td>0.8</td>
<td>6.8</td>
<td>6.0</td>
<td>9.9</td>
<td></td>
<td></td>
<td></td>
<td>1.8</td>
<td>3.7</td>
<td>1.2</td>
<td>17.2</td>
</tr>
<tr>
<td>Jay Em</td>
<td>7</td>
<td>40.3</td>
<td>0.8</td>
<td>0.9</td>
<td>8.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19.3</td>
<td>2.2</td>
<td>28.0</td>
</tr>
<tr>
<td>Cheyenne</td>
<td>8</td>
<td>63.7</td>
<td>4.0</td>
<td>5.8</td>
<td>13.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.9</td>
<td>4.0</td>
<td>34.2</td>
</tr>
</tbody>
</table>
The habitats of *Melanoplus mexicanus* are found chiefly in grasslands and in areas where land is broken or cleared and where crops are grown. In eastern Wyoming small numbers of less than one adult per square yard were present quite generally over the short-grass plains during the summers of 1943 and 1946. In some areas greater numbers were found. At station 1, Sheridan and at station 7, Jay Em, it was estimated that there were 4 to 7 adults per square yard. Both of these areas contained more forbs than are usually present on the ranges of eastern Wyoming. At Sheridan dandelions made up the major percentage of the forbs while at Jay Em several forbs, such as stickseed, sunflower, peppergrass, and lygodesmia were common. The soil at Sheridan was a clay loam and at Jay Em a fine sand. These areas as well as some others on the ranges of eastern Wyoming in which forbs constituted a large portion of the cover apparently served as favorable habitats for *M. mexicanus*. No physical measurements of the environment were taken, but from casual observation little difference should be expected between areas on the short-grass plains which contain high percentages of forbs and those which do not. Both types have many bare spaces and both are exposed to the full effects of the wind and the sun. An alternative reason for large populations of *M. mexicanus* in areas with high percentages of forbs and low populations in areas where grasses are preponderant, is that the former provide more and better food-plants than the latter. That this is probably the correct explanation is indicated by the results of the experimental work to follow.

Croplands in Wyoming are at times infested with large numbers of *M. mexicanus*. During the period 1941 to 1946 heavy infestations have been observed in wheat and in alfalfa fields. Ruderal communities also provide favorable habitats, for high densities are often present among the weeds and other vegetation of reverted farm lands and along roadsides.

A review of references which note the habitat of *M. mexicanus* shows that although its wide distribution in North America carries it into several biomes, it is more characteristic of grasslands. Vestal (1913) in studying the local distribution of grasshoppers at Douglas Lake, Michigan found the species in different grassland habitats including the clearings in deciduous forest, but not in the forest itself except on rare occasions. Urquhart (1941) working on Point Pelee, Ontario found it in sand dune habitats, sandy cultivated areas, and grassland but not in the deciduous forest, nor clearings of the forest, nor marsh. On the George Reserve, Michigan, Cantrall (1943) has found it to be "char-
acteristic" of the mixed grass-herbaceous habitat, "sporadic" in sparsely vegetated sand habitat, and "erratic" in deciduous forest. Fautin (1946) records *M. mexicanus* from the sagebrush community of the Northern Desert Shrub Biome in western Utah, but not from the shadscale, *Tetradymia*, or greasewood communities. He states that the sagebrush community has water requirements similar to the driest grassland community and often contains grasses and herbs as common associates. Shadscale and *Tetradymia* communities are shown to be more xeric than the sagebrush community. The above and other references to the habitat of *Melanoplus mexicanus* in various parts of its area of distribution are listed in Table 2.

*Melanoplus mexicanus* evidently has considerable ecological plasticity and as a consequence can be found in a wide variety of habitats. It is most common in grassland communities, and it is often found in large numbers in ruderal communities and in many culture communities. In addition the species has been reported from the edge and from the clearings of forests, from sand dune areas, and from sagebrush communities.

**Observations on Feeding in Natural Habitats**

The feeding of *Melanoplus mexicanus* has been observed in several of its natural habitats. The data obtained at station 1, Sheridan during 1944 are shown in Table 3. The number of first instar individuals observed feeding were few, as only two were found feeding on a small forb which was not identified. Older instars and adults were observed feeding mainly on dandelion, but a few were found feeding on native grasses. At the Sheridan station observations were made a year earlier on July 31 when the grasshoppers were adult. There was a good stand of green grass at the time, but the leafy portions of the dandelions had been entirely destroyed. Eight individuals were observed feeding on the following plants:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluestem</td>
<td>4</td>
</tr>
<tr>
<td>Dandelion</td>
<td>2</td>
</tr>
<tr>
<td>Sandberg bluegrass</td>
<td>1</td>
</tr>
<tr>
<td>Unidentified forb</td>
<td>1</td>
</tr>
</tbody>
</table>

The two which were found feeding on dandelion fed on the crowns or small sprouting leaves which were located below the level of the soil surface.

Observations of feeding in other areas were made. Five adult individuals were found feeding on thistle at station 2, Manville. In this area a few dandelions grew in the low places. These plants showed grasshopper injury which may have been caused, at least in part, by the feeding of *Melanoplus mexicanus*. At other places in eastern Wyoming...
<table>
<thead>
<tr>
<th>Habitat</th>
<th>Region</th>
<th>Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Grassland sandy soils, crops, ruderal communities</td>
<td>New York</td>
<td>Herrick and Hadley 1916</td>
</tr>
<tr>
<td>2. Dry sandy fields in coastal plain, crops, ruderal communities</td>
<td>New Jersey</td>
<td>Fox 1928</td>
</tr>
<tr>
<td>3. Grassland, open country, crops, ruderal communities</td>
<td>Virginia</td>
<td>Fox 1917</td>
</tr>
<tr>
<td>4. Open and weedy areas</td>
<td>Pennsylvania</td>
<td>Hebard 1937</td>
</tr>
<tr>
<td>5. Grassland, sand dune, sandy cultivated area</td>
<td>Ontario</td>
<td>Urquhart 1941</td>
</tr>
<tr>
<td>6. Open dry grassland</td>
<td>Nova Scotia</td>
<td>Piers 1917</td>
</tr>
<tr>
<td>7. Dry, grassy fields</td>
<td>Southeast</td>
<td>Morse 1904</td>
</tr>
<tr>
<td>8. High, dry land</td>
<td>United States</td>
<td>Garman 1894</td>
</tr>
<tr>
<td>9. Open dry grassland, edge of hardwood forest</td>
<td>Indiana</td>
<td>Fox 1914</td>
</tr>
<tr>
<td>10. Abandoned farm lands, cut over areas</td>
<td>Michigan</td>
<td>Dibble 1940</td>
</tr>
<tr>
<td>11. Mixed grass-herbaceous habitat, sparsely vegetated sand habitat</td>
<td>Michigan</td>
<td>Cantrall 1943</td>
</tr>
<tr>
<td>12. Grassland, ruderal communities</td>
<td>Michigan</td>
<td>Vestal 1913</td>
</tr>
<tr>
<td>13. Grassland, sand dune</td>
<td>Michigan</td>
<td>Hubble 1922a</td>
</tr>
<tr>
<td>14. Grassland, open areas</td>
<td>Minnesota</td>
<td>Somes 1914</td>
</tr>
<tr>
<td>15. Foredune, poplar, pine associates</td>
<td>Illinois</td>
<td>Strohecker 1937</td>
</tr>
<tr>
<td>16. True prairie</td>
<td>Iowa</td>
<td>Hendrickson 1930</td>
</tr>
<tr>
<td>17. Grassland, crops</td>
<td>North Dakota</td>
<td>Hubbell 1922b</td>
</tr>
</tbody>
</table>
## A List of Habitats from Which *Melanoplus mexicanus* Has Been Recorded in Various Regions of Its Distribution

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Region</th>
<th>Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. High prairie</td>
<td>Eastern Nebraska</td>
<td>Whelan 1938</td>
</tr>
<tr>
<td>19. Grassland, crops</td>
<td>Southwestern Nebraska</td>
<td>Bruner 1905</td>
</tr>
<tr>
<td>20. Range Grass</td>
<td>Western Nebraska</td>
<td>Hunter 1898</td>
</tr>
<tr>
<td>21. Prairie, crops, ruderal communities</td>
<td>Eastern Kansas</td>
<td>Woodruff 1937</td>
</tr>
<tr>
<td>22. Prairie, pastures</td>
<td>Eastern Kansas</td>
<td>Wilbur and Fritz 1940</td>
</tr>
<tr>
<td>23. Pasture, crops</td>
<td>Missouri</td>
<td>Jones 1939</td>
</tr>
<tr>
<td>24. Upland pastures</td>
<td>Arkansas</td>
<td>Horsfall, Dowell and Palm 1933</td>
</tr>
<tr>
<td>25. Grassland, meadows, crops</td>
<td>Arkansas</td>
<td>D. Isely 1938</td>
</tr>
<tr>
<td>26. Grassland, crops, ruderal communities, flood plains</td>
<td>Oklahoma</td>
<td>Hebard 1938</td>
</tr>
<tr>
<td>27. Grassland, mesquite area</td>
<td>Texas</td>
<td>F. B. Isely 1934</td>
</tr>
<tr>
<td>28. Grassland, crops</td>
<td>Arizona</td>
<td>Ball et al. 1942</td>
</tr>
<tr>
<td>29. Grasslands, crops</td>
<td>California</td>
<td>Urbahns 1919</td>
</tr>
<tr>
<td>30. Short-grass, montane forest openings</td>
<td>Colorado</td>
<td>Alexander 1933</td>
</tr>
<tr>
<td>31. Short-grass plains, crops</td>
<td>Colorado</td>
<td>Corkins 1923</td>
</tr>
<tr>
<td>32. Range Grass</td>
<td>Eastern Wyoming</td>
<td>Hunter 1898</td>
</tr>
<tr>
<td>33. Short-grass plains, ruderal communities, crops</td>
<td>Eastern Wyoming</td>
<td>Bruner 1902</td>
</tr>
</tbody>
</table>
TABLE 2—Continued

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Region</th>
<th>Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>34. Sagebrush community</td>
<td>Utah</td>
<td>Fautin 1946</td>
</tr>
<tr>
<td>35. Grassland, grain fields</td>
<td>Montana</td>
<td>Cooley 1904</td>
</tr>
<tr>
<td>36. Grassland, crops</td>
<td>Montana</td>
<td>Strand 1937</td>
</tr>
<tr>
<td>37. Grassland, mountain parks,</td>
<td>Western</td>
<td>Shotwell</td>
</tr>
<tr>
<td>crops, ruderal communities</td>
<td>United</td>
<td>1930</td>
</tr>
<tr>
<td>38. Sandy areas of sparse growth</td>
<td>Manitoba</td>
<td>Criddle 1933</td>
</tr>
<tr>
<td>39. Grassland, crops</td>
<td>British</td>
<td>Treherne and</td>
</tr>
<tr>
<td></td>
<td>Columbia</td>
<td>Buckell 1924</td>
</tr>
</tbody>
</table>

five observations of fifth instar and adult individuals feeding on lygodesmia were made, and one observation of an adult feeding on the inflorescence of blue grama. In a draw near Manville six fourth and fifth instar individuals were observed feeding on knotweed and one fifth instar on the flower of thistle. The draw was weedy and contained much downy chess which showed a large amount of grasshopper injury. Since about 80 per cent of the grasshoppers were *M. mexicanus*, it is

TABLE 3

OBSERVATION OF THE FEEDING OF *Melanoplus mexicanus* IN ITS NATURAL HABITAT AT SHERIDAN, WYOMING, 1944

<table>
<thead>
<tr>
<th>Food Plants</th>
<th>Number of Feeding Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May 29 to June 1</td>
</tr>
<tr>
<td></td>
<td>1st Instar</td>
</tr>
<tr>
<td>Dandelion</td>
<td>0</td>
</tr>
<tr>
<td>Sandberg bluegrass</td>
<td>0</td>
</tr>
<tr>
<td>Bluestem</td>
<td>0</td>
</tr>
<tr>
<td>Unidentified forbs</td>
<td>2</td>
</tr>
<tr>
<td>Dry dandelion</td>
<td>0</td>
</tr>
</tbody>
</table>
probable that this species was responsible for the greater part of the damage. Large-bracted vervain was also present, but this plant showed no injury. West of Gillette along the roadside an observation was made on the feeding of a large population of *M. mexicanus*. The grasshoppers were fifth instar and adult. Fifty individuals were found feeding on wild salsify. The leaves, the flowers, and the bark of the stems of these plants were eaten. Wild lettuce, thistle, sunflower, and bluestem were also present, but no grasshopper was observed feeding on them. However, some of these plants showed a slight amount of injury which may have been caused by the grasshoppers.

In reviewing the present observational data, it should be noted that in the great majority of cases certain forbs were fed upon more than other plants. At station 1, Sheridan where dense populations were present, the principal food-plant appeared to be dandelion. Observations in other areas were not made often enough through the season to learn what the chief host-plants were, but in almost all cases the plants upon which *M. mexicanus* fed were forbs. Circumstantial evidence, however, points to the fact that downy chess is eaten upon in quantity where this grass is present in the habitat. Native grasses were usually not fed upon, although several observations of feeding on species of *Poa* and bluestem have been made. Another fact which should be pointed out is that not all forbs were chosen as food. Usually a particular forb was selected out of the several growing in the habitat. The field data that have been obtained indicate that *M. mexicanus* is not a general feeder in the sense that it feeds upon all green plants with equal readiness. No doubt the number of plants that this grasshopper uses for food is quite large, yet the evidence clearly shows that it has definite food preferences.

A search was made through the literature for references to plants upon which *M. mexicanus* has been recorded as feeding. Few direct observations of feeding have been reported, but a large number of observations on the damage resulting from feeding have been published. These reports use such descriptive terms as “damaged,” “destroyed,” “attacked,” “defoliated,” etc. in reference to the plants fed upon. The validity of these reports is quite good when the insect population consists solely or largely of *M. mexicanus*; but when several other species are found in considerable numbers, one can never be sure whether *M. mexicanus* is responsible for all of the injury, for part of it, or for none of it at all. Most likely the damage to a crop is the summation of the feeding of all the species infesting the crop when the latter is a pure stand. When the crop has admixtures of other plants, differential selection is possible,
and only by direct observation can one determine with certainty the plants upon which the various species are feeding.

A list of plants reported as having been damaged by *M. mexicanus* is given in Table 4. In this list there are included both preferred and unpreferred plants. The large number of references to damage of wheat, alfalfa, corn, oats, and barley afford indirect evidence of a preference for these crops. Among the unpreferred plants are beets and potatoes which, according to Treherne and Buckell (1924), are eaten by *M. mexicanus* only under force of hunger.

### TABLE 4

PLANTS REPORTED AS HAVING BEEN FED UPON OR DAMAGED BY INDIVIDUALS OF *Melanoplus mexicanus*

<table>
<thead>
<tr>
<th>Field Crops</th>
<th>Garden Plants</th>
<th>Shrubs, Weeds &amp; Flowers</th>
<th>Fruit &amp; Other Trees</th>
<th>Grasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>Asparagus</td>
<td>Currants</td>
<td>Apple</td>
<td>Quack</td>
</tr>
<tr>
<td>Clover</td>
<td>Beans</td>
<td>Grape</td>
<td>Boxelder</td>
<td>grass</td>
</tr>
<tr>
<td>Red Clover</td>
<td>Beets</td>
<td>Hops</td>
<td>Cherry</td>
<td>Slender</td>
</tr>
<tr>
<td>Barley</td>
<td>Cabbage</td>
<td>Strawberries</td>
<td>Peach</td>
<td>wheat-</td>
</tr>
<tr>
<td>Corn</td>
<td>Carrots</td>
<td>Gladiolus</td>
<td>Pear</td>
<td>grass</td>
</tr>
<tr>
<td>Millet</td>
<td>Cauliflower</td>
<td>Hollyhocks</td>
<td>Plum</td>
<td></td>
</tr>
<tr>
<td>Oats</td>
<td>Celery</td>
<td>Milkweed</td>
<td>Sugar</td>
<td></td>
</tr>
<tr>
<td>Rye</td>
<td>Cucumber</td>
<td>Mint</td>
<td>locust</td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td>Melons</td>
<td>Russian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(young)</td>
<td>Onions</td>
<td>thistle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timothy</td>
<td>Peas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>Lettuce</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buckwheat</td>
<td>Potatoes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flax</td>
<td>Radishes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td>Squash</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar</td>
<td>Tomato</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>beets</em></td>
<td>Watermelon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tobacco</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Differential Selection of Plants for Food**

Experiments were carried out to test whether *Melanoplus mexicanus* would feed differentially upon selected species of plants under laboratory conditions. The method employed was to place samples of two species of plants in a screen cage with thirty adult grasshoppers and to observe the effects of feeding during and at the end of a 24 hour period. Thirteen different species of plants were tested, each species being paired with and tested against every other species; in all seventy-eight different pairs were tested. Three cages of grasshoppers were run simultaneously in obtaining the data. In each cage was contained a vial of water plugged with cotton wool from which the grasshoppers could drink. The
grashoppers were collected in the field from a short-grass plains area infested with dandelions and other weeds. When caught they were in the last nymphal stadia, but they were reared to the adult stage on dandelions and alfalfa before being used in the tests. The plants employed in the experiments were collected from fields around Laramie. They were cut green and placed in water through two holes in the metal lid of a half-pint fruit jar. The fruit jar was then fitted into a hole in the center of the cage floor. The dimensions of the cages were 11.5 x 11.5 x 10.7 inches. The tests were conducted at room temperatures around 25° C.

The thirteen plants used in these experiments were the following:

1. Dandelion
2. Thatcher wheat
3. Alfalfa
4. Kentucky bluegrass
5. Sunflower
6. Tumblemustard
7. Fringed sagebrush
8. Thistle
9. Bluestem
10. Needle-and-thread
11. Threadleaf sedge
12. Blue grama
13. Lamb's quarters

The results of the tests showed that under laboratory conditions *M. mexicanus* differentially selects plants for food. It was possible to arrange the results into three fairly distinct categories as follows: (1) one plant was eaten in large amounts, sometimes entirely consumed, while the other was only nibbled upon or very slightly eaten; (2) both plants were eaten, but one was consumed clearly more than the other; and (3) both plants were eaten about equally whether in small or large amounts. Forty-six tests fell into category 1, twenty-one tests in category 2, and eleven tests in category 3. Thus in the majority of cases, one species of plant was fed upon almost exclusively, while the other was fed upon not at all or only slightly.

The order of preference for food exhibited by the grasshoppers was as follows. Dandelion and wheat were selected over all others. In the test where these two plants were paired, both were eaten about equally, although later tests indicated that dandelion is preferred above wheat. Alfalfa was a second choice, being less preferred than dandelion and wheat but more preferred than the remaining plants. Kentucky blue-
grass was third choice. Sunflower, tumblemustard, and fringed sagebrush were in order next preferred, while less preferred were thistle, bluestem, needle-and-thread, and threadleaf sedge. The least preferred plants of all were blue grama and lamb’s quarters.

A number of the plants which were used in the tests were flowering, and it was observed that the flowers were preferred above the leaves. These plants included alfalfa, sunflower, fringed sagebrush, and thistle. In one test the heads of blue grama were devoured almost completely. Another noteworthy result was the observation that the flowers of sunflower appeared to be as much preferred as the leaves of dandelion and wheat.

In order to obtain some idea of the preference of *M. mexicanus* for a larger number of plants, a series of eighteen plants was paired with dandelion and with Kentucky bluegrass. The results of these tests are shown in Table 5. Notable is the preference of *M. mexicanus* for wild lettuce and garden lettuce.

**TABLE 5**

**DIFFERENTIAL SELECTION OF FOOD-PLANTS BY ADULT INDIVIDUALS OF *Melanoplus mexicanus***

<table>
<thead>
<tr>
<th>Food-Plants</th>
<th>Preferences</th>
<th>Kentucky bluegrass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dandelion</td>
<td></td>
</tr>
<tr>
<td>Desert saltgrass</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Indian ricegrass</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Prairie sandgrass</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sandberg bluegrass</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Big sagebrush</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Canadian thistle</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Curlycup gumweed</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Effuse eriogonum</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>False mallow</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Knotweed</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Kochia</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Nebraska lupine</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rabbitbrush</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Russian thistle</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wild lettuce</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Yellow sweetclover</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Garden beet</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lettuce</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

0 No preference detectable.

- Plant listed above preferred over plant listed in left column.

+ Plant listed in left column preferred over plant listed above.
Since the grasshoppers in these experiments were collected from an area in which their chief host-plant was dandelion, the possibility existed that the preference for dandelion shown in the tests resulted from conditioning to this plant. To test this hypothesis young adult grasshoppers were collected from four different areas and their food preferences investigated. The localities and the dominant plants in the habitats from which they came were as follows: (1) Sheridan—bluestem, Sandberg bluegrass, and dandelion; (2) Gillette—alfalfa and downy chess; (3) Manville—downy chess, bluestem, large-bracted vervain, and knotweed; (4) Lusk—crested wheatgrass, downy chess, and white sweetclover.

Seven plants were used in the tests, namely:

1. Dandelion
2. Tansymustard
3. Wheat
4. Alfalfa
5. Kentucky bluegrass
6. Downy chess
7. Bluestem

The results of the experiments indicated that there were little or no differences in the food preferences of the four groups of grasshoppers. Dandelion was first choice and bluestem last choice without exception. After dandelion, wheat and tansymustard were next preferred. Variable results, however, were obtained when alfalfa, Kentucky bluegrass, and downy chess were paired. In some tests one was preferred above the other, while in other tests the reverse was true. The amounts consumed of these three plants when tested in pairs were large, fitting category No. 3 described previously. Because the plants were fed upon with about equal readiness, chance feeding on the samples may have determined to some extent the amounts consumed rather than food preferences.

Further study of the possibility of conditioning was made by testing the food preferences of adults which had been reared on single species of plants through the nymphal stage. Seven plants were used: dandelion, tansymustard, wheat, downy chess, Kentucky bluegrass, thistle, and bluestem. In general, no changes in the preferences of the grasshoppers were detected as a result of the different feeding histories. Dandelion remained the most preferred food and bluestem and thistle the least preferred regardless of the species of plant on which the grasshoppers had been reared. Two exceptions, however, occurred. The grasshopper reared on dandelion, when given a choice of dandelion and downy chess, consumed about equal amounts of each. Also the grasshoppers reared on tansymustard, when given a choice of tansymustard and
dandelion, consumed about equal amounts of each. Whether these results should be regarded as significant deviations is uncertain. On the whole the data indicated that no conditioning of the grasshoppers to a particular food occurred.

Although the technique employed in measuring food preferences was sufficiently good to show that Melanoplus mexicanus is a selective rather than a general feeder, a more precise method would have been desirable. First of all the technique employed was not very quantitative. Large differences were easily detected, and it was these that were important in showing that M. mexicanus differentially selects its food. However, when both members of a pair were eaten in fairly large proportions, it became difficult to decide which plant was fed on the most and which one was the preferred plant. This problem became still greater when the members of a pair had different growth forms, such as a grass paired with an herb like tansymustard. Furthermore, the assumption that the plant most eaten is the preferred plant may be open to question when both members are almost equally eaten, for variations in water content and dry matter may have influenced the results in that grasshoppers feeding on one plant may have come to repletion faster than grasshoppers feeding on another. Because of these difficulties one should view with caution the consecutive ranking of plants according to preference.

In the literature several statements appear regarding the food preferences of M. mexicanus which should be noted here. Urquhart (1941) has written that M. mexicanus along with twelve other grasshoppers would accept as food any of nine grasses and two sedges. These grasshoppers also fed upon certain cultivated grasses, lettuce, spinach, carrot, parsnip, and corn in the course of rearing experiments. As this worker gives no details of the methods which he used, it is not possible to make direct comparisons of the present data with his. There is also some question of the significance and meaning of the term "would accept as food" in connection with the feeding of grasshoppers. The results of the present study indicate that the indigenous grasses were not preferred as food and that they were not fed upon in any appreciable quantities unless individuals of M. mexicanus were forced to eat them out of hunger. Possibly the latter response was observed also by Urquhart when he fed M. mexicanus native grasses.

Washburn, in the report of the State Entomologist of Minnesota for 1911-12, published the results of tests carried out by C. W. Howard on the feeding of M. mexicanus and two other grasshoppers upon twenty-two different plants. The methods were not given, but the results of feeding upon individual species of plants were described as "eaten greed-
ily,“eaten readily," “eaten slightly," “eaten somewhat," and "not eaten." Just how the authors were able to distinguish the first four reactions was not described, and the method is hard to visualize. Plants which were used in both Howards and my study were rated by Washburn as follows:

1. Alfalfa  eaten greedily
2. Lamb's quarters  eaten greedily
3. Dandelion  eaten readily
4. Beets  eaten readily
5. Sunflower  eaten somewhat

In the Wyoming tests dandelion and alfalfa were preferred plants, but dandelion was rated above alfalfa rather than below. Disagreement is also present in the results on the feeding of Lamb's quarters and beets, since I found that these plants were not preferred as food.

**Manner in Which Food-Plants Are Selected**

Differential selection by *M. mexicanus* was very marked in the majority of the food preference tests, but no information was obtained on just how the grasshoppers made the selections, since only the results of feeding were observed. In order to obtain information on this point, observations were made of the selection by *M. mexicanus* between a preferred and an unpreferred plant. The methods and materials were similar to the previous tests on food selection except that only ten adult grasshoppers were placed in a cage and the grasshoppers were starved for approximately 18 hours before the observations were begun. Water, however, was provided at all times in shell vials plugged with cotton. The grasshoppers were observed for 30 minutes, as this amount of time was sufficient for almost all grasshoppers to locate the food and to feed to repletion. The two plants selected for the tests were dandelion and lamb's quarters. The observations were conducted in the laboratory at temperatures ranging from 24° to 27° C.

The grasshoppers were usually located on the sides of the cage at the beginning of the tests. When the plants were placed in a cage, the grasshoppers began to crawl down the sides and towards the food. Approximately two minutes passed before the first grasshopper made contact with a plant. Original contacts were made as frequently with the unpreferred as with the preferred plant (Table 6). If a grasshopper contacted the preferred food, dandelion, it invariably proceeded to feed. After completion of feeding it usually crawled away from the plant and up one of the sides of the cage. A different response was observed when a grasshopper made original contact with lamb's quarters. It manipulated the leaves with its palpi in the same manner as those which first made contact with the dandelion; then it bit the leaf but usually did
TABLE 6

OBSERVATIONS ON ADULT INDIVIDUALS OF *Melanoplus mexicanus* MAKING A SELECTION OF FOOD WHEN PRESENTED WITH A PREFERRED AND AN UNPREFERRED PLANT

<table>
<thead>
<tr>
<th>Exp. No.</th>
<th>Total Number Grasshoppers</th>
<th>Number First Contacting</th>
<th>Transfers</th>
<th>Number Feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dandelion</td>
<td>Lamb's Quarters</td>
<td>Lamb's Quarters to Dandelion</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>5</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>1</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>20</td>
<td>23</td>
<td>17</td>
</tr>
</tbody>
</table>
not feed. It moved about the plant, working its palpi and taking a bite here and there and, apparently by chance, made contact with the adjacent dandelion. On the latter it finally fed. Sometimes a grasshopper would feed for a short time on lamb's quarters before transferring to dandelion; less often the grasshopper left the plant and crawled up the side of the cage without feeding.

An explanation of these reactions in terms of the sensory physiology of the grasshopper is not possible due to lack of experimental evidence on this subject. A few general statements may be made, however, as an outline of the problem. The grasshoppers were attracted to the food either by distant chemo-reception or by vision, or possibly by both. It appeared that no discrimination could be made between the preferred and the unpreferred food until contact with the plant was made, and even then it seemed that a bite into the plant was necessary. Apparently the final selection of the food was made by contact chemoreception of some sort or less probably by a tactile sense.

**Mortality and Survival as Affected by Diet**

Early in this study of the relation of food-plants to the ecology of certain range grasshoppers, experiments on mortality and survival were conducted in an open insectary at Douglas, Wyoming. The original plan was to take grasshoppers in the first instar and to rear them on selected species of plants to the adult stage. Unfortunately this goal was not realized. The young grasshoppers sustained heavy mortalities on all of the foods, even on the ones which were later found to be favorable. The reason for the high mortalities was probably starvation due to the inability of the young grasshoppers to find the food often enough in a large cage. The cages measured 11.5 x 11.5 x 10.7 inches and were constructed mainly of screen (Fig. 1). In subsequent experiments conducted in the laboratory, no difficulty was encountered in rearing the early instars on favorable foods when quart jars were used for cages. Because of the high death rate of young grasshoppers in the first tests conducted in the insectary, fourth and fifth instars were tried. Grasshoppers of this age survived very well when they were fed favorable food-plants.

The methods used in the insectary experiments at Douglas were as follows: Late instar nymphs were collected from weedy and cultivated areas in which *Melanoplus mexicanus* was present in large numbers. These grasshoppers were then transported to the insectary at Douglas where they were placed in the experimental cages within one or two days after their capture. Approximately fifty-five individuals were confined to one cage. The food of the grasshoppers was cut from the fields around Douglas or from a garden which was maintained behind the
insectary. Care was taken to feed only green plants, which were kept fresh by placing them in jars of water. Usually changes of food were made daily, but sometimes changes were made only every other day when the plants remained turgid and plentiful. Water, contained in vials plugged with cotton, was also provided for the grasshopper. The insectary faced southwest and all cages were arranged along this side to insure equal amounts of sunlight.

The results showed that mortality varied significantly among the cages of grasshoppers which had been fed different food-plants. The per cent mortalities sustained at the end of the first, second, third, and fourth weeks of the tests are shown in Table 7. Replications were made with fifteen of the diets. Statistical analyses of these replicates by use of the Chi-square method indicated that no significant differences in mortality occurred at the end of the fourth week except on the three following diets: (1) lamb’s quarters, cage a 50 per cent mortality, cage b 80 per cent mortality; (2) yellow sweetclover, cage a 52 per cent mortality, cage b 88 per cent mortality; (3) desert saltgrass, cage a 77 per cent mortality, cage b 100 per cent mortality. That these significant differences among replicates were encountered upon unfavorable food-plants is noteworthy. This suggests that wider variations in the response of grasshoppers occur when the nutritional level of the diet is low. Twelve other replicated diets gave results constant enough to indicate that the methods were reliable. The food-plant most replicated was barley. No
## TABLE 7

MORTALITY OF LATE INSTAR NYMPHS OF *Melanoplus mexicanus* FED SELECTED FOOD-PLANTS

<table>
<thead>
<tr>
<th>Food-Plants</th>
<th>Number Starting Tests</th>
<th>1st Week</th>
<th>2nd Week</th>
<th>3rd Week</th>
<th>4th Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>105</td>
<td>2</td>
<td>3</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Sunflower</td>
<td>110</td>
<td>3</td>
<td>9</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Alfalfa and barley</td>
<td>60</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Dent Corn</td>
<td>55</td>
<td>5</td>
<td>11</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>165</td>
<td>10</td>
<td>14</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Barley and common oat</td>
<td>55</td>
<td>11</td>
<td>16</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Dandelion</td>
<td>60</td>
<td>15</td>
<td>17</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Downy chess</td>
<td>110</td>
<td>15</td>
<td>18</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>Tumblemustard</td>
<td>109</td>
<td>8</td>
<td>16</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Barley</td>
<td>283</td>
<td>18</td>
<td>20</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>Crested wheatgrass</td>
<td>60</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>28</td>
</tr>
<tr>
<td>Slender scurfpea</td>
<td>59</td>
<td>22</td>
<td>25</td>
<td>29</td>
<td>31</td>
</tr>
<tr>
<td>Wild lettuce</td>
<td>70</td>
<td>11</td>
<td>21</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>Big sagebrush, fringed sagebrush and silver sagebrush</td>
<td>109</td>
<td>23</td>
<td>24</td>
<td>30</td>
<td>34</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>60</td>
<td>3</td>
<td>23</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>Plains bluegrass</td>
<td>60</td>
<td>0</td>
<td>15</td>
<td>30</td>
<td>48</td>
</tr>
<tr>
<td>Bluestem</td>
<td>163</td>
<td>21</td>
<td>29</td>
<td>43</td>
<td>54</td>
</tr>
<tr>
<td>Bluestem, blue grama, needle-and-thread, and threadleaf sedge</td>
<td>101</td>
<td>17</td>
<td>33</td>
<td>41</td>
<td>54</td>
</tr>
<tr>
<td>Woolly Indianwheat</td>
<td>60</td>
<td>0</td>
<td>50</td>
<td>62</td>
<td>65</td>
</tr>
<tr>
<td>Lamb’s quarters</td>
<td>110</td>
<td>22</td>
<td>45</td>
<td>62</td>
<td>67</td>
</tr>
<tr>
<td>Threadleaf sedge</td>
<td>54</td>
<td>52</td>
<td>52</td>
<td>65</td>
<td>72</td>
</tr>
<tr>
<td>Junegrass</td>
<td>54</td>
<td>28</td>
<td>57</td>
<td>65</td>
<td>72</td>
</tr>
<tr>
<td>Lamb’s quarters and Russian thistle</td>
<td>59</td>
<td>46</td>
<td>59</td>
<td>73</td>
<td>75</td>
</tr>
<tr>
<td>Yellow sweetclover</td>
<td>168</td>
<td>22</td>
<td>42</td>
<td>65</td>
<td>79</td>
</tr>
<tr>
<td>Indian ricegrass</td>
<td>59</td>
<td>46</td>
<td>66</td>
<td>69</td>
<td>81</td>
</tr>
<tr>
<td>Green needlegrass</td>
<td>105</td>
<td>38</td>
<td>67</td>
<td>79</td>
<td>85</td>
</tr>
<tr>
<td>Desert saltgrass</td>
<td>110</td>
<td>39</td>
<td>75</td>
<td>83</td>
<td>87</td>
</tr>
<tr>
<td>Needle-and-thread</td>
<td>58</td>
<td>61</td>
<td>81</td>
<td>91</td>
<td>93</td>
</tr>
<tr>
<td>Six-weeks fescue</td>
<td>60</td>
<td>8</td>
<td>67</td>
<td>92</td>
<td>93</td>
</tr>
<tr>
<td>Blue grama</td>
<td>106</td>
<td>54</td>
<td>80</td>
<td>92</td>
<td>93</td>
</tr>
<tr>
<td>Prairie sandgrass</td>
<td>109</td>
<td>49</td>
<td>78</td>
<td>93</td>
<td>96</td>
</tr>
<tr>
<td>Water only, no food-plant</td>
<td>60</td>
<td>48</td>
<td>88</td>
<td>98</td>
<td>100</td>
</tr>
</tbody>
</table>
significant differences in mortality occurred among five cages of grasshoppers fed this plant.

A small amount of mortality among the grasshoppers was due to parasitism and disease and probably to handling. An approximate figure on the amount of parasitism (about 5 per cent) was obtained, but no attempt was made to determine death from other causes. From the evidence provided by analyses of the replicates, the mortality due to these causes did not interfere greatly in making comparisons of the food value of the different diets.

The first eleven diets listed in the table provided foods upon which no significant differences in mortality occurred. This group is composed of weeds and cultivated plants and includes members of four different families. Native grasses did not provide favorable diets for *M. mexicanus*; in fact, the greatest mortalities were encountered among grasshoppers which were fed such grasses. Of the latter, plains bluegrass afforded the most favorable diet. It is interesting to note that the mortality on plains bluegrass is practically the same as on Kentucky bluegrass, an introduced species. This may mean that, in general, there is a similar response to the *Poa*'s. Not all weeds provided favorable diets, for grasshoppers survived in only small numbers on lamb's quarters and on woolly Indianwheat. The survival was also low on sagebrush.

Although plant affinities have been shown to govern the food habits of certain species of grasshoppers, little relationship can be seen in the present data. There are members of Gramineae, Fabaceae, and Compositae which afford high survivals and also members of the same families which do not. The family Chenopodiaceae has two members on which high mortalities of grasshoppers occurred, namely, lamb's quarters and Russian thistle. Further indication that this family does not furnish favorable food-plants for *M. mexicanus* is the fact that the garden beet was not selected for food in the food preference tests. Shotwell (1938), however, has reported that young Russian thistle is fed upon by the nymphs. As the present test was run using green but older plants, different results may possibly have been obtained with younger stages of Russian thistle.

A comparison of food preferences of adults with mortality-survival data shows a highly significant positive correlation of 0.9 between plants which are preferred and plants which afford high survival. This statistic was calculated by the use of Spearman's rank correlation formula.

Egg production of some of the grasshoppers in the mortality-survival series was measured. The data, which are summarized in Table 8, were obtained during the first three weeks of the oviposition period. The number of pods produced ranged from 0.27 pods per female among the
TABLE 8

POD PRODUCTION OF *Melanoplus mexicanus* FED SELECTED DIETS; PODS OBTAINED DURING FIRST THREE WEEKS OF OVIPOSITION PERIOD

<table>
<thead>
<tr>
<th>Food-Plants</th>
<th>Number Females</th>
<th>Total Number Pods</th>
<th>Mean Number Pods per Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dandelion</td>
<td>27</td>
<td>94</td>
<td>3.48</td>
</tr>
<tr>
<td>Alfalfa and barley</td>
<td>21</td>
<td>65</td>
<td>3.10</td>
</tr>
<tr>
<td>Wild lettuce</td>
<td>23</td>
<td>63</td>
<td>2.74</td>
</tr>
<tr>
<td>Downy chess</td>
<td>15</td>
<td>39</td>
<td>2.60</td>
</tr>
<tr>
<td>Wheat</td>
<td>31</td>
<td>78</td>
<td>2.52</td>
</tr>
<tr>
<td>Barley and oat</td>
<td>28</td>
<td>68</td>
<td>2.43</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>50</td>
<td>120</td>
<td>2.40</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>16</td>
<td>36</td>
<td>2.25</td>
</tr>
<tr>
<td>Barley</td>
<td>49</td>
<td>110</td>
<td>2.24</td>
</tr>
<tr>
<td>Crested wheatgrass</td>
<td>23</td>
<td>51</td>
<td>2.22</td>
</tr>
<tr>
<td>Dent corn</td>
<td>28</td>
<td>43</td>
<td>1.54</td>
</tr>
<tr>
<td>Slender scurfpea</td>
<td>22</td>
<td>25</td>
<td>1.14</td>
</tr>
<tr>
<td>Big sagebrush, fringed sagebrush,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>silver sagebrush</td>
<td>13</td>
<td>6</td>
<td>0.46</td>
</tr>
<tr>
<td>Bluestem</td>
<td>29</td>
<td>9</td>
<td>0.31</td>
</tr>
<tr>
<td>Bluestem, blue grama, needle-and-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>thread, thread leaf sedge</td>
<td>15</td>
<td>4</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Grasshoppers fed a mixture of native grasses to 3.48 per female among the grasshoppers fed dandelion. That food influences egg production is shown by the data, but whether the influence is through rate of egg production, through differences in preoviposition period, or through mortality and survival is not indicated. The correlation between survival as measured at the end of the fourth week and production of pods was positive and significantly high \((r = 0.76)\); however, this figure affords little information on the ways in which food may have influenced the total number of pods produced.

**Relation of Food-Plants to Egg Production**

In order to obtain more precise information on the influence of food-plants upon egg production, a series of tests were run at Laramie during the summer of 1947. In these tests the effects of feeding seven different species of plants were studied. Data were obtained on total egg production, rate of egg production, preoviposition period, and
longevity. The plants used were dandelion, wheat, tansymustard, alfalfa, thistle, Kentucky bluegrass, and bluestem. In addition the effects of alternating a favorable food-plant with an unfavorable one were investigated.

The methods and materials employed in these experiments were the following. Grasshoppers in the third, fourth, and fifth instars were collected from a short-grass plains area which contained much dandelion. Previous observations showed that *M. mexicanus* fed chiefly on this weed rather than on the indigenous grasses. The nymphal grasshoppers were kept in the laboratory at a temperature of $30 \pm 1^\circ C$ and were fed a mixture of dandelion, tansymustard, alfalfa, and Kentucky bluegrass. As soon as the grasshoppers molted for the last time, they were taken from the laboratory and placed outside on the ground in screen cages. These cages (Fig. 2) had inside dimensions of $5.5 \times 5.5 \times 10.5$ inches. Five males and five females were confined in each cage. The tests were replicated five times, thus making a total of 25 females

![Fig. 2.—Small cage used in open pens.](image)
from which egg production data were obtained for each kind of food-plant. Unfortunately a few individuals escaped as will be noted from the totals of 24 females on each of three foods in Table 9. The three females escaped before oviposition began and were not included in the tabulations. For this reason there was little interference in the analysis of the data.

The food-plants were collected daily from fields around Laramie or in the case of wheat from a small garden. Before being introduced into the cages the cut plants were placed in vials of water to keep them fresh. A fine sand was provided in the lower box on which the cage rested. Twice weekly the sand was sieved in search of egg pods. When oviposition began, the search was reduced to weekly intervals.

The first eggs were collected on August 8, and egg deposition continued as long as females remained alive. On October 23 the temperature fell to 11° F., freezing and killing the grasshoppers still alive at this time. The total egg production of the seven groups of grasshoppers fed different kinds of food-plants varied significantly. These data are shown in Table 9 as mean number of eggs per female. The progress of egg production by weeks, as well as the total production for the season, is shown in Fig. 3. Dandelion, wheat, tansymustard, and alfalfa were clearly the most favorable foods for high egg production. Much less favorable were thistle, Kentucky bluegrass, and bluestem.

Food affected the total egg production by its influence (1) on the length of the preoviposition period, (2) on the rate of egg production, and (3) on the longevity of the females. The preoviposition period was shorter among the grasshoppers fed the more favorable foods, ranging from 17.1 to 18.1 days for dandelion, wheat, tansymustard, and alfalfa (Table 9). The preoviposition period of grasshoppers fed Kentucky bluegrass was 18.9 days. This was not significantly longer than the periods of the grasshoppers fed the first four plants. However, the periods of the grasshoppers fed bluestem and thistle were 21.5 and 23.7 days, respectively, and were significantly longer. The differences in length of the preoviposition periods contributed in a small way to the differences in total egg production.

Just how the preoviposition period was determined should be explained here, since the length of the period was calculated from the time the females became adult and were placed on the experimental food to the time when eggs were first recovered from the cages. The method was not minutely exact due to the fact that on the latter date the average number of pods per cage for the seven groups of grasshoppers fed different food-plants ranged from 1.4 to 2.2. As a consequence the
<table>
<thead>
<tr>
<th>Food-Plants</th>
<th>Dandelion</th>
<th>Wheat</th>
<th>Tansy mustard</th>
<th>Alfalfa</th>
<th>Thistle</th>
<th>Kentucky bluegrass</th>
<th>Bluestem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days Proportion:</td>
<td>78.6</td>
<td>80.4</td>
<td>68.0</td>
<td>82.7</td>
<td>66.4</td>
<td>53.9</td>
<td>50.3</td>
</tr>
<tr>
<td>Mean Adult Females:</td>
<td>24</td>
<td>25</td>
<td>24</td>
<td>25</td>
<td>25</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Days Incubation:</td>
<td>18.1</td>
<td>17.1</td>
<td>17.5</td>
<td>17.7</td>
<td>23.7</td>
<td>18.9</td>
<td>21.5</td>
</tr>
<tr>
<td>Male Females:</td>
<td>24</td>
<td>25</td>
<td>24</td>
<td>25</td>
<td>25</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Female Eggs per Food-Plant:</td>
<td>Mean Number of</td>
<td>4.2</td>
<td>4.1</td>
<td>4.5</td>
<td>4.2</td>
<td>4.1</td>
<td>4.5</td>
</tr>
<tr>
<td>Male Eggs per Food-Plant:</td>
<td>Mean Number of</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Table 9: Egg Production of *Melanoplus mexicanus* Fed Selected Food-Plants, Reared at Laramie, 1947.
preoviposition period is slightly less than the median period which would be fixed by the first oviposition of the third female in each cage of five females. Greater accuracy could have been gained by searching for pods every day instead of twice weekly and by rearing only one female per cage instead of five, but the greater amount of time and materials needed for this probably would not have justified the additional information obtainable.
Longevity was affected significantly by the feeding of different kinds of food-plants. The average adult life of the females ranged from 50.3 days on bluestem to 82.7 days on alfalfa (Table 9). Some individual females lived as long as 98 days, the end of their life being terminated by freezing weather. The large differences in longevity among the grasshoppers fed different food-plants affected the time allowed for oviposition and as a consequence the total number of eggs produced.

The differences in total egg production caused by the longevity factor and by the rate of oviposition factor can be seen from the following calculations. In these calculations the relatively small differences in preoviposition periods were disregarded. If the oviposition period of grasshoppers fed dandelion had been as short as the oviposition period of grasshoppers fed bluestem, the former individuals would have produced only 98 eggs per female rather than 206. On the other hand if the oviposition period of grasshoppers fed bluestem had been as long as the oviposition period of grasshoppers fed dandelion, the former would have produced 97 eggs per female instead of 45. Yet due to differences in rate, the grasshoppers fed dandelion would have produced 109 more eggs per female than those fed bluestem (206 - 97 = 109). Fifty-two eggs of the total difference of 161 eggs between the grasshoppers fed dandelion and those fed bluestem can be attributed by these calculations to the difference in the length of the oviposition period and 109 to difference in rate of egg production. Similar results can be obtained by comparing the egg production of grasshoppers fed any of the three most favorable foods with those fed any of the three least favorable foods. However, certain other comparisons show that differences in total egg production were affected more by length of oviposition period than by rate of egg production. For example a comparison of the total egg production of grasshoppers fed alfalfa and those fed bluestem shows that the difference of 112 eggs between the two can be broken down to a difference of 59 eggs attributable to variation in oviposition period and a difference of 53 eggs attributable to variation in rate of egg production. Although these comparisons are only approximate, they indicate that both length of oviposition period and rate of egg production were important in the final number of eggs which were produced.

The longevity of the males fed different foods also varied significantly. Rank in longevity ranged in exactly the same order for males as for females, but the longevity of males was usually less than that of the females. In general the largest differences in longevity between males and females were encountered among the grasshoppers fed the most favorable food-plants.

As already noted, large variations in the rate of egg production resulted from the feeding of different kinds of food-plants (Fig. 4 and 5
and Table 9. The statistical analysis of rates shown in Table 9 was based on a comparison of the weekly rates recorded from the onset of oviposition to September 22. This shorter period was taken because the grasshoppers which were fed bluestem and Kentucky bluegrass died much sooner than the others.

Fig. 4.—Mean weekly rate of egg production of females of Melanoplus mexicanus fed selected food-plants.

Fig. 5.—Mean weekly rate of egg production of females of Melanoplus mexicanus fed selected food-plants.
Rate of egg production appeared to be influenced by temperature (Fig. 6). These data were obtained by averaging the mean weekly rates of the grasshoppers fed the four most favorable food-plants, namely dandelion, wheat, tansymustard, and alfalfa. The mean weekly temperatures were calculated from daily means published by the U. S. Weather Bureau. A highly significant positive correlation \((r = 0.74)\) between rate of egg production and mean temperature was obtained. Caution, however, should be exercised in the interpretation of this statistic, for the pairs of observations were ordered in time and consequently were not randomly drawn in the usual sense. The decrease in oviposition rate could possibly be due to aging of the grasshoppers.

![Graph showing weekly egg rate and mean temperature](image)

**Fig. 6.—** Mean weekly rate of egg production of females of *Melanoplus mexicanus* correlated with mean weekly temperature.

Attention should be called to the characteristic of the curves paralleling each other at a greater distance during the third, fourth, and fifth week than during the sixth week and thereafter. The reason for this has not been found, but several explanations may be conjectured. First, the females may have a higher rate of egg production when they are young than when they are old. This has been found to be true for *Drosophila melanogaster* (Robertson and Sang 1944), but no literature dealing with this point was encountered for grasshoppers. Another possibility was that the temperatures prevailing during the last part of the season were near the limits of toleration for egg production and oviposition. Parker (1930) found that the total number of pods produced by *M. mexicanus* held at constant temperatures of 27°, 32 and 37° C. was
about the same, that is, six to eight pods per female, but individuals held at 22° C. produced only 0.4 pod per female.

The peak of egg production, as shown by the curve in Fig. 6, came during the third week of the oviposition period and continued through the fourth and fifth weeks. This seems to indicate that rate of egg production is not as great during the first two weeks of the oviposition period as during the weeks immediately following. However, since the figures on weekly rates were secured from observations made on ninety-eight females, the mean can hardly apply to individual females. The rate during the first week is low at least in part due to the fact that only two-thirds of the females had laid their first batch of eggs by this time. These results, therefore, do not preclude the possibility that rate of egg production of individual females is approximately equal during the first several weeks of the oviposition period.

Calculations were made of the number of days required to produce batches of twenty eggs, this number being the average in a pod for this series of experiments (Table 10). The calculations were based on data obtained during the first thirty-five days of the oviposition period. The assumption was made that rate of egg production was equal during this time. A striking fact which can be observed was the smaller range of the preoviposition periods compared with the range in number of days.

<table>
<thead>
<tr>
<th>Food-Plants</th>
<th>Preoviposition Period, Days</th>
<th>Number of 20 Eggs for First 35 Days of Oviposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dandelion</td>
<td>18.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Wheat</td>
<td>17.1</td>
<td>5.7</td>
</tr>
<tr>
<td>Tansymustard</td>
<td>17.5</td>
<td>6.0</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>17.7</td>
<td>6.6</td>
</tr>
<tr>
<td>Thistle</td>
<td>23.7</td>
<td>12.3</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>18.9</td>
<td>10.7</td>
</tr>
<tr>
<td>Bluestem</td>
<td>21.5</td>
<td>15.7</td>
</tr>
<tr>
<td>Mean</td>
<td>19.2</td>
<td>8.9</td>
</tr>
<tr>
<td>Range</td>
<td>6.6</td>
<td>10.6</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>6.0</td>
<td>9.9</td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>31.4%</td>
<td>112.4%</td>
</tr>
</tbody>
</table>
required for batches of twenty eggs. This was a somewhat surprising result, for a greater range in the longer oviposition periods might have been expected, since statistical observations show that greater variations are found among units of larger size. Although these results can not be explained from the present data, the problem might be discussed with profit in light of Pfeiffer's (1945) work on the development of the eggs of *Melanoplus differentialis*.

Pfeiffer found that the first several days following the final molt constituted a period which was physiologically distinct from the remainder of the adult stage. During this period the weights of water and total dry matter increased. In normal females the early period was characterized also by growth of the oocytes to the size at which yolk deposition could begin, by a rapid rise in fatty acid content and hypertrophy of the fat body due to rapid fat storage, and by an increase in the weight of non-fatty dry matter. Later, due to the attainment by the corpora allata of an effectiveness which these glands do not have during the early period, a metabolic change occurs around the twelfth day. This metabolic change was followed by a reduction of the fat stores in both normal and castrated females, which suggested that the activity of the corpora allata affects fat metabolism in two ways: through inducing the utilization of stored fat in a process which operates independently of the ovaries and through facilitating the production of yolk, which in turn affects fat metabolism. Fat stores undergo reduction until certain minimum levels are reached and then tend to become stabilized. Pfeiffer states that since reduction of the fat stores to these levels is usually accomplished by the time the first group of eggs completes development and since great changes in fat body size do not accompany production of subsequent groups of eggs, it appears that reactions involving the utilization of fat may take place rapidly as long as the reserves in the fat body exceed the minimum levels but thereafter must proceed at rates corresponding to the rates at which nutrient materials enter the system.

If metabolism and egg production follow the same pattern in *Melanoplus mexicanus*, a ready interpretation of the results is possible. Stores in the fat body accumulate from the very beginning of the imaginal stage and become available for yolk deposition sometime later when the corpora allata become active or possibly when the oocytes become competent to respond to the glands' influence. There is thus established for the first batch of eggs an endogenous source of nutriments as well as an exogenous source from ingested food. Poorer food-plants do, however, prolong the deposition of the first pod. Whether this is a prolongation of the initial period or the yolk deposition period or both can not be decided from the present data. Nevertheless, the effects of poorer nutrition on egg production are felt more fully during the oviposition
period when egg development “must proceed at rates corresponding to the rates at which nutrient materials enter the system.”

The effects on egg production of alternating a favorable with an unfavorable food-plant were investigated. Dandelion was alternated with bluestem in one series of experiments and with Kentucky bluegrass in another series. Eighty grasshoppers, half males and half females, were used in each series. Ten individuals were placed in a cage as in the previous tests. All grasshoppers were fed dandelion for approximately two weeks, after which the food-plants were alternated weekly to September 8. From September 8 half of each series was fed continuously on dandelion to the end of the season, while half of one series was fed continuously on bluestem and half of the other series on Kentucky bluegrass. The results are summarized in Figures 7 to 10 and in Table 11.

![Graph](image1)

**Fig. 7.—Mean weekly rate of egg production of females of *Melanoplus mexicanus* fed dandelion and bluestem alternately.**

![Graph](image2)

**Fig. 8.—Mean weekly rate of egg production of females of *Melanoplus mexicanus* fed dandelion and Kentucky bluegrass alternately.**
Alternating dandelion with bluestem or Kentucky bluegrass affected the rate of egg production and also total number of eggs produced. These measurements were intermediate in value as compared with measurements obtained when each plant was fed throughout the entire imaginal stage. On dandelion the egg production was higher than on dandelion alternated with bluestem. On bluestem the egg production was lower than on bluestem alternated with dandelion. Similar results

![Graph showing mean egg production of females of Melanoplus mexicanus fed dandelion and bluestem both alternately and continuously; accumulative by weeks.](image-url)
were obtained when using dandelion and Kentucky bluegrass. The rates of the first two weeks provide some indication that change to bluestem resulted in an immediate reduction in the rate of oviposition. Afterwards the effects of alternation did not appear until the following week (Fig. 7). The same delayed response was shown by the grasshoppers alternately fed dandelion and Kentucky bluegrass. The differences, however, were not quite as marked (Fig. 8). Hill (1946) who alternate-

![Graph](image-url)

**Fig. 10.**—Mean egg production of females of *Melanoplus mexicanus* fed dandelion and Kentucky bluegrass alternately and continuously, accumulative by weeks.
ly fed potatoes and less favorable food-plants to tuber flea beetles, found that the rate of oviposition was affected usually two or three days following the change. Probably the response of tuber flea beetles to a change of diet is noted sooner due to the fact that they lay eggs singly rather than in groups of approximately 20, as does *M. mexicanus.*

- When half of the grasshoppers were fed bluestem continuously after September 8 and the other half dandelion, the rates of egg production of grasshoppers fed bluestem became relatively low and the rates

**TABLE II**

EGG PRODUCTION OF *Melanoplus mexicanus* WITH DIFFERENT DIETARY HISTORIES DURING IMAGINAL STAGE

<table>
<thead>
<tr>
<th>Food-Plant From Sept. 8 to end of Season</th>
<th>Previous Food-Plant</th>
<th>Number of Females Alive Sept. 8</th>
<th>Number Eggs per Female Sept. 8 to End of Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dandelion</td>
<td>Bluestem</td>
<td>17</td>
<td>77.3</td>
</tr>
<tr>
<td>Dandelion</td>
<td>Dandelion</td>
<td>23</td>
<td>74.2</td>
</tr>
<tr>
<td>Dandelion</td>
<td>Kentucky bluegrass</td>
<td>15</td>
<td>45.5</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>Dandelion</td>
<td>19</td>
<td>41.3</td>
</tr>
<tr>
<td>Bluestem</td>
<td>Dandelion</td>
<td>13</td>
<td>28.2</td>
</tr>
<tr>
<td>Bluestem</td>
<td>Bluestem</td>
<td>18</td>
<td>5.9</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>Kentucky bluegrass</td>
<td>11</td>
<td>5.3</td>
</tr>
</tbody>
</table>

of those fed dandelion relatively high. A change in rates, however, was not nearly so great in the series of tests in which Kentucky bluegrass and dandelion were used. When half were fed continuously on Kentucky bluegrass and half on dandelion, the rates remained approximately the same. Further information on the differences in reaction are shown in Table 11. The number of eggs produced per female by grasshoppers changed from bluestem to dandelion for the remainder of the season was 77.3. This egg production is even higher than that of the grasshoppers fed dandelion through their entire imaginal life. This indicates that egg laying ability was not reduced by the previous experience on bluestem, a less favorable food. On the other hand, grasshoppers which were alternately fed Kentucky bluegrass and dandelion did not produce a comparably high number of eggs when changed to a continuous dandelion diet. These grasshoppers produced only 45.5 eggs per female. This
seems to indicate that egg laying ability was adversely affected by the experience on Kentucky bluegrass. Obviously these conclusions are conflicting, and further tests will have to be run to elucidate this aspect of the problem.

The grasshoppers whose diets were changed to either bluestem or Kentucky bluegrass for the remainder of the season produced a greater number of eggs than the grasshoppers which had been fed the two grasses through their entire imaginal life. Here the evidence from both series of tests is consonant in indicating that the previous experience on a good diet favorably affected egg production.

**Relation of Food-Plants to Growth**

The growth of individuals of *Melanoplus mexicanus* reared from the egg stage upon selected food-plants was studied. For these tests eggs were collected from a weedy alfalfa field and incubated in the laboratory under a lamp. As the young grasshoppers hatched they were placed, in groups of approximately ten, into quart jar cages. The jars were laid on their sides and were fitted with screen lids. When the grasshoppers in each jar reached the fourth instar, they were transferred to 5.5 x 5.5 x 10.5 inch screen cages.

The food-plants used were tansymustard, dandelion, wheat, downy chess, Kentucky bluegrass, bluestem, thistle, and alfalfa. All plants except wheat were taken from fields around Laramie. The wheat was grown in the laboratory. It was probably less satisfactory as a food-plant than if it had been grown outside, for it was less green and less preferred by the grasshoppers.

The food-plants were cut and placed in vials of water. The food was changed daily or occasionally every other day. The temperature in the rearing room was maintained at 30 ± 1°C. The relative humidity fluctuated between 20 and 32 per cent. Measurements were taken on survivorship, time of nymphal development, and weight of adults on the first day of adult life, and on the length of the hind femur, the tegmen, the pronotum, and the width of the head. The length of the pronotum was measured on the middorsal line and the width of the head at its widest part. An analytical balance was used for weighing and a steel rule was used in taking linear measurements. The linear measurements were made to the closest 0.25 mm. and the weights to the closest milligram. The data were treated statistically by analysis of variance or by the t-test.

The sizes attained by grasshoppers reared upon different food-plants varied significantly. These data are shown in Table 12. The weights of the newly emerged adults were greater in ascending order when the following plants were fed: alfalfa, thistle, bluestem, Kentucky blue-
<table>
<thead>
<tr>
<th>Food Plants</th>
<th>No. Starting Tests</th>
<th>Per Cent Mortality</th>
<th>No. Becoming Adult</th>
<th>Mean Weight mg.</th>
<th>Mean Length Femur mm.</th>
<th>Mean Length Pronotum mm.</th>
<th>Mean Width Head mm.</th>
<th>Mean Length Tegument mm.</th>
<th>Mean Nympahal Period Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tansymustard</td>
<td>18</td>
<td>0</td>
<td>10</td>
<td>8</td>
<td>267.3</td>
<td>12.33</td>
<td>4.93</td>
<td>4.03</td>
<td>21.25</td>
</tr>
<tr>
<td>Dandelion</td>
<td>36</td>
<td>25</td>
<td>11</td>
<td>16</td>
<td>277.8</td>
<td>12.50</td>
<td>4.90</td>
<td>3.96</td>
<td>20.06</td>
</tr>
<tr>
<td>Wheat</td>
<td>31</td>
<td>29</td>
<td>14</td>
<td>8</td>
<td>236.7</td>
<td>11.75</td>
<td>4.58</td>
<td>3.81</td>
<td>19.77</td>
</tr>
<tr>
<td>Downy chess</td>
<td>27</td>
<td>33</td>
<td>9</td>
<td>9</td>
<td>232.2</td>
<td>11.71</td>
<td>4.58</td>
<td>3.87</td>
<td>19.17</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>30</td>
<td>30</td>
<td>7</td>
<td>14</td>
<td>204.4</td>
<td>11.50</td>
<td>4.50</td>
<td>3.82</td>
<td>19.57</td>
</tr>
<tr>
<td>Bluestem</td>
<td>17</td>
<td>65</td>
<td>4</td>
<td>2</td>
<td>211.5</td>
<td>11.38</td>
<td>4.63</td>
<td>4.00</td>
<td>19.94</td>
</tr>
<tr>
<td>Thistle</td>
<td>19</td>
<td>11</td>
<td>8</td>
<td>9</td>
<td>198.1</td>
<td>10.96</td>
<td>4.25</td>
<td>3.93</td>
<td>18.61</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>30</td>
<td>83</td>
<td>2</td>
<td>3</td>
<td>144.5</td>
<td>9.38</td>
<td>3.63</td>
<td>3.13</td>
<td>11.63</td>
</tr>
</tbody>
</table>

**Significance**

** Highly significant
grass, downy chess, wheat, dandelion, and tansymustard. The other measurements of size which were taken showed a significant positive correlation with weight (Table 13). The highest correlation was found to be between weight and length of the hind femur, and between weight and length of the pronotum. Tegmen length also showed a high degree of correlation with weight; less correlation existed between weight and head width. Brett (1947) found that width of the head capsule was the least variable of any of the body parts that he measured. The head width in the present study was also the least variable measurement. The small degree of variability was no doubt responsible for the smaller positive correlation with weight.

**TABLE 13**

**CORRELATION OF WEIGHT WITH SEVERAL OTHER MEASUREMENTS OF ADULT *Melanoplus mexicanus* REARED FROM THE EGG STAGE UPON SELECTED FOOD-PLANTS**

<table>
<thead>
<tr>
<th></th>
<th>Weight with Femur Length</th>
<th>Weight with Pronotum Length</th>
<th>Weight with Tegmen Length</th>
<th>Weight with Head Width</th>
<th>Weight with Survivorship</th>
<th>Weight with Nymphal Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>.97**</td>
<td>.95**</td>
<td>.84**</td>
<td>.78*</td>
<td>.73*</td>
<td>-.45</td>
</tr>
<tr>
<td>Female</td>
<td>.93**</td>
<td>.92**</td>
<td>.85**</td>
<td>.79*</td>
<td>.73*</td>
<td>-.63</td>
</tr>
</tbody>
</table>

* Significant
** Highly significant

The length of the nymphal periods of grasshoppers reared on the different food-plants ranged from a mean of twenty-nine days to a mean of forty-two days. In general the nymphal period was shortest among grasshoppers fed the most favorable food-plants and longest among the grasshoppers fed the least favorable ones, but notable exceptions occurred. The nymphal period of grasshoppers fed alfalfa was relatively short. However, the small numbers reaching the adult stage on this food make the data somewhat unreliable. Brett (1947) reports nymphal periods of forty-five and fifty-three days for males and females, respectively, which had been reared on alfalfa under similar conditions of temperature and relative humidity. These figures fall in line with the trend of longer nymphal periods and smaller sizes seen in Table 12.
The number of young grasshoppers to reach the adult stage varied greatly depending on the food-plant. A significant positive correlation of survivorship with weight existed. The results, however, were influenced by the effect that bacterial diseases had on mortality and survival. Dandelion was a favorable food in promoting large size, but a great amount of mortality occurred in some cages. A number of the grasshoppers fed this plant had difficulty in successfully completing the final molt. Some lost hind legs and some failed to expand the wings to the normal condition. Because of the possible confounding influence of bacterial, fungal, and other diseases, percentage of survival to the adult stage did not appear to be the best measure of the value of a food-plant. Another result which should be pointed out in this connection is that a large percentage of grasshoppers fed thistle survived to the adult stage, but the weights of the adults were relatively light and the nymphal periods long, indicating an unfavorable diet. So far as revealed by these data, the size attained by the adults appeared to be the most reliable index of a favorable food-plant.

Alfalfa seems to hold an anomalous position in the physiology and ecology of *M. mexicanus*. Tests on egg production and longevity of adult grasshoppers have indicated that alfalfa is a favorable food, yet tests on growth of nymphs hatched from eggs showed that alfalfa was the poorest of all the foods used. Another fact which needs explaining is the large populations of *M. mexicanus* which build up in alfalfa fields. Brett (1947) regarded alfalfa as a trap crop. The species is attracted to this plant but the poor quality of the food, he thinks, prevents the grasshoppers from reaching a size comparable with the size of the large migratory form, *M. mexicanus* phase *spretus*. Brett suggested that a partial explanation for the disappearance of *spretus* is the replacement of native vegetation by alfalfa in the breeding areas. However, the evidence for such a conclusion does not appear very convincing. No information is available concerning the food-plants upon which *spretus* originally developed so that nothing can be said about the plants replaced by alfalfa. Also there have been heavy infestations of *M. mexicanus* on range land within the so-called permanent breeding areas since the 1870’s. This should have given opportunity for *spretus* to arise if the proper conditions had been met, notwithstanding the relatively small acreages of alfalfa grown in the region.

The great abundance of weeds often present in alfalfa fields should be considered as a possible factor in the development of large populations. These weeds are available for food and some of them no doubt are extensively utilized. The food of a grasshopper can be limited to a single plant such as alfalfa in the laboratory, but in the field it is very
unlikely that an individual grasshopper will feed entirely on one species of plant. Observations in this study show that even when a preferred plant like dandelion is present in ample supply, some feeding on native grasses occurs. Alfalfa fields in this area often contain large percentages of downy chess and dandelion, both of which are good food-plants and probably play an important role in the nutrition of *M. mexicanus* in this habitat.

**Relation of Alfalfa to the Nutrition of Grasshoppers of Different Ages**

Clearly the response of *Melanoplus mexicanus* to alfalfa requires more investigation. Additional information was obtained by rearing grasshoppers of different ages. Individuals in the first four stadia were caught in the field and brought to the laboratory, where they were reared on selected food-plants at a temperature of $30 \pm 1^\circ$ C. Besides alfalfa the plants used for food were dandelion, wheat, Kentucky bluegrass, and bluestem. The mortality at the end of four weeks of feeding and the size of the hind femur and of the tegmen of the adults were measured.

In Table 14 the mortalities sustained at the end of the fourth week are given. The same data are shown graphically in Fig. 11. Also in this figure are shown the data on mortality of grasshoppers reared from the egg stage. The individuals which were collected in the field in the first stadium sustained a large amount of mortality on all foods, but especially on alfalfa, Kentucky bluegrass, and bluestem. A sharp decrease in mortality occurred among the grasshoppers fed alfalfa when the tests were begun with the older instars, but no great decrease occurred among the grasshoppers fed Kentucky bluegrass or bluestem. This seems to

![Fig. 11.—Mortality of field collected individuals and individuals reared from eggs of *Melanoplus mexicanus* at the end of four weeks of feeding upon selected food-plants.](image-url)
TABLE 14

MORTALITY OF FIELD COLLECTED INDIVIDUALS OF *Melanoplus mexicanus* AFTER FOUR WEEKS OF FEEDING ON SELECTED FOOD-PLANTS, GRASSHOPPERS CAUGHT AND CAGED IN FOUR DIFFERENT STADIA

<table>
<thead>
<tr>
<th>Food-Plants</th>
<th>Instar 1</th>
<th>Instar 2</th>
<th>Instar 3</th>
<th>Instar 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dandelion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number beginning tests</td>
<td>15</td>
<td>50</td>
<td>40</td>
<td>47</td>
</tr>
<tr>
<td>Per cent mortality</td>
<td>40</td>
<td>20</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number beginning tests</td>
<td>15</td>
<td>50</td>
<td>50</td>
<td>48</td>
</tr>
<tr>
<td>Per cent mortality</td>
<td>47</td>
<td>40</td>
<td>44</td>
<td>31</td>
</tr>
<tr>
<td>Alfalfa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number beginning tests</td>
<td>15</td>
<td>50</td>
<td>50</td>
<td>48</td>
</tr>
<tr>
<td>Per cent mortality</td>
<td>93</td>
<td>42</td>
<td>40</td>
<td>29</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number beginning tests</td>
<td>29</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Per cent mortality</td>
<td>97</td>
<td>86</td>
<td>86</td>
<td>58</td>
</tr>
<tr>
<td>Bluestem</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number beginning tests</td>
<td>29</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Per cent mortality</td>
<td>100</td>
<td>98</td>
<td>88</td>
<td>64</td>
</tr>
</tbody>
</table>
indicate that alfalfa is a favorable food-plant for individuals older than the first instar.

A rather puzzling response is the comparatively low mortality at the end of the four weeks of grasshoppers reared from eggs. Several conjectures are possible in attempting an interpretation of these results. The grasshoppers reared from eggs may have been less exposed to etiologic agents. Or for those fed unpreferred plants, the reason may have been that they ate the given food more readily because they had never fed previously on a preferred plant. A third possibility is that the grasshoppers reared from eggs were in better physical condition because they were never exposed to handling with a net.

The data on length of the hind femur and of the front wing are shown in Table 15. On all of the foods except alfalfa, the size of the hind femur was greatest when the grasshoppers were reared from the egg stage. In contrast, the grasshoppers reared from the egg stage upon alfalfa were much smaller than those reared upon the same plant from the second, third, or fourth instars. The length of the front wing showed essentially the same relationships. Thus both sets of data on size as well as the data on mortality indicate that alfalfa is a poor food-plant for grasshoppers reared from eggs, but a fairly adequate food for second or later instars.

Size of Adults From Two Different Habitats

The sizes of adults of Melanoplus mexicanus collected in 1947 from two different habitats were measured. The grasshoppers were captured at Sheridan from rangeland heavily infested with dandelion and at Gillette from an alfalfa field. The latter contained a large amount of downy chess and a small amount of other weeds. The data are summarized in Table 16. The size of grasshoppers from rangeland was significantly greater than the size of grasshoppers from the alfalfa field. Whether this difference in size was due to heredity or to environment is not known. However, even if heredity could be ruled out, several environmental factors would have to be considered and as a consequence the variations in size could not be attributed with any degree of certainty to nutritional differences between alfalfa and dandelion.

A comparison of the size attained by grasshoppers reared on dandelion and on alfalfa with size of grasshoppers collected from rangeland infested with dandelion and from an alfalfa field, shows that the laboratory reared individuals fed dandelion were larger than the grasshoppers collected on dandelion in the field while the laboratory reared individuals fed alfalfa were smaller than the grasshoppers collected from the alfalfa field. This seems to indicate that grasshoppers in an alfalfa field
**TABLE 15**

LENGTH OF HIND FEMUR AND OF TEGMEN OF ADULT *Melanoplus mexicanus* R E A R E D FROM FIELD COLLECTED SPECIMENS IN DIFFERENT STADIA AND FED SELECTED FOODS

<table>
<thead>
<tr>
<th>Food-Plants</th>
<th>Sex</th>
<th>Length Hind Femur mm.</th>
<th>Length Tegmen mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Instar 1</td>
<td>Instar 2</td>
</tr>
<tr>
<td>Dandelion</td>
<td>Male</td>
<td>11.92</td>
<td>11.61</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>12.50</td>
<td>12.52</td>
</tr>
<tr>
<td>Wheat</td>
<td>Male</td>
<td>11.50</td>
<td>11.56</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>12.70</td>
<td>12.43</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>Male</td>
<td>11.38</td>
<td>11.33</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>12.06</td>
<td>11.85</td>
</tr>
<tr>
<td>Kentucky</td>
<td>Male</td>
<td>11.30</td>
<td>11.25</td>
</tr>
<tr>
<td>bluegrass</td>
<td>Female</td>
<td>11.25</td>
<td>11.25</td>
</tr>
<tr>
<td>Bluestem</td>
<td>Male</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Differences significant
** Differences highly significant
TABLE 16

SIZE OF ADULTS FROM TWO DIFFERENT HABITATS IN WYOMING

<table>
<thead>
<tr>
<th>Locality</th>
<th>Number</th>
<th>Mean Femur Length mm.</th>
<th>Mean Pronotum Length mm.</th>
<th>Mean Head Width mm.</th>
<th>Mean Tegmen Length mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheridan</td>
<td>56</td>
<td>12.06</td>
<td>4.65</td>
<td>3.98</td>
<td>19.15</td>
</tr>
<tr>
<td>Gillette</td>
<td>69</td>
<td>11.63</td>
<td>4.53</td>
<td>3.94</td>
<td>18.25</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td>0.43**</td>
<td>0.12*</td>
<td>0.04</td>
<td>0.90**</td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheridan</td>
<td>56</td>
<td>12.91</td>
<td>4.83</td>
<td>4.21</td>
<td>19.35</td>
</tr>
<tr>
<td>Gillette</td>
<td>53</td>
<td>12.06</td>
<td>4.58</td>
<td>4.07</td>
<td>17.84</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td>0.85**</td>
<td>0.25**</td>
<td>0.14*</td>
<td>1.51**</td>
</tr>
</tbody>
</table>

* Significant
** Highly significant

are maintained at a better nutritional level than grasshoppers reared on alfalfa in the laboratory. This is likely because other plants in the alfalfa field, such as downy chess, probably made up part of the diet. However, the lack of control of the environmental factors in the field leaves this conclusion disputable.

Discussion

The problem of the factors in the environment which control the distribution of grasshoppers is of interest to both the ecologist and the economic entomologist. Some work has been done in an attempt to reach a solution, but the conclusions drawn have not always been concordant; this is especially true concerning the role that vegetation plays. Several ecologists have held that vegetation influences the distribution by its modifying control of the physical factors such as evaporation rate and heat, while certain others have emphasized the importance of the food value of the vegetation. Among the latter is Ball (1936) who studied the food habits of Arizona grasshoppers. He found that many of the Arizona grasshoppers were monophagous or oligophagous and were found only where their host-plants occurred. Criddle (1933) who studied the biology and food habits of grasshoppers in Canada held the view that if a grasshopper is confined in its diet to one or to a comparatively few plants, its range must be restricted to territory within their distribution, but if a grasshopper has diversified food habits, its range
is likely to be more widespread. F. B. Isely (1938) as a result of his studies on the ecology of grasshoppers in Texas concluded that plant species as food play an important role in the distribution of many species of grasshoppers.

On the other hand certain workers, Vestal (1913), Strohecker (1937), and Urquhart (1941), attach little importance to the food value of vegetation in influencing the distribution of grasshoppers. Vestal (1913) wrote that there is very seldom any direct relation between grasshopper species and species composition of the plant associations, as few grasshoppers are selective feeders. His work was a study of communities, little if anything being done in observing grasshoppers feed and nothing being done experimentally on the relation of food-plants to grasshopper nutrition.

Strohecker (1937) also regarded lightly the value of plants as food in determining distribution. He concluded that the factors which controlled the local distribution of the Orthoptera of the Chicago area were heat and soil moisture. He arrived at this conclusion by picking out the physical factor which showed a marked variation from one community to the next and correlated the change of Orthopteran species with the change in that particular physical factor. The conclusion that physical factors were all important or even more important than biological factors in limiting the distribution of Orthoptera seems unjustified since both physical and biological factors varied.

Urquhart (1941) studied the ecology of the Saltatoria (jumping Orthoptera) in Ontario and concluded that, of the various physical factors directly affecting insects, the rate of evaporation is the most important in limiting the ecological distribution of species in a given locality. On the basis of data obtained from rearing experiments, inter-habitat transferences, and the work of other authors, he decided that food preference is not a limiting factor. However, his rearing experiments are very few. Some of his tests are based on a number of species accepting several grasses and sedges as food. Such tests are inadequate to determine the food value of a plant, because many grasshoppers will feed on unpreferred plants if forced to do so. Biological indexes such as mortality, growth, and egg production must be measured to determine whether a plant will serve as a favorable food or not. Rearing was done using cultivated plants. This procedure gives no information on the value of native plants. Many cultivated plants are said to be “neutral” in that they do not repel certain insects and can serve as adequate diets.

In summary, the arguments of Vestal, Strohecker, and Urquhart relegating the nutritional values of different plants to a role of insignif-
icance in the distribution of the Acrididae do not appear to be valid. Before food-plants can be dismissed as a factor of little consequence in the distribution of a grasshopper species, autecological tests must first be made upon that species and the significance of food-plants learned. To be sure, there are a number of physical requirements which must be met in the habitat and these no doubt are important factors in the distribution of every acridid species. Clark (1948) in his paper on the ecology of British grasshoppers has made a searching review and analysis of the problems involved in distribution. Further information and summaries of other studies on the subject of distribution are provided by this author.

Although the case for food-plants being an important factor in limiting the distribution of monophagous and oligophagous species seems adequately supported by research data, little evidence has been reported that food-plants so influence the distribution of the “general feeders.” Criddle (1933) wrote that *Melanoplus mexicanus* will eat all any plant which grows and on this basis accounted for its wide distribution and general abundance. F. B. Isely (1938) stated that in cage tests it proved to be a general feeder. There are others who have referred to the indiscriminate feeding of *M. mexicanus*. However, Brett (1947) in his thorough work of comparing the food value of lettuce, alfalfa, and corn in promoting the growth of *M. mexicanus*, proved that these plants do not have equal value. The present study also showed that all plants do not have equal food value as demonstrated by tests with a number of ecologically important species. These results and the results of the food preference tests and of the observations made in the field show that *M. mexicanus* is not as general in its feeding habits as usually reported and indicate that the absence of proper food-plants may be a limiting factor in its distribution.

The relationship of food-plants to abundance of *M. mexicanus* requires consideration. Although this species appears to have a continuous distribution over the grasslands, it is not equally numerous in all places. Often large populations of both nymphs and adults are found in certain crops such as alfalfa and wheat, in ruderal communities, and in local areas on the range where forbs abound. The environment of these habitats appear to be more conducive to high populations than is the environment of habitats where *M. mexicanus* is few in numbers. The factor or factors responsible for these differences in numbers cannot be categorically asserted. Both the physical and biological environments of a ruderal area or of crop land such as an alfalfa field appear to be different from the physical and the biological environments of a short-grass plains area. In this example there is a confounding of factors, but
the results of the present study seem to indicate that a factor at least partially responsible is the different food values of the plants in these areas. Weeds such as downy chess and dandelion are favorable foods for all stages of grasshoppers, and alfalfa is favorable for second instar and older stages. On the other hand, native grasses have been found to be unfavorable as food for the several stages tested.

Areas can be found in the short-grass plains where heavy grazing or some other disturbance has permitted an invasion or an increase of forbs such as dandelion and mustards. Although no measurements of the physical factors have been made in these short-grass areas, little difference in heat and in evaporation can be visualized between those areas containing high percentages of forbs and those containing low percentages. This is likely because both types are open to the sun and wind and both can be found adjacent to each other so that precipitation is similar. Soil in some cases may vary. Nevertheless, the most obvious difference is the species composition of the vegetation, and until further work is done on the other factors which may have caused or may have contributed to the differences in abundance, the nutritional differences of the vegetation are considered to be the most important causal factors.

The present study has shown that all plants do not have equal food value for *M. mexicanus*. These variations may have been due to differences in the nutritive qualities of the plants themselves or due to differences in the quantities of food eaten by the grasshoppers or both. Specific experiments have not been devised to test this problem, but there are some indications that the differences were due to the quantity factor. The positive correlation between the results on food preferences and the results on survival, growth, and egg production, together with the observation that *M. mexicanus* fed freely on the favorable plants and not on the unfavorable ones, suggests the importance of the quantitative factor. Nevertheless, these observations do not preclude possible qualitative differences being at least partially responsible for the observed differences in growth and egg production.

**SUMMARY**

A study was made of the importance of food-plants in the ecology of the grasshopper, *Melanoplus mexicanus mexicanus* (Sauss.). Both observational and experimental work was done. Field studies were limited chiefly to areas in the short-grass plains of eastern Wyoming, and rearing work was carried out either at Douglas or Laramie, Wyoming.

*M. mexicanus* was observed to feed mainly on certain forbs growing on the short-grass plains and very seldom on the indigenous grasses. Food preference tests showed that *M. mexicanus* preferred certain forbs and
certain cultivated plants, while other forbs and native grasses were not preferred. Among the preferred plants were dandelion, tansy mustard, wheat, and alfalfa. Some of the least preferred plants were blue grama and lamb's quarters.

The basis for the differential feeding appeared to depend on the sense of taste. In cage tests individuals were attracted to an unpreferred plant as often as to a preferred plant, but a grasshopper upon biting into an unpreferred plant elicited no feeding response. Contact with a preferred plant resulted in feeding.

Late nymphal instars of *M. mexicanus* were taken from the field, caged in an insectary, and maintained on selected food-plants. Thirty-two diets were employed. Mortalities at the end of four weeks were significantly different, ranging from 10 to 100 per cent. The mortalities were least on certain forbs and cultivated plants and greatest on certain other forbs and native grasses. A significant positive correlation existed between food preferences and the survival upon different plants.

Food-plants were found to affect significantly the total egg production, the rate of oviposition, the length of the preoviposition period, and the adult longevity. Seven different species of plants were fed to grasshoppers confined in screen cages on the ground. The food-plants arranged in ascending order of favorableness for egg production were: (1) bluestem, (2) Kentucky bluegrass, (3) thistle, (4) alfalfa, (5) tansy mustard, (6) wheat, and (7) dandelion. Total egg production varied from an average of 45 eggs to 206 eggs per female. Mean preoviposition periods ranged from seventeen to twenty-four days and mean adult longevity of females ranged from fifty to eighty-three days depending on the food-plant. The total egg production was found to be a function of oviposition rate and of length of oviposition period. Alternating a favorable food-plant with an unfavorable one at weekly intervals yielded intermediate values in total egg production compared with values obtained when the diet was limited to either plant. A delay of approximately one week in increase or decrease of oviposition rate resulted from feeding favorable and unfavorable food-plants alternately. Eight different plants were used in rearing *M. mexicanus* from egg to adult stage. Significant differences in size of the newly emerged adults and in the length of the nymphal period were found. Food-plants arranged in ascending order of favorableness for growth were: (1) alfalfa, (2) thistle, (3) bluestem, (4) Kentucky bluegrass, (5) downy chess, (6) wheat, (7) dandelion, and (8) tansy mustard. Tests showed that alfalfa as a food-plant provided much better growth if feeding was begun with second or later instar individuals than with first instar individuals.
<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big sagebrush</td>
<td>Artemisia tridentata Nutt.</td>
</tr>
<tr>
<td>Blue grama</td>
<td>Bouteloua gracilis (H. B. K.) Lag.</td>
</tr>
<tr>
<td>Bluestem</td>
<td>Agropyron smithii Rydb.</td>
</tr>
<tr>
<td>Broom snakeweed</td>
<td>Gutiérresia sarothrae (Pushr.) B. &amp; R.</td>
</tr>
<tr>
<td>Buffalo grass</td>
<td>Buchloe dactyloides (Nutt.) Engelm</td>
</tr>
<tr>
<td>Canadian thistle</td>
<td>Cirsium arvense (L.) Scop.</td>
</tr>
<tr>
<td>Crested wheatgrass</td>
<td>Agropyron cristatum (L.) Beauv.</td>
</tr>
<tr>
<td>Curlycup gumweed</td>
<td>Grindelia squarrosa (Pushr) Dunal</td>
</tr>
<tr>
<td>Dandelion</td>
<td>Taraxacum erythrospermum Andr.</td>
</tr>
<tr>
<td></td>
<td>(This species was the one found on the short-grass plains.)</td>
</tr>
<tr>
<td>Dandelion</td>
<td>Taraxacum officinale Weber</td>
</tr>
<tr>
<td></td>
<td>(This species was used in the experimental studies.)</td>
</tr>
<tr>
<td>Desert saltgrass</td>
<td>Distichlis stricta (Torr.) Rydb.</td>
</tr>
<tr>
<td>Downy chess</td>
<td>Bromus tectorum L.</td>
</tr>
<tr>
<td>Effuse eriogonum</td>
<td>Eriogonum effusum Nutt.</td>
</tr>
<tr>
<td>False mallow</td>
<td>Malvastrum coccineum (Pushr) Gray</td>
</tr>
<tr>
<td>Fringed sagebrush</td>
<td>Artemisia frigida Willd.</td>
</tr>
<tr>
<td>Goosefoot</td>
<td>Chenopodium leptophyllum (Moq.) Nutt.</td>
</tr>
<tr>
<td>Green needlegrass</td>
<td>Stipa viridula Trin.</td>
</tr>
<tr>
<td>Indian ricegrass</td>
<td>Oryzopsis hymenoides (R. &amp; S.) Ricker</td>
</tr>
<tr>
<td>Japanese chess</td>
<td>Bromus japonicus Thunb.</td>
</tr>
<tr>
<td>Junegrass</td>
<td>Koeleria cristata (L.) Pers.</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>Poa pratensis L.</td>
</tr>
<tr>
<td>Knotweed</td>
<td>Polygonum aviculare L.</td>
</tr>
<tr>
<td>Kochia</td>
<td>Kochia scoparia (L.) Schrad.</td>
</tr>
<tr>
<td>Lamb's quarters</td>
<td>Chenopodium album L.</td>
</tr>
<tr>
<td>Large-bracted vervain</td>
<td>Verbena bracteosa Michx.</td>
</tr>
<tr>
<td>Lygodesmia</td>
<td>Lygodesmia jucnea (Pushr) D. Don.</td>
</tr>
<tr>
<td>Mutton grass</td>
<td>Poa fendleriana (Steud.) Vasey</td>
</tr>
<tr>
<td>Nebraska lupine</td>
<td>Lupinus platensis S. Wats.</td>
</tr>
<tr>
<td>Pennroyal</td>
<td>Hedeoma hispida Pushr</td>
</tr>
<tr>
<td>Peppergrass</td>
<td>Lepidium apetalum Willd.</td>
</tr>
<tr>
<td>Plains bluegrass</td>
<td>Poa arida Vasey</td>
</tr>
<tr>
<td>Ponderosa pine</td>
<td>Pinus ponderosa Dougl.</td>
</tr>
<tr>
<td>Prairie sandgrass</td>
<td>Calamovilfa longifolia (Hook.) Scribn.</td>
</tr>
<tr>
<td>Rabbitbrush</td>
<td>Chrysothamnus pumilus Nutt.</td>
</tr>
<tr>
<td>Red three-awn</td>
<td>Aristida longiseta Steud.</td>
</tr>
<tr>
<td>Russian thistle</td>
<td>Salsola pestifer A. Nels.</td>
</tr>
<tr>
<td>Sandberg bluegrass</td>
<td>Poa secunda Presl.</td>
</tr>
<tr>
<td>Sand dropseed</td>
<td>Sporobolus cryptandrus (Torr.) A. Gray</td>
</tr>
<tr>
<td>Shrubby oreocarya</td>
<td>Oreocarya suffruticosa (Torr.) Greene</td>
</tr>
<tr>
<td>Silver sagebrush</td>
<td>Artemisia cana Pursh</td>
</tr>
<tr>
<td>Six-weeks fescue</td>
<td>Festuca octoflora Walt.</td>
</tr>
<tr>
<td>Slender scurfpea</td>
<td>Psoralea tenuiflora Pursh</td>
</tr>
<tr>
<td>Slender wheatgrass</td>
<td>Agropyron pauciflorum (Schwein.) Hitche.</td>
</tr>
<tr>
<td>Stickseed</td>
<td>Lappula occidentalis (Wats.) Greene</td>
</tr>
<tr>
<td>Sunflower</td>
<td>Helianthus petiolaris Nutt.</td>
</tr>
<tr>
<td>Tansymustard</td>
<td>Descurainia Sophia (L.) Webb</td>
</tr>
<tr>
<td>Thistle</td>
<td>Cirsium platense (Ryd. Chil.</td>
</tr>
<tr>
<td>Threadleaf sedge</td>
<td>Carex filiformis Nutt.</td>
</tr>
<tr>
<td>Tumblemustard</td>
<td>Sisyphyllum altissimum L.</td>
</tr>
<tr>
<td>Turkeyfoot</td>
<td>Andropogon Hallii Hack.</td>
</tr>
<tr>
<td>Wild lettuce</td>
<td>Lactuca Scariola L.</td>
</tr>
<tr>
<td>Wild salsify</td>
<td>Tragopogon porrifolius L.</td>
</tr>
<tr>
<td>Wooly Indianwheat</td>
<td>Plantago Purshii Roem. &amp; Schult.</td>
</tr>
</tbody>
</table>


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