

JUNE, 1939

BULLETIN 406

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION

M. F. MILLER, *Director*

Grasshopper Outbreaks in Missouri

GEORGE D. JONES

COLUMBIA, MISSOURI

KNOWN OUTBREAKS OR YEARS OF GRASSHOPPER DAMAGE IN MISSOURI

<i>Year</i>	<i>Species</i>	<i>Location in State</i>
1818, 1819, 1820	Rocky Mountain and likely native kinds	Western part and general
1829	Not given but probably native kinds	Likely only in eastern part
1855, 1856, 1857	Rocky Mountain and very probably native kinds	Central and likely general
1866 to 1869	Rocky Mountain and native kinds	Western and eastern and probably general
1873 to 1876	Rocky Mountain and native kinds	Western half and perhaps general
1885	Native kinds	Northern half
1892	Native kinds	Northern and central
1899	Native kinds	State-wide
1902	Native kinds	Eastern and southeast
1911	Native kinds	Northwestern area
1917 to 1926	Native kinds	Localized general infestations
1928 to 1935	Native kinds	Localized general outbreaks
1936	Native kinds	General over entire western half of state and rather localized over remainder
1937	Native kinds	Rather generally localized but most severe in northwest quarter
1938	Native kinds	Most severe in north central third but rather general and localized

Grasshopper Outbreaks in Missouri

GEORGE D. JONES

Grasshoppers are very common insects and most people are familiar with them. They belong to the large group or order of insects known as the Orthoptera, which means the "straight-winged insects." In addition to grasshoppers the order includes the crickets, katydids, cockroaches, walking-sticks, and mantids.

This study of grasshoppers and their outbreaks in Missouri will deal with those insects which belong to the family Locustidae and which are commonly spoken of as locusts or short-horned grasshoppers. The word "locust" is properly applied only to these insects. The insects spoken of in the Bible and in other books dealing with grasshoppers or locusts are members of this family.

There is a large number of species of locusts in North America, and Missouri seems to have its share of them. Recent studies in the state show that there are several species present although only five or six are regarded as harmful. While all grasshoppers have chewing mouth-parts and feed on different kinds of grasses and other vegetation they all cannot be considered harmful. Those feeding on grasses and plants which have no economic value are classed as neutral so far as damage is concerned. Only those species which feed upon our crops will be considered in this study.

Native grasshoppers became very abundant during the years 1818, 1819, 1820 and 1821 in the states to the east, north, and west of Missouri.¹ They were reported as far east as the New England states. The infestation seemed to be general over a large area and no doubt similar outbreaks occurred in Missouri.

The invasion of western Missouri by the Rocky Mountain locust during 1820 and 1821 was the first time that this species was recorded in the state. They apparently came late in the summer and in some localities caused serious damage. As a general thing, however, they did not cause widespread losses. Few studies were made as regards species at this early date and no doubt common or native species were responsible for some of the damage reported.

Turkeys were referred to as factors in control during this outbreak.² The literature of the time reviewed indicates that people looked upon the large scale migrations as punishment for some crime or evil happening. Weather records were not available and little information about the areas of infestation or damage was found.

¹*First Annual Report of the United States Entomological Commission*, 1878, pp. 53-112.

²*Proceedings of Missouri State Horticultural Society, Missouri State Board of Agricultural Report*, 1867, p. 417.

The outbreak during 1829 was centered in the eastern part of the state and according to the information native species were responsible for the damage.

A considerable drought was experienced in several mid-western and western states during the years of 1855, 1856 and 1857. The outbreaks during 1857 were supposed to have been caused by the Rocky Mountain locust; but if authentic records were available, they would probably show that the damage may have resulted from local species. The damage seemed to be confined to south central Missouri. Rocky Mountain locusts were reported to have been present in Kansas and Iowa and other mid-western states during 1856 and 1857. Rain-fall data for northwest Missouri were about normal during 1856 and only slightly less than normal during 1857.³

No outbreaks were mentioned during the period from 1858 to 1865.

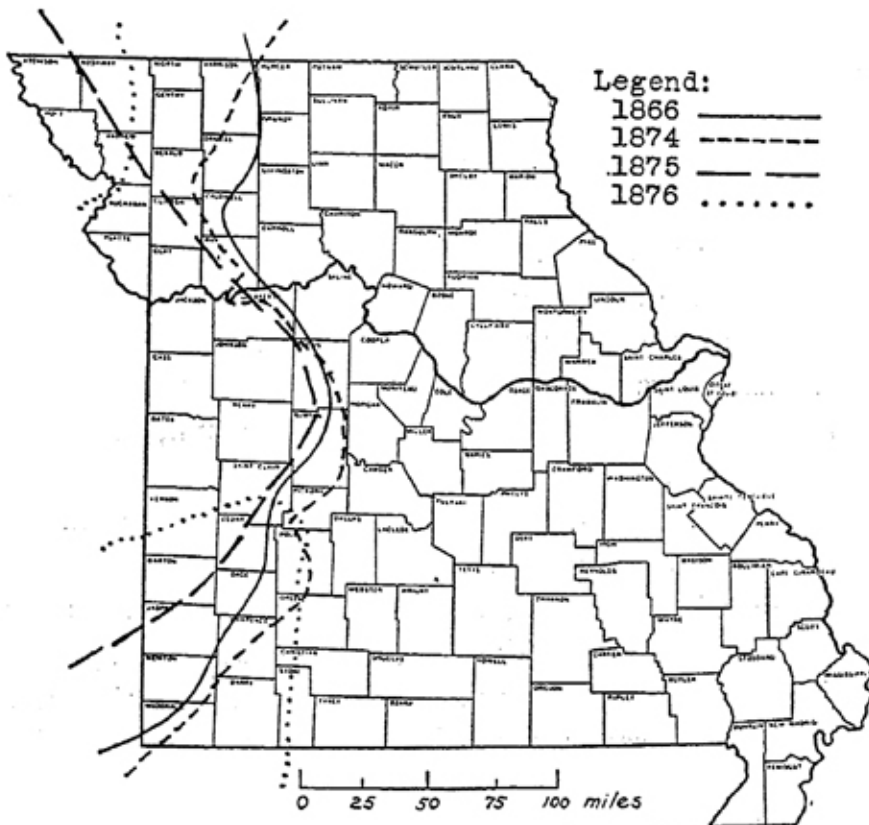


Fig. 1.—Rocky Mountain locust invasions in Missouri (C. V. Riley's Reports VII, VIII, and IX). The lines indicate the extent of some of the worst invasions. Note that the invasion of 1866 extended farther east in the northern part of the state than the one of 1874 but in the southern part of the state the reverse is true. The other invasions did not extend as far east as either of these. The greatest damage was done during 1875, and it was in this year that great suffering was experienced.

From 1866 to 1869 many central and western states were damaged severely by grasshopper outbreaks. Their numbers and damage were so extensive that they attracted national attention. Missouri was among the states which were invaded by the Rocky Mountain

³Riley, *Seventh Annual Report*, 1875, p. 172.

locust during this period. In 1866 the invasion extended into the state to a great extent as shown by Fig. 1. They came late in the summer and did not do much damage but laid large numbers of eggs. The eggs hatched in the spring of 1867 and the young hoppers did some damage but the greatest damage came later in the season when fresh swarms migrated into the state. Native or local grasshoppers were present in the state and they caused considerable damage in several sections.

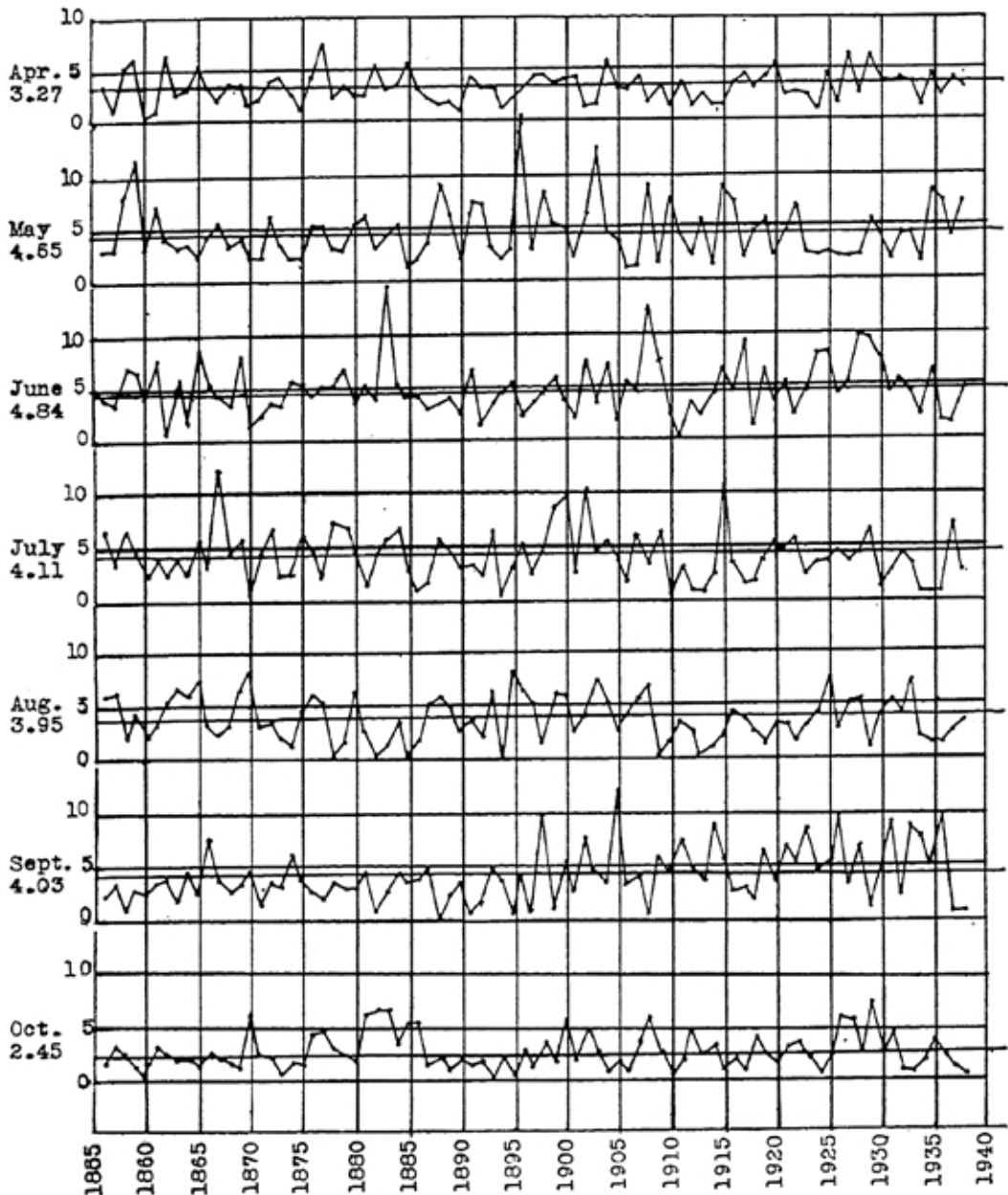


Fig. 2.—Total and average monthly rainfall in inches, Oregon, Missouri, 1856-1938.

The weather data as shown in Fig. 2 indicates that northwest Missouri had experienced slightly less than normal rainfall during the fall months of 1867, and the rainfall during the year of 1866 was

little above normal during the crop growing season. St. Louis also reported less than normal rainfall for the year 1867. The fall months were decidedly deficient. The year 1868 was deficient in rainfall at Oregon all during the summer months as shown by the weather data.⁴ In 1869 April and May were below normal in rainfall at Oregon but throughout the remainder of the season normal or above rainfall was had. In certain localized areas in the eastern part of the state native grasshoppers were very destructive during 1868 and 1869.

The following quotation describes the extent of damage.

"In 1869, they were if anything worse than in 1868. I remember that in the vicinity of St. Louis in addition to their ordinary injuries they stripped the tops of Norway spruce, Balsam Fir, and European Larch; took the blossoms off Lima beans; severed grape stems, and ate numerous holes into apples and peaches, thereby causing them to rot. They were indeed abundant all over Illinois, Missouri, Iowa, and even Kentucky; but attracted no attention East."⁵

Native grasshoppers were also present in the northwestern part of the state. The following statement, dated August 27, 1869, describes the damage, ". . . our own stock was bad enough but on the 18th of June we received a large addition of flying ones from the south which in some places took half of the corn. . . ."⁶

The first reference to enemies and parasites of grasshoppers in Missouri was found during this outbreak. The silky mite (*Trombidium sericeum*, Say), the scarlet mite (*T. holosericeum*, L), and the locust mite (*Astoma gryllaria*, Le Baron), were reported to be very abundant. The locust mite attacked grasshoppers and flies and was reported to be killing them in large numbers in northwest Missouri. The Tachina-fly (*Tachina anonyma*) and the common flesh-fly (*Sarcophaga carnaria*, Linn) also attacked the pests at this time.

Certain control suggestions were found for the first time during this outbreak. In 1868 and 1869, cresylic acid soap was sent by Riley to Mr. Blanchard for use on plants in Oregon, Holt county, but the repellent was reported no good. Other repellents were advised but none proved helpful. Other control measures were recommended, such as natural agencies or birds; artificial means of destroying the eggs by discing and harrowing or by plowing deeply; destruction of nymphs by driving them into straw or hay and destroying by fire or by collecting in a ditch.⁷

From 1873 until 1876 western Missouri was again invaded by the Rocky Mountain locust. The invasions of 1873 and 1874 were quite

⁴The weather data is taken from the climatic summary of the United States Weather Bureau, U. S. D. A., 1930, Washington, D. C.

⁵Riley, *Seventh Annual Report*, p. 172.

⁶*Ibid.*, p. 140.

⁷Riley, *Seventh Annual Report*, pp. 174-183.

similar to 1866 and 1867. During the fall of 1873 flights of adults came in and did not cause much damage but laid large numbers of eggs. The young hoppers which hatched from the eggs during the early summer of 1874 caused much damage, and the year was the worst grasshopper year up to that time. The heavy crop loss during 1874 and the total destruction of crops during May in 1875 caused tremendous suffering.

The season of 1875 opened with rains but as dry weather set in during April and May farmers in entire communities became panicky. The suffering was great. Grasshoppers had been bad for two years and the year started out more seriously than any other. Livestock was driven to more favored counties and relief committees were organized. Conditions in the infested areas were bad. The following is a copy of the proclamation by the governor of the state who recognized the gravity of the situation. It was issued about the middle of May, 1875.⁸

"Whereas, owing to the failure and losses of our crops much suffering has been endured by many of our people during the past few months and similar calamities are impending upon larger communities, and may possibly extend to the whole state and if not abated will eventuate in sore distress and famine;

"Wherefore be it known that the 3rd day of June proximo is hereby appointed and set apart as a day of fasting and prayer that Almighty God may be invoked to remove from our midst those impending calamities and to grant instead the blessings of abundance and plenty; and the people and all the officers of the state are hereby requested to desist during that day, from their usual employments, and to assemble at their places of worship for humble and devout prayer, and to otherwise observe the day as one of fasting and prayer.

"In testimony whereof, I have hereunto set my hand and caused the great Seal of the State of Missouri to be affixed, in the City of Jefferson, this 17th day of May, 1875. . . . C. H. Hardin

By the Governor:

M. K. McGrath, Secy. of State."

A second proclamation was issued on the 24th day of May urging contributions of food and seed to stricken farm families and along with instruction to whom they should be sent. The response to the cause was better than expected and much good came from the efforts. (See Fig. 1 for the area in which the greatest suffering occurred.)

It was during this outbreak in 1875 that Riley prepared a meal with grasshoppers as the main source of food.⁹ This was done at Warrensburg State Teachers' College. The results were satisfactory and some prepared grasshoppers were sent to certain chefs in St. Louis where they were prepared in a soup and pronounced delicious. Riley also took baked specimens to France and England, where they were tasted and reported better than expected. The tests and experiments

⁸Riley, *Eighth Annual Report*, p. 95.

⁹Riley, *Eighth Annual Report*, p. 144.

were undertaken because many families in Missouri and Kansas and in other western states were at the point of starvation during the outbreak in 1875 and perhaps some did resort to a diet of grasshoppers.

The locusts began to disappear during early June and many farmers in the stricken area began to replant corn and other crops. The areas in the heavily infested districts reported remarkably good crop conditions considering the damage and suffering experienced in the early part of the season of 1875.¹⁰

Rainfall during the outbreak was very deficient in the western part of the state. The year 1873 was an exceptionally dry season. Figure 3 shows that the rainfall at Oregon, was below normal for the en-

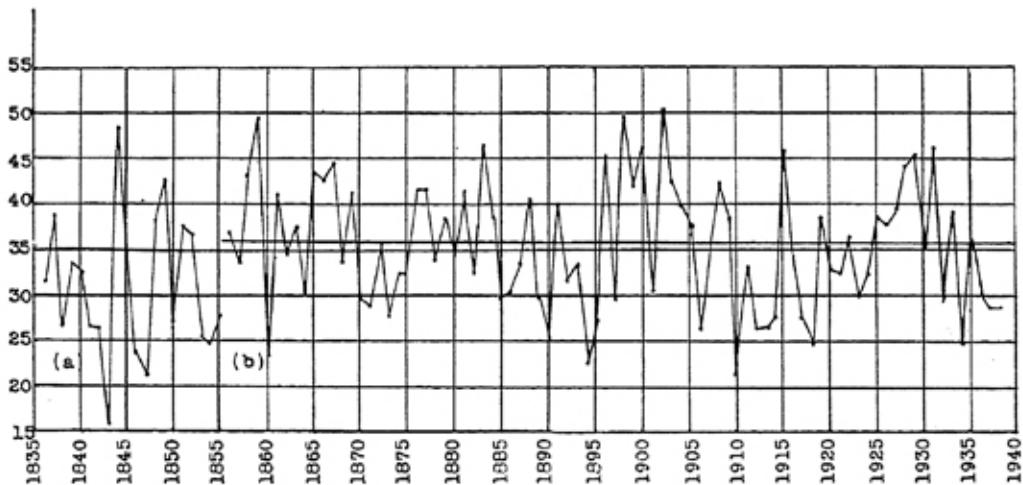


Fig. 3.—(a) Total and average yearly rainfall in inches, Leavenworth, Kansas, 1836-1855. Average for station, 102 years, 34.82 inches. (b) Total and average yearly rainfall in inches, Oregon, Missouri, 1856-1938. Average for station, 82 years, 35.96 inches.

tire period from 1870 to 1876. (See Fig. 2) The rainfall was below normal for every month during 1873 except April. At St. Louis the rainfall was normal or above during the outbreak. Damage by the two-striped, the differential, the red-legged and the atlantis species was apparent in most parts of the state during the fall months of 1875.¹¹ During 1876 the Rocky Mountain locust invaded only a few counties in the northwestern and southwestern parts of the state. They came in late and in several counties seriously damaged the fall-sown wheat. Large numbers of eggs were laid in a few places. See Fig. 1 for the counties infested by this species during this outbreak.

Crop losses during this period were the worst ever experienced in the history of the state. The damage during 1875 alone was estimated at \$15,000,000.

¹⁰*Ibid.*, p. 119.

¹¹Riley, *Eighth Annual Report*, p. 150.

Farmers in the early part of the epidemic attempted to destroy the pests by fall plowing, collecting eggs and permitting hogs to feed on the eggs in the soil. Toward the end of the epidemic they resorted to trapping, burning, tramping, trenching, and poisoning with Paris green as a spray.¹² None of these measures proved very effective in preventing widespread losses. White-washing trees was found successful as a repellent and was recommended for fruit and shade trees with a smooth bark. National and state legislation was much discussed and Missouri as well as other states enacted laws to encourage the destruction of the pests.¹³ A federal appropriation was made for the purpose of studying the habits of the Rocky Mountain locust.

It was during 1876 and 1877 that Riley discovered blister beetle larvae feeding on grasshopper eggs.¹⁴ The parasites already mentioned and additional enemies of the eggs aided in control of the pests during this outbreak.¹⁵

Some interesting studies on eggs were conducted during this period. A summary of the studies along with control suggestions is given:

“. . . . First—Frost has no injurious effect on the eggs; its influence is beneficial rather, in weakening the outer shell.

“Second—Alternately freezing and thawing is far less injurious to them than we have hitherto supposed, and tends to their destruction, if at all, indirectly, by exposing them to the free air.

“Third—The breaking open of the egg-masses, and exposure of the eggs to the atmosphere, is the most effectual way of destroying them. Hence, the importance of harrowing in the Fall is obvious.

“Fourth—Moisture has altogether less effect on the vitality of the eggs than has heretofore been supposed, and will be of little use as a destructive agent, except where land can be overflowed for two or three days at the time when the bulk of the young are hatching.

“Fifth—Plowing under of the eggs will be effectual in destroying them, just in proportion as the ground is afterward harrowed and rolled. Its effect varies with the nature of the soil. Other things being equal. Fall plowing will have the advantage over Spring plowing, not only in retarding the hatching period, but in permitting the settling and compacting of the soil; while where the ground is afterwards harrowed and rolled, the Spring plowing will prove just as good, and on light soils, perhaps better.”¹⁶

During this period the first full discussion about the destructive native kinds of grasshoppers in the state was found.¹⁷ The most destructive and most common species was the widespread red-legged locust (*Melanoplus femur-rubrum*, De Geer), which was often confused with the true Rocky Mountain species. The next most injurious was the differential locust (*Melanoplus differentialis*, Walk.), which

¹²*Ibid.*, pp. 126-131.

¹³Riley, *Ninth Annual Report*, p. 111.

¹⁴*First Report of the United States Entomological Commission*, p. 292.

¹⁵Riley, *Ninth Annual Report*, pp. 91-99.

¹⁶Riley, *Ninth Annual Report*, pp. 99-106.

¹⁷*Ibid.*, *Eighth Annual Report*, p. 173.

was distinguished from the red-legged locust, not only by its larger size, but by its brighter yellow and green colors. Next in importance was the two-striped locust (*Melanoplus bivittatus*, Say), also a larger species, of a dull, olive-green color, with two yellow lines extending from above the eyes along each side of the thorax. The long-winged or so-called bird-grasshopper (*Schistocerca americanum*) was mentioned frequently as causing damage in the state; *Melanoplus atlantis*, Riley, which was called the atlantic migratory locust because of its distribution in the eastern states, was first taken in Missouri during 1875 and was described as being smaller than either the Rocky Mountain or the red-legged species.¹⁸ Its general structure and length of wing more nearly approached the Rocky Mountain locust in these respects. Entomologists during the period were not entirely in agreement as to the proper identification of these species. Several seemed to think that the Rocky Mountain and the atlantic migratory species were strains of the common red-legged grasshoppers and had adapted themselves to certain areas.

The grasshoppers began to decline in importance during 1876 and no reports of damage were found in the state until 1885. Rainfall at Oregon and at St. Louis, Missouri, was above normal during both years of 1876 and 1877. It was well distributed as indicated in Fig. 2.

Very little detail could be found regarding the infestation in 1885 which described the species involved and extent of damage. The damage was confined to the area north of the Missouri River.¹⁹ The rainfall data shows that at Oregon the early fall months were dry and that the year 1885 was below normal for every month of the growing season except April. Less than normal rainfall was had throughout northeast and central Missouri. Native grasshoppers were probably responsible for the damage.

In 1892 grasshoppers caused considerable damage to crops in Northern and Central Missouri. The *State Board of Agriculture Report* for that year mentions grasshopper damage along the margins of wheat fields in the fall²⁰ in several sections of the state. The infestations were scattered and not general. Caldwell County is mentioned specifically, and this would indicate that at least northwest Missouri was infested to a noticeable extent. Native grasshoppers were responsible and had no doubt built up in numbers during the previous dry years. The data shows that all during the year at Oregon the rainfall was below normal except during May. Similar conditions existed in St. Joseph, Missouri. Several stations reported

¹⁸Riley, *Seventh Annual Report*, p. 169; *Eighth Annual Report*, p. 116.

¹⁹Missouri State Board of Agriculture Report, 1885, p. 198.

²⁰Missouri State Board of Agriculture Report, 1892, p. 277.

less than normal rainfall during late summer. Apparently, it was a dry fall.

In 1899 grasshoppers were reported as causing much damage to crops throughout the entire state. Nearly all crops were damaged to some extent. In some localities they appeared in great numbers and caused serious losses. The infestation, while rather general, was very spotted and would vary from one farm to another. The hoppers, in some instances, destroyed entire fields of corn. Oats were cut from the stalk and dropped to the ground. Clover and young millet and potatoes were consumed and much damage was done to young orchards and nursery stock. Meadows were stripped of blades and pastures eaten to the ground and kept bare throughout the remainder of the season. No data were found which described the species but no doubt native hoppers were responsible. The rainfall at Oregon was above normal for the year but the fall months showed dry conditions. At St. Louis the rainfall was below normal during the year. Other stations throughout central and southern Missouri showed similar conditions. This outbreak was the worst general infestation since 1876. Eastern and southern areas seemed to be worse affected.

In 1902 grasshoppers were reported as causing considerable damage in southeast Missouri counties. Native species undoubtedly were responsible for these outbreaks. The rainfall data at Oregon shows that 1901 was a very dry season in northwest Missouri. This is noted as one of Missouri's worst drought years. The year 1902 at Oregon was a very wet season as indicated by Fig. 2. At St. Louis the rainfall for 1902 was slightly below normal. Stations in the central and southeast areas reported less than normal rainfall and drought conditions. The report telling of damage is very meagre and it is difficult to tell anything about the kinds of grasshoppers involved or the extent of the damage.

A comment on grasshoppers in the state about this time was as follows:

“ . . . Our most common grasshopper is known as the Red-legged Grasshopper. Another grasshopper which becomes more abundant later in the summer and is much larger in size, is known as the Bird Grasshopper, and occasionally this insect occurs in sufficient quantities to seriously injure corn fields. The Olive Grasshopper and the two-striped grasshoppers, are two common species that we frequently find eating of the corn plant, but they are not liable to cause so much trouble as the two former species. Of course, we have a good many other grasshoppers that one will find occasionally in corn fields, but the four I have mentioned seem to be the more common ones. . . . The most successful method of fighting grasshoppers now seems to be by the use of what is known as the Criddle mixture. This mixture is made in the following way: To a barrel of fresh horse manure thoroughly mix a pound of salt and two pounds of

Paris green, or one pound of powdered arsenic. If this mixture is made of perfectly fresh horse manure the salt may be omitted, but if the horse droppings are not perfectly fresh, the salt must be added. This Criddle mixture, so called, should be placed in handfuls about the corn field where the grasshoppers are doing the most mischief, and it will attract them for several feet. They will feed upon it in preference to any other known substance, and will be killed by the arsenic, which has been thoroughly mixed with it. This same Criddle mixture is, of course, valuable in connection with other plants that are being injured by these insects."²¹

This is the first reference found in which a poison bait was recommended.

This is also the only record found since Riley's reports which tells about specific species of grasshoppers in the state. It would seem that native grasshoppers were not considered as dangerous pests at that time. People undoubtedly thought that the native species could not build up to destructive numbers and cause widespread losses. The review of literature on the serious outbreaks during the seventies leaves one in doubt as to the importance of native species as destructive agents. In view of the present situation one wonders if native kinds should not have been given more study during the early outbreaks.

No records of damage have been found for the years from 1902 until 1910. In 1911, crops throughout northwest Missouri were damaged to a very marked extent. Several other states were infested also. A statement in the St. Louis *Globe-Democrat* describes the outlook for grasshopper damage in several midwest and western states.²² It is noted that at Oregon rainfall during 1910 was very scant and that in 1911 moisture was also deficient. Every month during the season was below normal except September. Native hoppers were responsible and undoubtedly had built up in numbers during the previous dry seasons. Control efforts were not very successful and considerable damage was reported.²³

From 1912 until 1916, no mention of grasshoppers was found. The rainfall data for this period were below normal at Oregon, but no records of grasshopper damage were located. It is noted that the months of May and September and October at Oregon for each of the years had about normal or above normal rainfall which might tend to indicate that conditions were not entirely suited for the pests to increase in numbers. At St. Louis and several other stations rainfall averaged normal or above during most of the years. It is noted that the fall months of 1916 at Oregon were below normal in rainfall and that the year of 1917 was very deficient in rainfall.

²¹Thirty-eighth Report of the Missouri State Board of Agriculture, for 1905, paper by Professor J. M. Stedman, Professor of Entomology, College of Agriculture, University of Missouri.

²²St. Louis (Missouri) *Globe-Democrat*, February 27, 1911, p. 11.

²³Holt County *Sentinel*, July 14, 1911.

During the period 1917 to 1926 some grasshopper damage was noticeable every season. Most of the reports came from the north central and western counties. Native species undoubtedly caused most of the damage. It is noted that at Oregon every year except four was decidedly below normal in rainfall. The data each month does not indicate much surplus moisture during any year. It apparently was a dry ten-year period. The damage was most severe during 1918, 1919, and 1924 with a gradual decrease in importance until 1927 when no damage was reported. The largest number of inquiries came to the Department of Entomology, University of Missouri, during the years of 1918, 1919, 1920 and 1924. These years all indicate dry and below normal rainfall at Oregon. The rainfall data for St. Louis, Fayette, Kirksville and Hermann during this period indicates very similar conditions. The infestation during 1918 was widespread and included all parts of the state, except southeast counties. The 1924 infestation extended to all sections of the state. During this period farmers were becoming more familiar with the poison bran bait mixtures which were being recommended at that time and some reported good results.

The period 1928 to 1935 was really the beginning of the present outbreak of native grasshoppers. Every year since 1928 requests for information on grasshoppers have come to the Department of Entomology. The infestations have varied from year to year and no widespread outbreaks have occurred during the period. This has been especially true since the fall of 1930 when several reports of grasshopper damage were published.²⁴ Grasshoppers were abundant in localized areas during 1931, and six counties carried on demonstrations. During 1932, the infestation gradually increased and according to the records 19,099 pounds of bait were used in thirty-one counties. The infestation was more severe in southern Missouri but it appeared somewhat general. In 1933 they were reported as causing damage in only isolated areas. In 1934 no record of their attack is found. However, some moderate damage undoubtedly took place. The serious drought ruined the corn crop in the northern, central, and western parts of the state.

During the fall of 1935 numerous reports of grasshoppers damaging fall wheat and alfalfa and others crops were made.

Native species continued to cause the damage. Some felt that there were migrations into the state. Conditions were ideal for egg laying as the whole state suffered from a lack of moisture during

²⁴The author's notes and information found in the writer's annual extension entomology reports for the years 1930 to 1938 inclusive were used as reference materials.

the early fall months. At Oregon, July and August had less than normal rainfall and September and October were only slightly above normal. This tends to indicate that Missouri continued dry following 1934 which was in many sections the most severe drought ever experienced in the state. It is noted that the rainfall all during the season of 1933 was normal or above normal and no doubt this had much to do with the few hoppers in 1934.

The grasshopper outbreak during 1936 will no doubt be remembered as the worst grasshopper epidemic since the years of 1874, 1875, and 1876. It is of interest because native species which includes the big yellow grasshopper, *M. differentialis*, the two-striped grasshopper, *M. bivittatus*, the lesser migratory grasshopper, *M. mexicanus*, and the red-legged grasshopper, *M. femur-rubrum*, were the ones responsible for the damage. The map in Fig. 4 shows the area of the state in which grasshoppers were so destructive. The

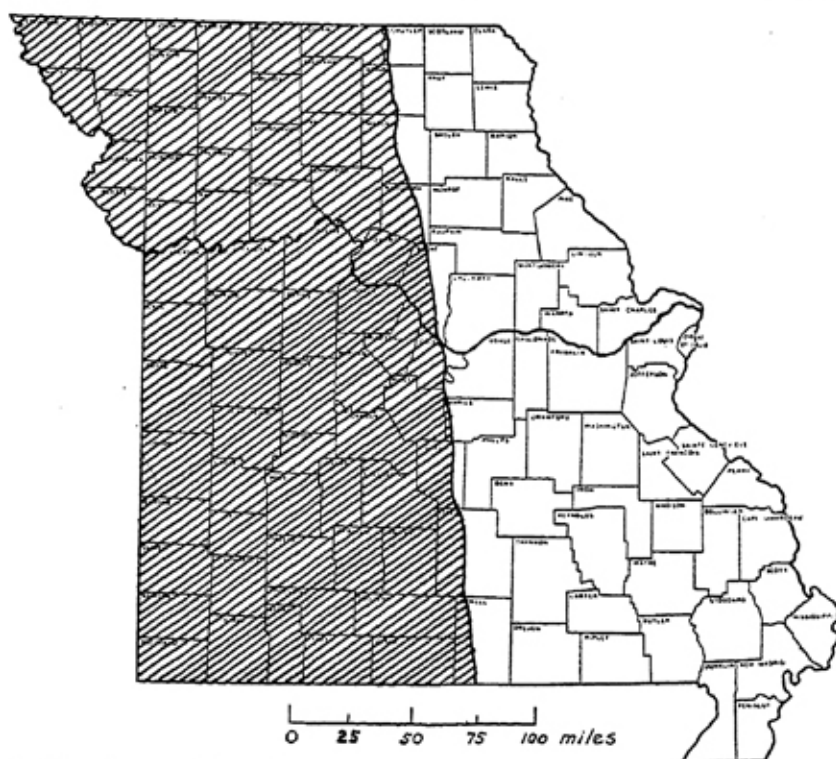


Fig. 4.—Grasshopper infested areas during 1936. The cross-hatched section designates the portion of the state most seriously infested by native grasshoppers. All of the area east of the line was infested only in spots. The grasshopper area coincides to a remarkable extent with the severe drought areas of that year. *M. differentialis* was the most destructive species present and it was assisted in the northern part by *M. bivittatus* and in the southern and eastern part by the *M. mexicanus*. *M. femur-rubrum* was present over most of the southern and eastern parts but was not of much economic importance.

year 1936 was another exceptionally dry hot summer and much of the grasses and natural food for the pests withered up and caused the pests to concentrate on green succulent crops. The monthly rainfall chart (Fig. 2), at Oregon indicates fairly accurately rainfall con-

ditions over the entire state. April was only fairly dry. May had above normal rains which aided in producing about a normal wheat crop. June, July, and August were hot and dry. Rainfall came in September breaking the drought and October had normal precipitation. The hoppers laid large numbers of eggs.

Because of several states being involved, a federal appropriation for grasshopper control was made available during June, 1936, for use in controlling grasshoppers in the several infested states. It was a federal-state program and the federal government furnished straight bran and sodium arsenite. The state and county committees agreed to furnish sawdust, store and mix the materials and distribute the bait to the farmers at cost. A charge of about thirty cents per hundredweight on a wet basis enabled most county organizations to operate on a paying basis. The mixture contained equal parts of bran and sawdust and one gallon of poison to each two hundred pounds of materials. Molasses was not recommended but many farmers wanted it added. Mixing stations were set up in some seventy infested counties in the state. The Bureau of Entomology and Plant Quarantine officials in charge established their regional headquarters at Kansas City, Missouri. The appropriation was late in being made available and many fields were damaged before any bait could be distributed. Many farmers were skeptical of the bait and believed that their livestock would be killed. In spite of these handicaps, some 20,000 farmers were reported using the bait. In spite of heroic efforts on the part of the men in charge the hoppers stripped over 1,000,000 acres of corn and other crops. Over 2,000 tons of bait were used which made it possible for many drought stricken farmers to protect completely their crops. By using the bait many farmers were able to save enough feed to carry all of their livestock through in spite of the drought. Many of those who did not try to protect their crops against the pests had to sacrifice their livestock. The drought and the pests together made conditions very bad. Gardens, young fruit trees, and alfalfa stands were severely injured. Several young orchards were ruined. Weeds, branches on trees, and shrubs were often peeled by the pests. Many farmers proved to themselves that crops could be protected at a very small cost and in a practical manner. (See Figure 5 which shows what the use of bait did for a Grundy County farmer). There was much suffering and had it not been for the Federal Drought Relief many families would have been destitute.

With the assistance of federal workers a partial egg-survey was made during the fall months. It was not very complete but most



Fig. 5.—Results of control effort. This field of corn on the A. D. Barton farm in Grundy county was protected by poison bait during the summer of 1936.

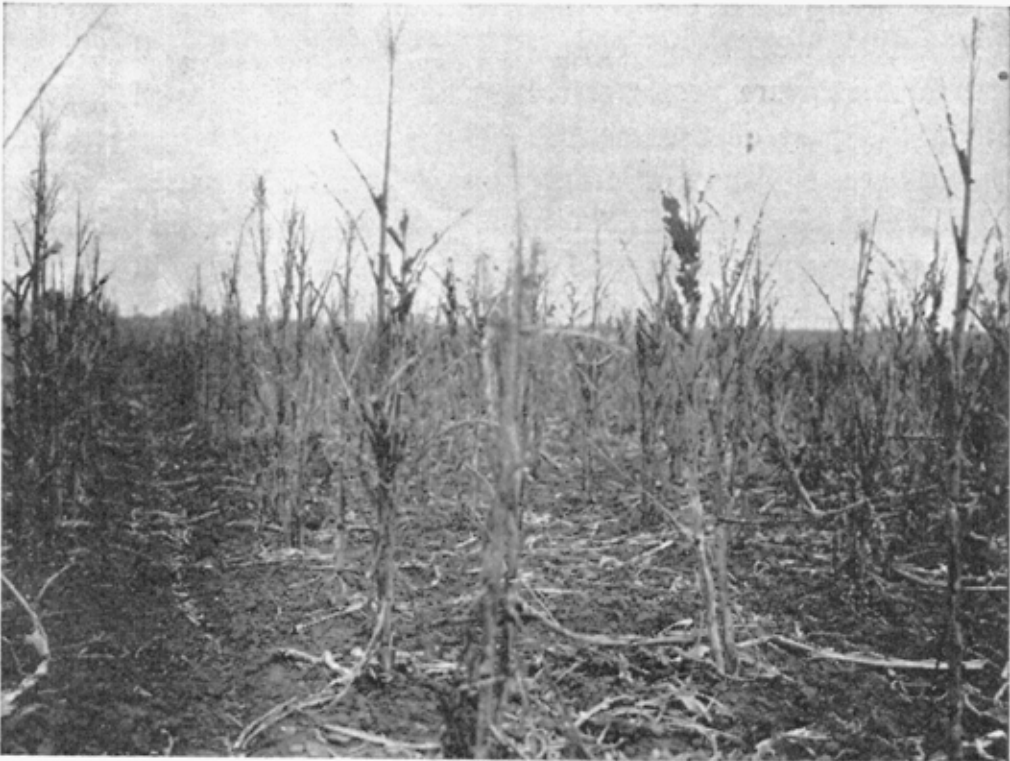


Fig. 6.—Result where no control effort was made. This field of corn across the road from the field shown in Fig. 5 was totally destroyed by grasshoppers during the summer of 1936. No baiting was done.

of the areas of heavy oviposition were located. The surveys were supervised by Robert L. Shotwell, U. S. D. A., Grasshopper Laboratory, Bozeman, Montana, who directed the work and furnished the information and the method of rating the infestations in all the states. The survey work was done by counties, and in each county representative grasses and typical egg-laying places were examined in at least five places in the county. These locations were well scattered over the county, and ratings of normal, light, threatening, severe, and very severe were given to each particular stop. County summaries were prepared and from this information county, and finally state, estimates on bait needs were arrived at. This is the first time that detailed surveys were made in the state.

The survey estimates indicated that a total of 6,123 tons of dry bait (sawdust and bran) would be needed for the year 1937.

During the egg survey several parasites were found attacking the egg-pods. The most numerous seemed to be blister beetle larvae and bee-fly larvae. Several of the adult hoppers were attacked by red mites and certain fly maggots. Not over 10 per cent of the egg-pods were found infested. The red mites were numerous but little damage seemed to be done by them.

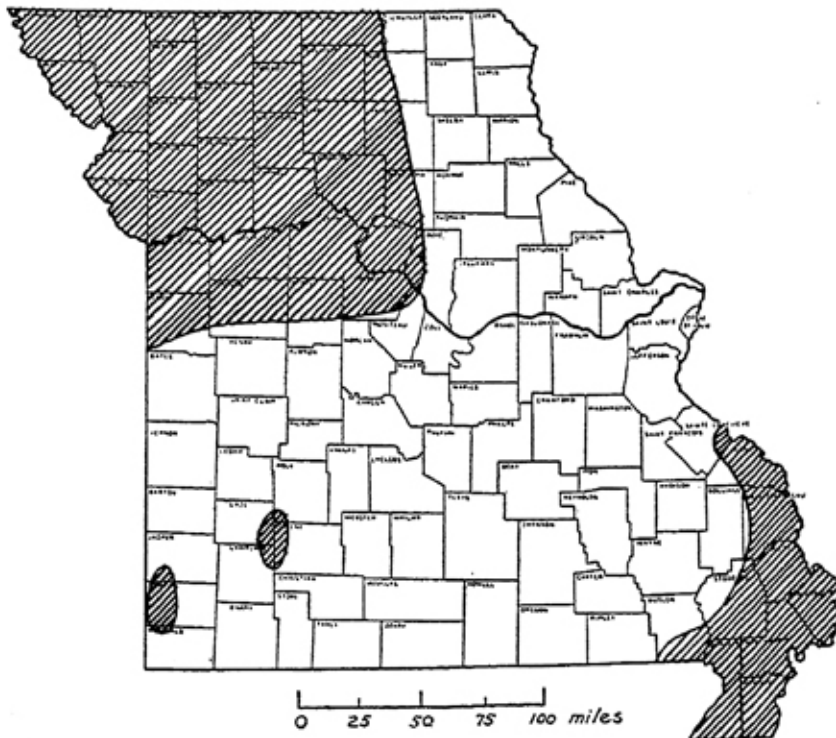


Fig. 7.—Grasshopper infested areas during 1937. The cross-hatched areas designate the portion of the state most seriously infested by native grasshoppers during 1937. *M. differentialis* was the most destructive species in the state during the year. *M. bivittatus* was abundant in the northern part of the state; *M. femur-rubrum* was of little importance except in the northeastern part, and *M. mexicanus* was extremely serious in the southern half and eastern part of the state. General damage was not as severe as during 1936. *M. mexicanus* developed a partial second brood during the fall months.

The grasshoppers during 1937 were not as severe in their attack on crops in the state as they were during 1936. Drought conditions did not prevail. Greatest damage occurred in the northwest quarter of the state; however, spotted damage occurred in nearly every county. A federal appropriation for materials was again made available and county mixing stations functioned in 91 of the 114 counties. Figure 7 shows the areas of infestations. It is estimated that 1,115,782 acres were protected and 7,588 tons of wet bait were used to stop the pests. Reports showed that almost \$5,000,000 were saved the farmers by using the bait. Unusually good results were had with the baiting work after the wet and cool periods during early summer had passed. The bait formula was changed during 1937 and it consisted of one part mill run bran, three parts of sawdust, and one gallon of the poison to each 200 pounds of mixture. The use of molasses in the mixture was not recommended but many farmers insisted that it be added. One to two gallons to each one hundred pounds of dry mixture were used. In several counties a small amount of amyl acetate was also added. These materials were added at the expense of the individual farmer.

The federal materials were shipped to the counties free of cost, but each county as in 1936 had to store, furnish sawdust, mix, and supervise the work in its county. An average cost of about thirty-five cents per hundredweight of wet bait was charged to pay local expenses.

The infestation will be remembered as the one in which *M. mexicanus* was so abundant over the entire southern two-thirds of the state. This species developed an entire second generation during the late summer and laid eggs in the fall. The *M. differentialis* was the most dominant species in the state and especially so in the northwestern section where the greatest damage occurred. *M. bivittatus* was abundant in the northern half of the state while *M. femur-rubrum* was confined largely to the northeastern quarter. Large numbers of eggs were laid in the soil as was revealed by a fall survey which was conducted in the same manner as outlined during the year 1936. The largest and the most consistent number of eggs was found in the northwest quarter and in southeast Missouri. Many of the ratings were severe and very severe. The number of eggs in the soil was very large and a large portion of the state was threatened. Conditions apparently were ideal for egg development and laying. The remainder of the state had heavy but localized egg infested areas.

About the same number of parasites were present as during 1936. Fewer eggs were found in the counties bordering the Missouri River in the extreme northwest corner of the state.

No fungus diseases were observed or reported during the year. The rainfall data in Figures 2 and 3 show the conditions for northwest

Missouri and it indicates dry fall months were ideal for heavy egg depositions. Normal rains came during April and May which slowed egg hatching but the subsequent dry periods permitted the hoppers to develop rapidly.

The fall survey indicated a large potential problem for 1938 and it was estimated that some 8,500 tons of dry (mixed) bait or about 15,000 tons of wet bait would be needed during 1938.

The potential possibility of grasshopper damage during 1938 was believed to be the greatest since the epidemic during 1874, 1875, and 1876. Unbelievable numbers of eggs were in the soil in nearly every county. A statewide insect control organization was perfected. Governor Lloyd Stark was interested in the situation and assisted in appointing the leaders in each township in the state. There were 1300 leaders appointed and every county was organized with a county insect pest control council. The county agent served as the county leader. With the aid of federal appropriations a very complete state and county organization was developed and materials were available in each county. Rains and cool weather during April, May, and June practically reduced the population to normal conditions except in localized areas in the southern two-thirds of the state. From one to five hundred hoppers per square yard were observed shortly after hatching in many counties but weather conditions apparently were not favorable for their development.

The egg-survey made during the fall of 1937 was accurate as was shown by the hatching of the young grasshoppers in the counties. In all sections of the state reports from farmers indicated that the young hoppers were present but after a few days disappeared.

The northern third of the state and certain localized areas remained relatively dry and the greatest damage occurred in these areas. Figure 8 shows where the areas of greatest infestation occurred. About 4,000 tons of wet bait were used and some 550,000 acres of crops were baited. The savings were around \$2,000,000, but the losses were about as great since much of the damage could not be classed as severe and no crop protection was undertaken. The same bait formula as discussed for 1937 was used and good results as a whole were reported.

M. mexicanus and *M. bivittatus* were the dominant species in the southern half of the state early in the season but their numbers were so reduced by the unfavorable weather that crop damage occurred only in localized spots. Later *M. differentialis* occurred in the area but little damage resulted. This species was the dominant one in the northern half of the state. *M. differentialis* hatched out in enormous numbers throughout the infested areas, but except in the north cen-

tral part of the state a general infestation was not evident. *M. femur-rubrum* did not cause much damage in the state and its distribution was limited largely to the northeastern quarter. *M. mexicanus* did not develop much of a second brood nor did it cause much damage except in localized areas in the southern part.

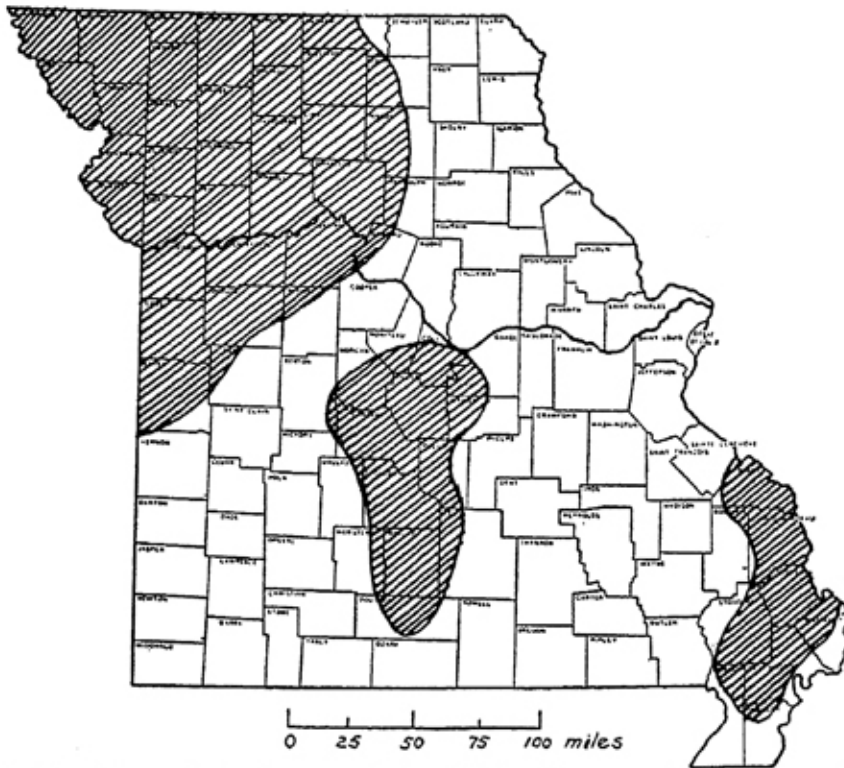


Fig. 8.—Grasshopper infested areas during 1938. The cross-hatched areas designate the portions of the state most seriously infested by native grasshoppers during 1938. Rains and cool weather during the critical hatching periods relieved the farmers of a potentially serious infestation as the entire state was heavily infested with eggs. The northwestern quarter was the most generally, and the most heavily infested area. *M. mexicanus* was so reduced by weather factors that it ceased to be of serious importance except in a few south central counties. *M. bivittatus* was also abundant in the south central counties and in the northern counties. *M. differentialis* was again the most destructive species in the state. *Schistocerca americana* and *M. differentialis* were the most destructive species in the southeastern counties.

Grundy and Harrison Counties along with adjacent areas in the northern part of the state were seriously attacked. Grundy County carried out a very complete control program and most farmers protected their crops. Harrison County did not use as much bait as Grundy County and as a result suffered greater losses.

A fungus disease identified by Dr. W. E. Maneval, Botany Department, University of Missouri, as *Empusa grylli* attacked *M. bivittatus* in the southern part of the state. Several reports of the disease came in from west central and northwest Missouri. It was not of great importance except in localized spots. It was present during late June and early July.

Parasites continued to be present during 1938 to about the same extent as during the two previous years. A slightly greater number of egg-pods were found infested in the fall by blister beetle larvae.

Mites were about normal in their abundance. Many of the adult hoppers were attacked by maggots.

An egg survey was conducted as discussed for the year 1936 in most counties of the state. The survey indicated the greatest number of eggs in the soil in the north central portion of the state with scattered and isolated infested spots in nearly every section of the state. Generally speaking eggs in the soil, even in the worst infested counties, were fewer in numbers than during the fall of 1937. Most of the ratings were light to threatening and only a few were classed as severe. The estimated needs for 1939 totalled approximately 4,000 tons of dry bait.

LIFE HISTORY OF THE NATIVE GRASSHOPPERS IN MISSOURI AND OBSERVATIONS MADE DURING RECENT OUTBREAKS

Figure 9 shows the Rocky Mountain locust and the native grasshoppers which have caused damage to crops in this state. The yearly

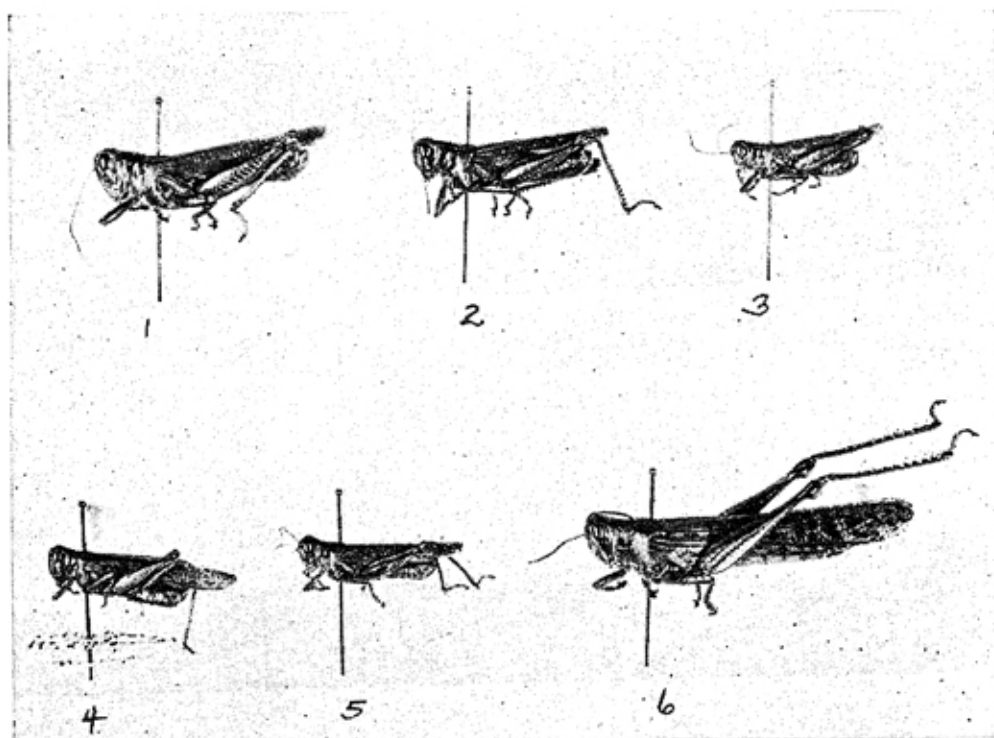


Fig. 9.—The destructive kinds of grasshoppers in Missouri. 1. the yellow grasshopper (*M. differentialis*, Thomas). 2. the two-striped grasshopper (*M. bivittatus*, Say). 3. the red-legged grasshopper (*M. femur-rubrum*, De Geer). 4. the Rocky Mountain locust (*M. spretus*, Walsh). 5. the lesser migratory grasshopper (*M. mexicanus*, Sauss). 6. the bird-grasshopper (*Schistocerca americana*, Drury).

life cycles of the harmful kinds are very similar. All of them pass through the same stages; however, there is considerable variation

among the different species with regard to time of development. They all winter over in the egg stage in the soil as shown in Figure 10. The so-called bird grasshopper winters over to some extent in

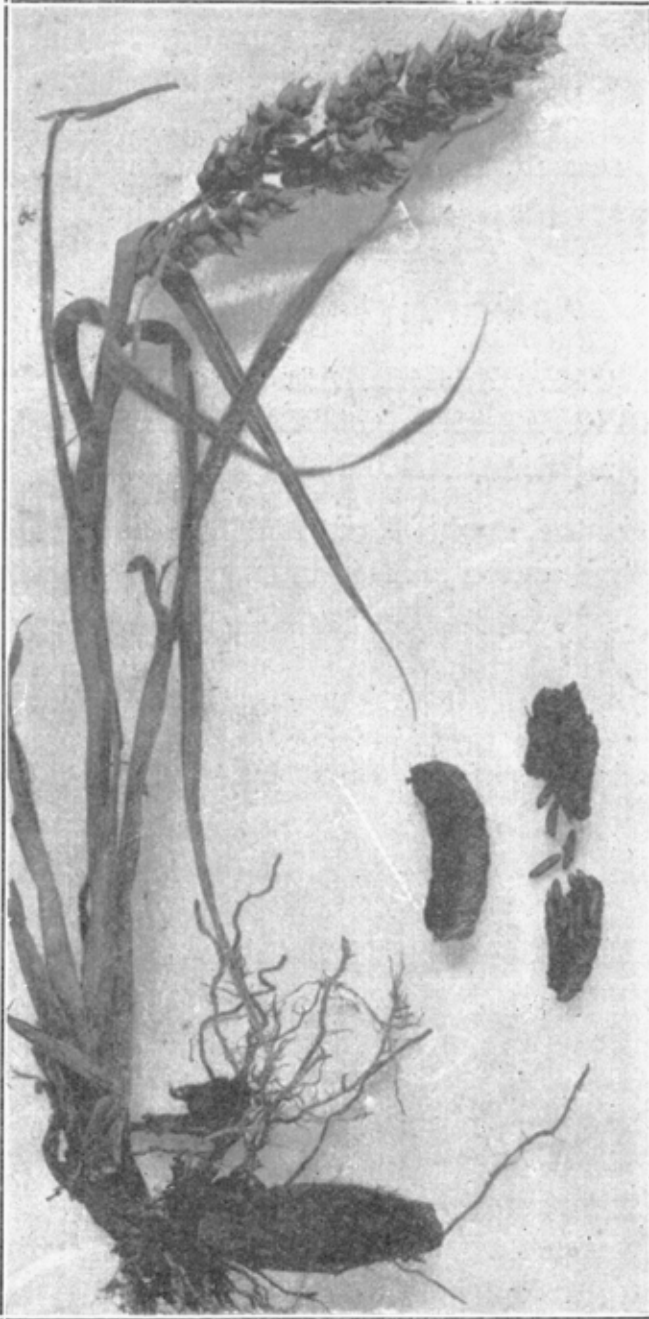


Fig. 10.—Grasshopper egg packets shown attached to the roots of a common grass. Six pods or packets were found at the ground level in the clump of grass.

the adult stage. Some of this species no doubt migrates into the state during the early spring months. The eggs hatch over a period of a few weeks during early summer. The young nymphs gradually

increase in size and by late summer or early fall they become full grown. The adults live for several days and the eggs are laid in the soil as shown in Figure 11. There is normally only one brood each season.

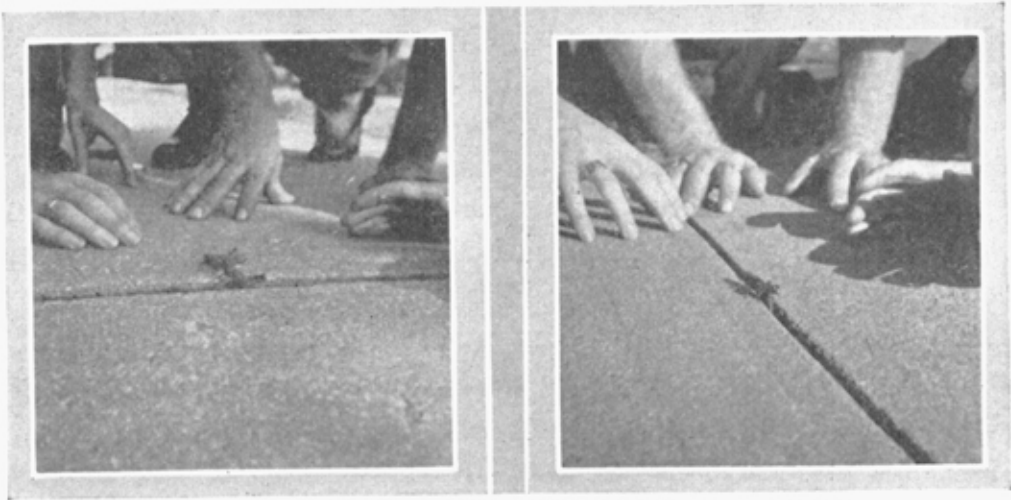


Fig. 11.—Grasshopper laying eggs. The different species of grasshoppers tend to select certain definite areas in which to deposit their eggs, and not all species select the same places. The yellow grasshopper *M. differentialis* shown in the picture tends to select certain grassy areas or individual grasses along field margins in which to place its eggs. The crack in the pavement, as shown in the picture, apparently was a suitable place.

The different species do not hatch at the same time. In some the embryo develops farther in the soil before cold weather sets in. This was observed with the lesser migratory and the two-striped species. The time of laying the eggs in the fall influences this perhaps. The lesser migratory species is the first one to hatch from the eggs in the spring. The two-striped species is next and is followed by the differential and the red-legged species in the order as given. The lesser migratory grasshopper developed a partial second brood during the fall of 1937. Only a very small second brood developed in 1938. It is very likely also that this species developed a partial second brood during the fall of 1935 and of 1936. This is the only grasshopper in the state, that is known to develop a second brood.

Weather conditions will influence the length of time required for development to a great extent. During 1937 and 1938 cold and wet weather delayed hatching. The hot dry weather during 1936 caused the eggs to hatch earlier. The eggs can withstand freezing temperatures and wet conditions. During February of 1937 certain areas were flooded in southeast Missouri. In many places the water was over the land continuously five to six weeks. It was later observed that the hoppers hatched in the flooded area and apparently the eggs had suffered but little damage. Tests in the laboratory showed

that eggs in the soil can withstand sub-zero temperatures without serious injury. Eggs in exposed pods were found more susceptible to the sub-zero temperatures. Weather conditions affect the development of nymphs to a marked extent. It was observed during 1938 that cool temperatures during May and June reduced their populations. From 100 to 500 nymphs per square yard were reduced to an average of one per square yard on some farms. This was observed near Boonville and Linneus and in several other locations. During 1936 when the temperature was high during May and June hoppers developed faster than normal. Cool temperature slowed up development during 1937 and 1938. The young grasshoppers pass through five or six instars during their nymphal period.

The adult stage of grasshoppers is reached at different times of the year. The lesser migratory one reached the adult stage throughout central Missouri as a rule during June and early July. The two-striped grasshopper reached the adult stage about the middle of July. The differential adults appeared during late July and early August. The red-legged species matured about the same time as the differential. It was observed that the different species began egg laying within a few weeks after reaching maturity. The second brood of the lesser migratory grasshoppers became very abundant during early September in 1937. The eggs of this species must have gone in the ground very soon after the adults matured. It was observed that the majority of the adult two-striped grasshoppers were gone by late August or early September. This would mean that they had laid their eggs and died. The differential grasshoppers were usually more abundant during late August and early September and had laid a majority of their eggs by late September.

Observations on egg laying showed that the number of eggs per pod varied considerably also according to species. During 1937 the egg packets of the differential and the two-striped grasshoppers contained on the average about 100 eggs per pod. Figure 10 shows the normal size of the pods which contained about 100 eggs. During 1938 the average number of eggs per pod were about sixty. The lesser migratory and the red-legged egg packets contained on the average about twenty eggs during 1937.

It was observed that each year the different species tended to select certain rather definite places in which to deposit their eggs. The differential grasshopper seemed to prefer firm grassy margins along ditch banks and roadsides. Individual grass plants of barnyard and crab grasses found along the edges of alfalfa and pastures close to corn fields were also selected. A few pods could nearly al-

ways be found in an alfalfa field or a pasture, but the eggs could be found more readily in the above places. The hoppers were observed to move from the uplands and hill country to the valleys during 1936 where they deposited their eggs in the cooler and more moist areas. It was interesting during 1937 to observe how the infestation seemed to follow valleys. The same trend appeared evident during 1938. In southeast Missouri the infestation was worse in the so-called "black" lands. This meant that they selected the lower lands also in that locality.

The two-striped grasshopper tended to select the same places as the differential grasshopper in which to lay its eggs. Frequently individual weeds and corn stalks would be selected and the eggs would be found under the brace roots. During the fall of 1937 enormous numbers of eggs of these two species were found in grassy margins along ditch banks and roadsides in valley sections throughout the infested areas. Near Carrollton, Brunswick, and Glasgow it was not uncommon to find from twenty to eighty pods per square foot in selected places. Certain firm and tight sod clumps two or three inches square would contain twenty-five to fifty pods.

The lesser migratory grasshopper which was more abundant in the southern two-thirds of the state tended to select the firm bare places in pasture, alfalfa and lespedeza fields in which to lay their eggs. Throughout south central Missouri during 1937 the eggs of this species could be found readily in the cooler and slightly moist bare places in pastures. From five to twenty-five pods per square foot were encountered near Bourbon and Columbia. In southeast Missouri firm sandy areas were often selected. In a peach orchard near Sikeston as many as ten pods per square foot were found on the average in the selected spots. It was very difficult to locate eggs of this species during the fall of 1938. The red-legged locust seemed to be confined to the northeastern and eastern parts of the state. At no time during the present outbreaks did this species seem to be of much importance. The eggs were found in the same location as the lesser migratory species. It is rather difficult to distinguish between the egg pods of these species.

The large bird grasshopper seemed to lay its eggs more or less scattered over pastures and hay fields. No definite egg beds were observed during the fall of 1938 in southeast Missouri where this species was very numerous in certain isolated areas.

The differential grasshopper was the most destructive species during the years of 1936, 1937, and 1938. The two-striped species was abundant in many localities but it never became so abundant as the

above species. The lesser migratory grasshopper developed in large numbers but it caused less widespread damage to corn than did the differential grasshopper. The red-legged grasshopper did not build up to destructive numbers. They were present throughout the areas infested by the lesser migratory species but their damage was considered negligible. The bird grasshopper was most abundant in the southeastern sections and it seemed to be in large numbers in only certain spots. It did not cause much widespread damage. One young apple orchard near Kennett was found defoliated by this hopper.

The outbreaks of grasshoppers in Missouri during recent times came after small grain harvest. The most extensive damage was caused to the corn crop, young orchards, alfalfa and clover fields, pastures, hay crops, and gardens. Small grains were attacked only to a limited extent and in only certain areas.

In the control work the use of poisoned baits was widely practiced. Several farmers used home made hopper catchers or hopper dozers and fastened them on the front of a car or tractor. They would collect millions of grasshoppers by driving back and forth across the infested fields. Some felt that the method was very successful especially under certain conditions where the hoppers were numerous over a level field. Several farmers in Saline and other counties used these machines. It was the opinion, however, of the majority of farmers that a poisoned bait was cheaper to use, both from the cost and time basis. The poisoned baits were very cheap and good control was had at costs of a few cents to approximately a dollar per acre for materials which varied according to specific conditions.

Previous to 1936 the recommended bait formula consisted of white arsenic or Paris green, four pounds; bran, one hundred pounds; molasses, two gallons; juice of a dozen oranges and sufficient water to make a crumbly mass. The federal formula during 1936 consisted of sodium arsenite, one gallon; one hundred pounds of bran and a bulk of hardwood sawdust equivalent to one hundred pounds of bran and water to mix to a crumbly mass. During 1937 the formula recommended to the mixing stations consisted of sodium arsenite, two gallons; one hundred pounds of mill run bran and a bulk of sawdust equivalent to 300 pounds of the bran and sufficient water to mix properly. The formula for 1938 was the same as for 1937. Many farmers added molasses and a few added amyl acetate at their own expense. It was found that the hoppers would eat the mixture readily without the additional ingredients when all conditions were right. It was rather difficult sometimes to be sure just what was wrong when the bait was

not eaten. This situation caused many to "doctor" the baits with different things. The hoppers were found to have definite feeding periods. They would practically stop feeding as soon as the temperature dropped below 70° F. or when it went above 90° F. When baiting was done on the basis of this information, good results were had. Much bait was lost during 1937 because it was used too early in the mornings when the hoppers were not feeding. It was noted also that when soil temperature reached a certain point, the hoppers would climb up on objects and get away from the heat. This was noted during early July, 1938, in Grundy County. Figure 12 shows the hoppers "off the ground" when the air temperature registered 102° F.



Fig. 12.—Grasshoppers escaping soil temperatures. These grasshoppers were lined up on the weeds and the wires of fences during the hottest period of the day. The picture was taken during the first week in July, 1938, in Grundy county. The temperature was 102 degrees.

The recommended rate of application of bait was twenty pounds of wet bait or ten pounds of dry bait per acre. It was necessary to keep baiting infested areas every three or four days until the populations were reduced. Migration from adjacent areas often took place. It was found best to apply the bait during the morning periods just

before feeding took place. Frequently farmers applied the bait at the rate of thirty to forty pounds per acre. It was observed that heavy applications were not as effective as when smaller amounts were applied more frequently.

In orchards, baits proved fairly successful. Many growers sprayed the trees with a solution of lime and water. Others used a Bordeaux mixture and from reports a marked repellent action was noted.

No harmful effects to chickens, turkeys, cattle, horses, hogs, and other kinds of animals were noted where the animals were permitted to graze over properly baited areas. The county agents and leaders tried to check on every case where animals were reported poisoned. Invariably carelessness and lack of precautions in some manner were found to be responsible for the losses. Several farmers who failed to follow instructions found that in spreading the bait their fingers would get sore. No serious results occurred when precautions were followed in handling the poison materials. Some people, however, could not handle the materials without experiencing unpleasant irritation.

Although several methods were used in spreading the bait, most of it was spread by hand. Only a very few specially constructed mechanical spreaders were used. Several farmers used endgate seeders but the majority spread the bait by hand.

It was observed that natural controls such as diseases and parasites along with the weather factors played important parts in reducing the populations. The fungus *Empusa grylli* was observed to reduce the populations to a marked extent in certain localized areas only during 1938. South central, western and northwestern counties seem to have been more generally involved. It appeared to attack only *M. bivittatus* to any extent. Of the animal parasites blister beetle larvae seemed to be the most abundant egg parasite. Certain bee-fly larvae were present to some extent but did not appear to be as numerous as the blister beetle larvae. Red mites were present each year and undoubtedly aided in reducing the adult population to some extent. Certain round worms, flesh fly maggots, and larvae of ground beetles were observed in some locations. From indications all of these various parasites aided somewhat but weather and other ecological factors were more important in controlling the grasshoppers.

Nymphal, adult and egg surveys were conducted during 1936, 1937, and 1938. The results showed that such surveys are helpful. The information proved valuable in carrying out the county-wide control work each year. It was observed that it was possible for weather factors to reduce a serious threat to a normal situation in one year.

The survey information was important, however, since considerable time is required to develop a state-wide project. Past experience indicates that more data should be secured about weather factors and their influence on grasshopper outbreaks. This information along with further studies on survey methods and analyses would make the planning of grasshopper control work more efficient.

SUMMARY

1. Information presented indicates that the area which is now the state of Missouri has no doubt experienced grasshopper damage over a long period of time.
2. During the period from the time when Missouri became a state in 1821 up to and including 1938 (a period of 117 years), grasshopper damage occurred in the state during thirty-eight of the 117 years (of the period). The areas of infestation and the damage done varied from season to season.
3. In practically all of the outbreaks or years of recorded damage, native species were mentioned as being present. The Rocky Mountain locust was mentioned in (approximately) ten of the outbreaks. The species most abundant during the early periods were: the Rocky Mountain locust (*M. spretus*, Walsh), the yellow grasshopper (*M. differentialis*, Thomas), the two-striped grasshopper (*M. bivittatus*, Say), the red-legged grasshopper (*M. femur-rubrum*, De Geer), and the lesser migratory grasshopper known at that time as *M. atlantis*. During recent times *M. differentialis*, *M. bivittatus*, *M. mexicanus* (Sauss), which is thought to be similar to or perhaps identical (with) the Rocky Mountain locust, and *M. femur-rubrum* were the most important harmful species. *Schistocerca americana* (Drury) caused only limited damage during certain seasons.
4. The study showed that grasshoppers are not pests every year but that they are adapted to the conditions and can develop into damaging numbers in any part of the state when certain factors favor their development.
5. Nearly all records of grasshopper outbreaks reviewed, whether in other countries or in Missouri or in other states, contained statements telling of the dryness of the years when grasshoppers were present. The concensus seems to be that drought conditions are necessary for grasshopper abundance.
6. It is recognized that lack of moisture is not the only factor responsible for ideal grasshopper development but it is assumed that when rainfall is deficient during the growing season, other factors will favor their development.

7. The graphs showing rainfall data for Oregon, Missouri, and Leavenworth, Kansas, were chosen because the western part of the state has been most often attacked by grasshoppers. With the exception of 1829 and 1902, northwest Missouri was infested with grasshoppers at least to some extent during all of the thirty-eight outbreaks. A study of the rainfall data at St. Louis for the period from 1837 to 1938 reveals dry years or dry periods in that area when grasshopper outbreaks occurred in that part of the state.
8. A study of the years of worst outbreaks in the western part of the state shows that rainfall in the affected areas was below average during each of the years and often serious drought conditions prevailed. See data as given for Oregon, Missouri, for the years of 1868, 1874, 1875, 1886, 1892, 1911, 1918, 1920, 1921, 1924, 1936, 1937, and 1938. Rainfall data at several other stations showed similar conditions.
9. It is interesting to note how often average or below average rainfall conditions prevailed during the fall months in northwest Missouri preceding the grasshopper outbreaks.
10. Information studied shows that when periods of average to less than average rainfall exists in a given area for at least two or three years under Missouri conditions, native grasshoppers increased to such an extent that crop losses resulted. Successive dry fall months and spring months seemed to be required.

It is observed that during the past twenty years rainfall at Oregon, except for one five-year period, 1925 to 1930, was below normal. It was noted that during this five-year period rainfall was above average every year. No record of grasshopper damage was recorded in the state during 1927, but since 1928 grasshoppers gradually increased in abundance.
11. Rainy and cool weather during May and June appeared unfavorable for grasshopper development during 1938 and was responsible for the reduction of large grasshopper populations. From data found it seemed evident that weather factors influenced population more than parasites, cropping practices, and control operations.
12. Control operations during the present outbreak indicates that baiting as crop protection is possible at a relatively small cost per acre and is practical under Missouri farming conditions.
13. Baiting and other control practices to eradicate grasshoppers completely does not appear practical under Missouri conditions.

14. Surveys as conducted during the recent outbreaks were remarkably accurate in determining potential infestations.
15. The study shows that more information is needed about the influence of weather on grasshopper abundance. This would make survey data under Missouri conditions more dependable and more efficient.

BIBLIOGRAPHY

- Carver, Jonathan, *Three Years Travels Through the Interior Parts of North America* . . . Glasgow, Scotland. Printed by E. Miller for A. and J. Leslie, 1805.
- Drake, C. J. and Decker, G. C., "Grasshopper Outbreaks in Iowa," *Journal of Economic Entomology*, Vol. 31, October, 1938.
- Graves, Mrs. W. W., "In the Land of the Osages—Harmony Mission," *The Missouri Historical Review* (Columbia, Missouri), Vol. 19, April, 1935.
- Henshaw, Samuel (prepared by), *Bibliography of American Economic Entomology* . . . The Important Writings of Benjamin D. Walsh and C. V. Riley. Parts I, II, and III. The United States Department of Agriculture, Bureau of Entomology. Washington, D. C., Government Printing Office, 1890.
- Hauck, Louis, *The Spanish Regime in Missouri* . . . Vols. I and II. Chicago, R. R. Donnelley and Sons Company, 1909.
- Jones, George D., Annual Reports of Extension Entomology to the College of Agriculture and the United States Department of Agriculture. (Not published.)
- Majors ~~Hajors~~, Alexander, *Seventy Years on the Frontier* . . . (Edited by Col. Prentiss Ingraham.) Chicago, Rand, McNally and Company, 1893.
- Missouri Agricultural Extension Service, *Annual Reports*, 1918 to 1930. (Columbia, Missouri.)
- Missouri College of Agriculture Experiment Station, *Annual Reports*, 1920 to 1936. (Columbia, Missouri.)
- Missouri State Board of Agriculture, *Annual Reports*, 1-56; 1865-1924. (Jefferson City.)
- Morse, Jedidiah, *A Report to the Secretary of War on Indian Affairs* . . . in the Summer of 1820. New Haven, printed by S. Converse, 1822.
- [Perkins, James Handasyd] *Annals of the West* . . . Pittsburg, Pennsylvania, W. S. Haven, 1856.
- Riley, C. V., *Seventh, Eighth, and Ninth Annual Reports on the Noxious, Beneficial and Other Insects of Missouri*. Jefferson City, 1875, 1876, and 1877.

- Riley, C. V., Packard, A. S., Jr., and Thomas, Cyrus, *First Report United States Entomological Commission for the Year 1877*. Washington, D. C., Government Printing Office, 1878.
- Shotwell, R. L., "Grasshoppers Responsible for Recent Outbreaks," *Journal of Economic Entomology*, Vol. 31, October, 1938.
- Stedman, J. M., "The More Important Insects Injurious to Corn in Missouri," *The Thirty-eighth Annual Report of Missouri State Board of Agriculture for 1905*.
- Switzler, William Franklin, *Switzler's Illustrated History of Missouri from 1541-1877*. St. Louis, C. R. Barns, Editor and Publisher, 1879.
- Taylor, Alexander S., An Account of the Grasshoppers and Locusts of America, condensed from an article written and furnished by Alexander S. Taylor Esq. of Monterey, California, *Annual Report of the Smithsonian Institute*, 1858. Washington, D. C., James B. Steedman, 1859.
- The Western Journal of Agricultural Manufacturers and Mechanical Arts*. Vols. 1-14. St. Louis, Tarver, M. and Rich, T. F., 1848-1855.
- Thwaites, Rueben Gold (Editor), *Early Western Travels*, Vol. 5 (Travels in the Interior of America in the years 1809, 1810, and 1811 by John Bradbury); Vols. 14-17 (Account of an Expedition from Pittsburg to Rocky Mountains) Cleveland, Ohio, Arthur Clark Company, 1905.
- Thwaites, Rueben Gold (Editor), *Travels and Explorations of the Jesuit Missionaries in New France 1610-1791*, Vols. 6, 18, 14. Cleveland, Ohio, The Burrows Bros. Publishers, 1896-1901. Vols. 1-73.
- The American Entomologist*, Vols. 1 and 2, St. Louis, R. P. Studley and Company, 1868-1870. Walsh, Benjamin D. and Riley, C. V. (editors).